Tennessee Valley Authority

GROUNDWATER INVESTIGATION REPORT

WATTS BAR NUCLEAR PLANT
SPRING CITY, TENNESSEE

AUGUST 2004

ARCADIS
Infrastructure, buildings, environment, communications

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Groundwater Investigation Report

Watts Bar Nuclear Plant
Spring City, Tennessee

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Abbreviation/Acronym Listing

BCGs	Biota Concentration Guides
CB	Catch Basin
CCW	Condenser Cooling Water
cfs	cubic feet per second
CLP	Cask Loading Pit
DCN	Design Change Notice
fps	feet per second
ft	feet
FTC	Fuel Transfer Canal
FTT	Fuel Transfer Tube
gpd	gallons per day
gpm	gallons per minute
MCL	Maximum Contaminant Level
msl	mean sea level
pCi/L	picocuries per liter
PER	Problem Evaluation Report
psig	pounds per square inch gauge
Rad Waste Line	Liquid Radioactive Effluent Line
RAOs	Remedial Action Objectives
REMP	Radiological Environmental Monitoring Program
RWST	Refueling Water Storage Tank
SFP	Spent Fuel Pool
Site	Watts Bar Nuclear Plant
TVA	Tennessee Valley Authority
USDOE	U.S. Department of Energy
WBN	Watts Bar Nuclear
YHP	Yard Holding Pond

Executive Summary

ARCADIS has prepared this report to document the findings of the groundwater investigation at the Tennessee Valley Authority (TVA) Watts Bar Nuclear Plant (WBN) (Site) located near Spring City, Tennessee (Figure ES-1). TVA personnel initiated the investigation in March 2003 following the detection of tritium in newly-installed groundwater monitor wells associated with the Department of Energy tritium production program site preparation activity. A number of corrective measures were completed by TVA (described below) during 2003, prior to retaining ARCADIS to support their efforts. The primary objectives of the investigation were to:

- Identify the potential source(s) of tritium releases;
- Characterize groundwater movement; and
- Determine the nature and extent of tritium in the subsurface environment.

Two tritium sources have been identified:

- Liquid Radioactive Effluent Line (Rad Waste Line) which appears to have resulted in a dual branch tritium plume that extends from the Rad Waste Line toward the river and to the Turbine Building; and
- Fuel transfer canal leak into the Unit 2 fuel transfer tube (FTT), which appears to have resulted in a tritium plume that is localized in the vicinity of the Unit 2 Shield Building.

Overview/Background

As part of planned plant modifications to produce tritium for the U.S. Department of Energy (USDOE), TVA expanded the Radiological Environmental Monitoring Program by installing four additional monitor wells adjacent to the Rad Waste and Cooling Tower Blowdown Lines in December 2002. Initial samples in January 2003 indicated the presence of tritium in three of the four new monitor wells.

The Nuclear Regulatory Commission Site Resident at WBN and the Tennessee Department of Environment and Conservation - Department of Radiological Health were notified and are being kept informed as investigations continue. No tritium or other radionuclides have been detected at levels exceeding background in water samples from off-site wells, public drinking water supplies, or the Tennessee River. In March 2003, a team consisting of both site and corporate TVA personnel was established to locate the source(s) of the tritium and eliminate the path(s) to groundwater. Potential sources were identified based on tritium concentrations in the component or system, location within the plant, and relative tritium concentrations and distribution in groundwater. The following components were considered as possible sources of tritium in groundwater:

- Rad Waste and Cooling Tower Blowdown Lines;
- Fuel Transfer Canal (FTC), Fuel Transfer Tube (FTT), Spent Fuel Pool (SFP), and Cask Loading Pit (CLP);
- Refueling Water Storage Tank (RWST);
- Auxiliary Building Passive Sump;
- Various Auxiliary Building tanks; and
- Reactor Refueling Cavity.

Work began immediately on source identification. This work included leak testing of lines and storage components, evaporation calculations of the SFP and RWST, installation and sampling of groundwater wells, inspection of drain lines, and boroscopic investigation of SFP, CLP, and FTC leak collection system channels and drains.

After the most recent refueling outage during the fall of last year, ARCADIS was retained in January 2004 to aid TVA in identifying the source(s) of tritium, define groundwater movement and tritium extent, and support remedial planning.

Summary of Groundwater Investigation Data

The primary types of new environmental data collection included hydraulic and groundwater quality information from strategically placed monitor wells. Groundwater levels were measured over the course of the investigation to determine the direction of groundwater flow and potential preferential pathways of movement. In general, regional groundwater movement is southerly across the Site toward the river, with the exception of groundwater captured by a French drain system surrounding the Unit 1 and Unit 2 Shield Building, Auxiliary Building, Control Building, and Turbine Building. Groundwater dewatering provided by the French drain, described below, has resulted in a groundwater capture zone surrounding the Power Block.

The French drain surrounding the Power Block consists of an 8-inch porous concrete pipe bedded in a horizontal blanket of gravel. A sump collects groundwater from the French drain on the east side of the Auxiliary Building. This sump continuously receives flow from both the north and south French drain lines and periodically is pumped based on the level in the sump. The north leg of the French drain routinely exhibits a higher flow rate than the south leg.

As part of a systematic program to determine the tritium source(s), 34 additional monitor wells were installed during 2003 and early 2004 to further delineate the extent of tritium. These wells have been periodically sampled since their installation, with a maximum tritium concentration [353,700 picocuries per liter (pCi/L) in October 2003] occurring at groundwater Monitor Well K near the Rad Waste Line, east of the Power Block. Tritium extends from this general area near the Unit 1 Cooling Tower, south toward the Tennessee River, and westward toward the Power Block. Based on the monitoring network and collected data, detectable concentrations of tritium have not yet reached the river. Relatively low concentrations of tritium were also detected around the Unit 2 Shield Building.

Recently, concentrations of tritium in the groundwater sump have been declining, which seems to have resulted from tritium abatement activities described below. The south leg of the sump continues to exhibit approximately twice the tritium concentration of the north leg. However, the total activity of tritium entering the sump is greater in the north leg (although a lower concentration) due to its higher flow rate. The presence of tritium in these two legs entering the sump suggests that two sources are likely.

Based on solute migration transport parameters and limited available information, it is estimated that the tritium plume movement is approximately 300 feet/year. Tritium is a radioactive form of hydrogen and decays with a half-life of 12.33 years, but is not susceptible to either biological or chemical degradation enhancement. Other natural attenuation parameters do not have a substantial impact on tritium retardation. That is, groundwater velocity and tritium migration are similar.

Source Assessment

Based on the distribution of tritium in groundwater and refined understanding of groundwater flow conditions, the tritium plumes observed at the Site are likely associated with two separate sources; the Rad Waste Line and the Unit 2 FTT seismic gap.

Source #1 – Rad Waste Line

Documented leaks from the Rad Waste Line appear to have resulted in tritium extending in a dual branch fashion west from the Well K vicinity to the southeast edge of the Turbine Building, and south from the Well K vicinity toward the Tennessee River

(Figure ES-2). The Rad Waste Line, extending past Well K, was pressure tested, acoustically monitored, and excavated at several locations to identify potential leak locations. A leak was identified east of the Power Block (Figure ES-2) after overburden was excavated on May 1, 2003. The leak appeared to be caused by accelerated corrosion from the pipeline exterior due to a tear in the protective pipe wrap. The line was cut, inspected, and repaired. Through the fall of 2003, possible additional leaks in the line were investigated, but no additional leaks have been found.

The Rad Waste Line leak, identified and repaired in May 2003, is suspected of being the primary source of tritium. A portion of the tritium originating from the leak location has migrated toward the south leg of the French drain system along preferential pathways associated with the assumed relatively permeable bedding material surrounding the subsurface infrastructure piping. Another portion of the tritium plume originating from the leak appears to follow major subsurface lines toward the Tennessee River. Again, this directional behavior is likely associated with preferential groundwater movement associated with the higher permeability bedding material surrounding subsurface piping.

When WBN was constructed, engineered fill was placed over a majority of the Site. The tighter hydraulic properties make the fill more difficult for groundwater to flow through than the gravel packs surrounding the numerous pipe systems associated with facility infrastructure. Tritium migration toward the Turbine Building appears to be influenced by the south Condenser Cooling Water (CCW) discharge line running from the Turbine Building to the Unit 1 Cooling Tower. Tritium migration toward the river is strongly influenced by the Cooling Tower Blowdown Line, Waste Heat Park Lines, and other piping infrastructure, as their position within the subsurface is coincident with the groundwater table along portions of their length. Based on calculations of tritium in the south leg of the French drain, it is likely that a majority of the activity resides within the more permeable gravel packs of the discharge CCW Line and Raw Cooling Water Lines, because it cannot be fully accounted for with tritium observed in groundwater monitor wells. A majority of the groundwater monitor wells have shown decreasing concentrations of tritium, indicating that the primary source has been eliminated.

Source #2 – Unit 2 Fuel Transfer Tube Seismic Gap

In February 2003, it was identified that water was leaking into the Unit 2 Shield Building annulus, through the Unit 2 FTT sleeve connection between the Auxiliary Building and Unit 2 Shield Building. All of these units (SFP, CLP, and FTC) have the potential to be inter-connected behind the stainless-steel liner since the liner is not continuously bound in the concrete. A 1-inch seismic gap exists between the Auxiliary

Building and Unit 2 Shield Building where the FTT passes through these buildings (Figures ES-3 and ES-4). Tritiated water, between the steel tube (20-inch diameter) and the concrete building, was observed flowing into the Unit 2 Shield Building annulus in February 2003. This water must flow across the seismic gap to get from the Auxiliary Building to the Unit 2 Shield Building, which provides a pathway to groundwater. This gap is filled with fiberglass and is glued on one side to the Unit 2 Shield Building. Potentially, water from the SFP, CLP, or FTC that has leaked behind the stainless-steel liner could migrate to the Unit 2 FTT sleeve.

Occasional FTC leakage has been identified over the past 5 to 6 years and attempted repairs were made. The individual "tell-tale" drain systems of the SFP and adjacent CLP, along with the FTC, are designed to detect leakage through the liner welds. Inspection of the "tell-tale" drain system is complicated due to its piping configuration. Neither of these drain systems have exhibited recent leakage, although investigations indicate that the drain system for the SFP and FTC is clogged, making leak detection by this method problematic. Subsequent efforts to clear these drain systems have resulted in a functioning drain system for the FTC. The SFP system still does not drain efficiently, and additional efforts are being developed. The Cask Loading Area drain system appears to be functioning as designed.

Leaks through the FTT sleeve and seismic gap have resulted in groundwater impact surrounding the Unit 2 Shield Building (Figure ES-3). The difference in potential head between the bottom of the FTT sleeve and the French drain directly north of the seismic gap is approximately 1.25 feet, indicating that water would flow toward the French drain from this point (either to the north or to the east). Calculations using the tritium concentrations in these areas of nearly 100 million pCi/L indicate it would take only a small volume of tritiated water to result in the concentrations being observed in the north leg of the French drain, and in groundwater monitoring points around the Unit 2 Shield Building.

Risk analysis is the process of organizing and systematically evaluating information pertaining to the likelihood and magnitude of adverse effects. In the context of environmental contamination, this typically includes separate analyses of the risks to human health and risks to ecological receptors. Actual risks to human and ecological receptors posed by tritium that has entered the environment at WBN are likely to be acceptable based on available environmental data and existing radiological screening criteria. However, risks may be perceived by the public to be higher than actual because the constituent of concern is a radionuclide. Therefore, it is important to demonstrate that measures are being taken to ensure protection of human health and the environment.

Based on the groundwater investigation findings and risk screening, remedial planning can be conducted to evaluate the need for and corrective action options. This process initially must identify remedial action objectives (RAOs) to establish and guide remedial planning. RAOs for the Site include:

- Protect ecological receptors in the Tennessee River from impacted groundwater;
- Prevent groundwater plume growth to ensure it does not migrate off site;
- Protect human health of plant workers from exposure to impacted groundwater; and
- Remove tritium mass in plume core to assist in natural attenuation of remaining plume.

The primarily remedial technology for tritium corrective action is hydraulic control (pumping). A hydraulic control system positioned at the leading edge of the tritium plume, could be used to intercept tritiated groundwater before it reaches the Tennessee River. Prior to designing a hydraulic control system, refinement of the plume extent, and a better understanding of the engineered fill along the utility corridor would be required. Once this is completed, hydraulic testing could be conducted to develop the necessary data to design the recovery wells and size the system.

Recommendations

Based on these initial findings, the following observations/recommendations are made to correct the tritium releases.

- *Unit 2 FTT Sleeve Repair*: Tritiated water must be prevented from crossing the seismic gap in the Unit 2 FTT sleeve, or prevent water from entering the FTT sleeve. WBN is currently investigating the application of a coating/sealing system for the transfer canal liner to preclude leakage into this area. This is documented in the site Problem Evaluation Report (PER) number 12430.
- *Replacement of Rad Waste Line Sections*: Because the existing Steam Generator Blowdown/Rad Waste Lines likely have minor existing leaks, continuing releases could be occurring from this line system. In order to prevent these possible current or future leaks, WBN is replacing this line under Design Change Notice (DCN) number 51690.

- *Monitoring Program Development*: Groundwater sampling procedures have been refined over time to make improvements when necessary. These should be further revised to examine the sequence of well sampling and use of dedicated sampling equipment. A monitoring program should be designed to continue to collect those data that will provide information on current site conditions, and what is necessary to evaluate a remedial solution/progress. Once the monitoring program has met these needs, it should be reduced or eliminated.
- *Refinement of Plume Extent*: Additional groundwater monitor wells are needed to better define the tritium plume and to monitor its movement at the distal end near the Tennessee River.
- *Source #1 Remedial Measures*: Source #1 is somewhat controlled by inducing groundwater flow to the plant buildings by the French drain and actively pumping the groundwater sump. A hydraulic control system may be used to capture the entire plume by installing recovery wells in the downgradient leading edge of the plume, south of the plant. Aquifer testing and a fate and transport model may be used to design the hydraulic control system.
- *Source #2 Remedial Measures*: Source #2 is completely contained by the French drain and actively pumping the groundwater sump. The extent of tritium in groundwater at Source #2 has likely been influenced by moderate to large storm events and underground infrastructure (i.e., RWST tunnel). Nevertheless, the plume around the Unit 2 Shield Building remains focused and contained, and no additional remedial actions are needed.

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Figure ES-1
Distribution of Tritium Concentrations
in Groundwater, March 2004
TVA, Watts Bar Nuclear Plant, Spring City, Tennessee

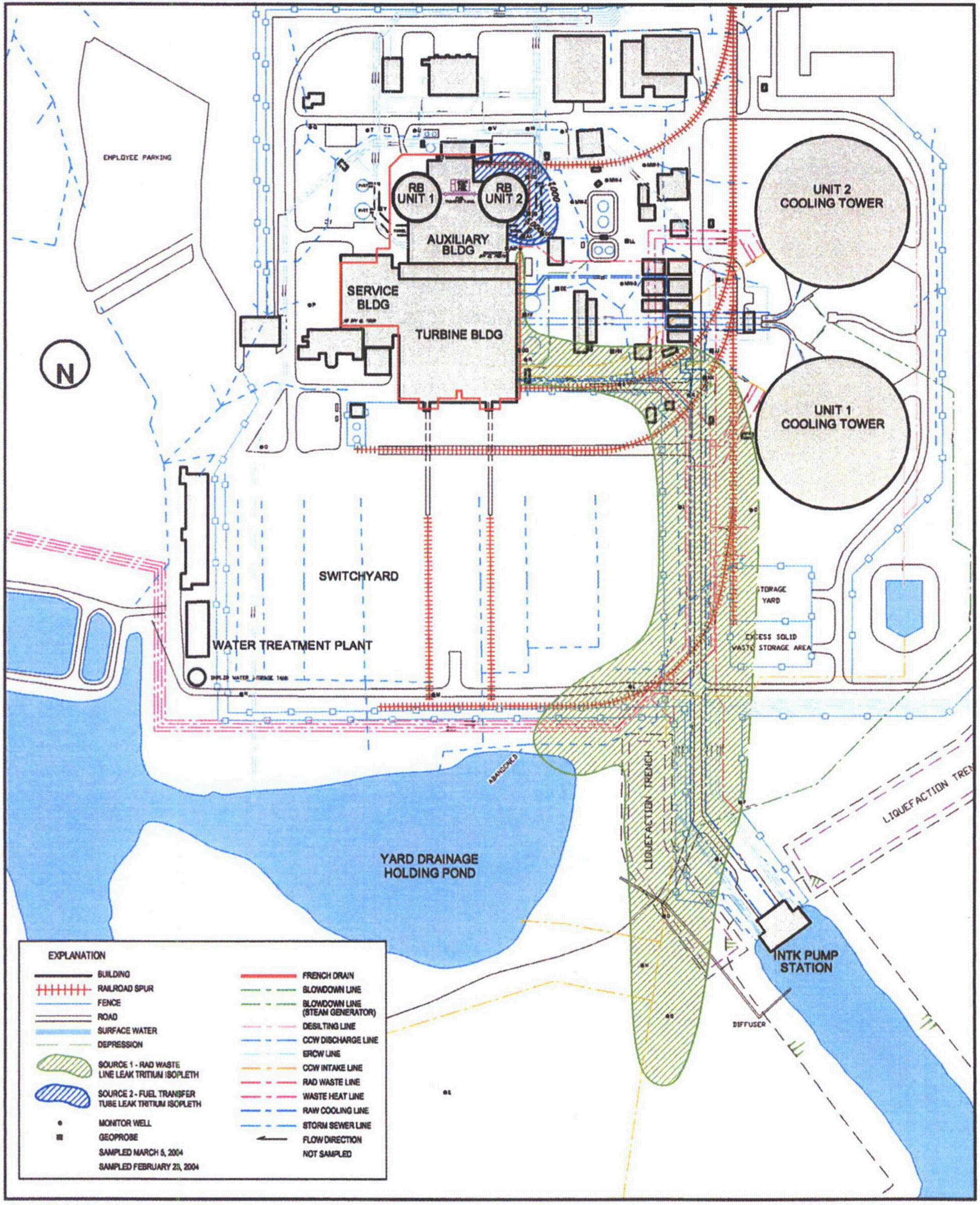

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Figure ES-2
Source #1 - Rad Waste Line Leak
TVA, Watts Bar Nuclear Plant, Spring City, Tennessee

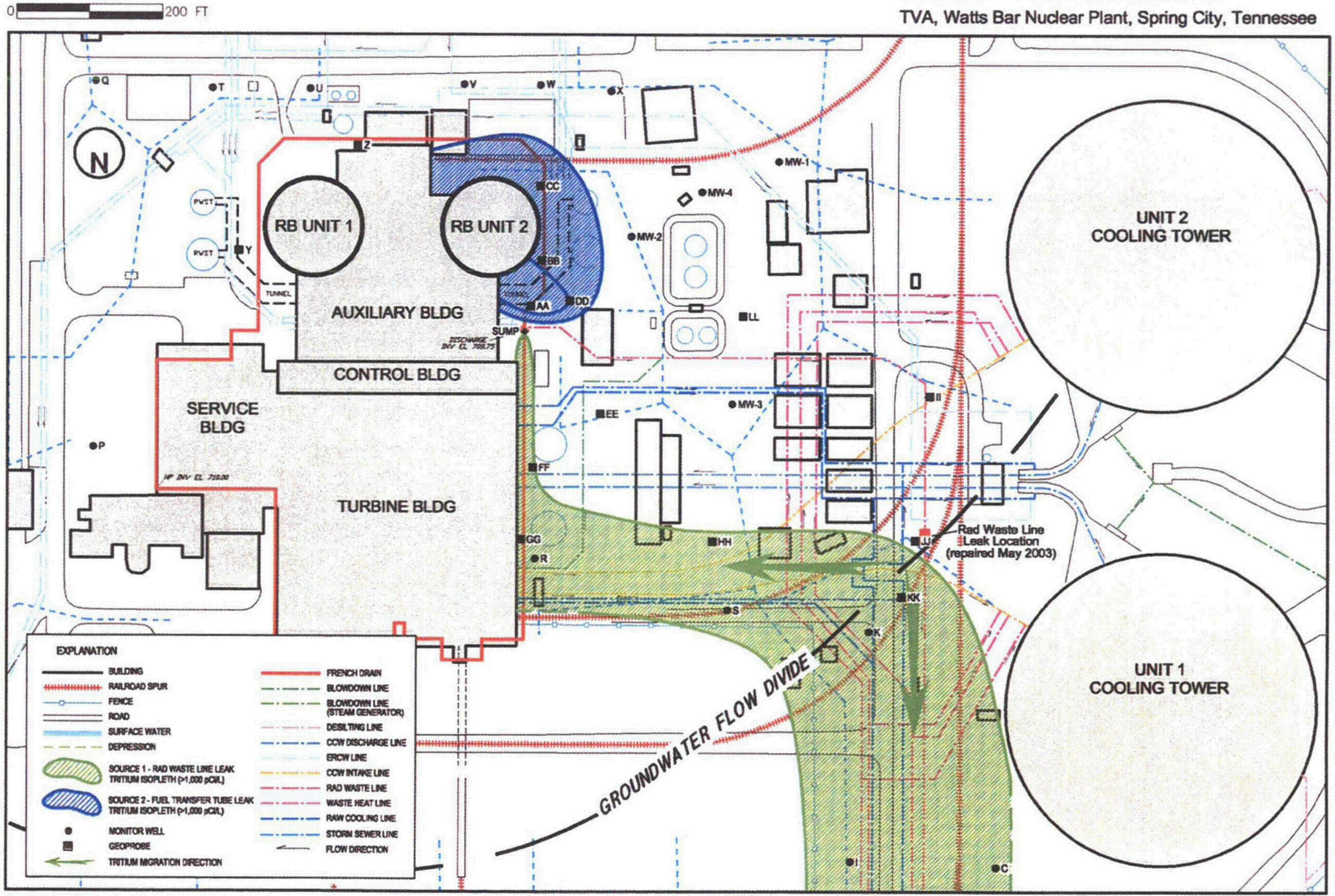

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Figure ES-3
Source #2 - Unit 2 Fuel Transfer Tube Sleeve

TVA, Watts Bar Nuclear Plant, Spring City, Tennessee

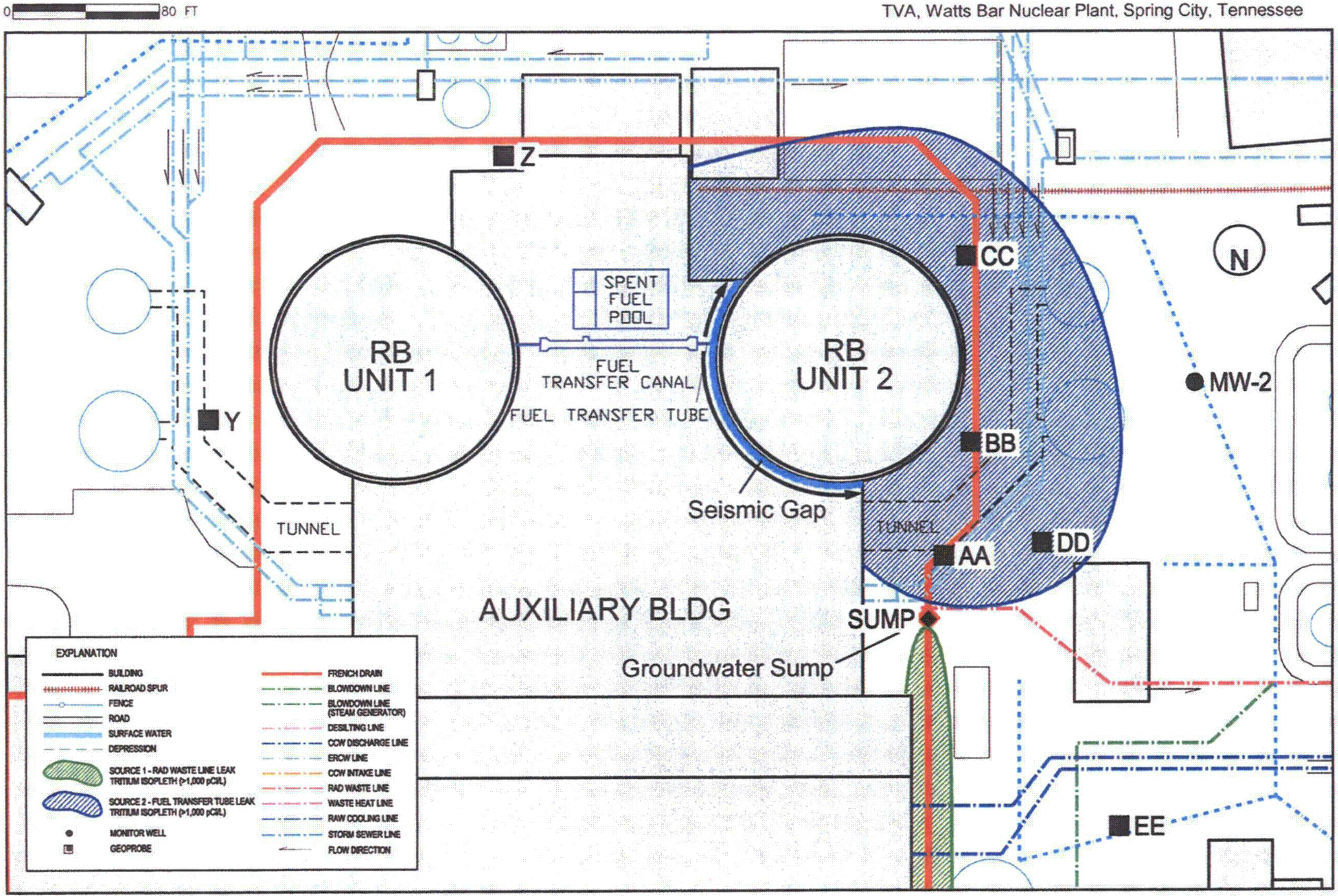

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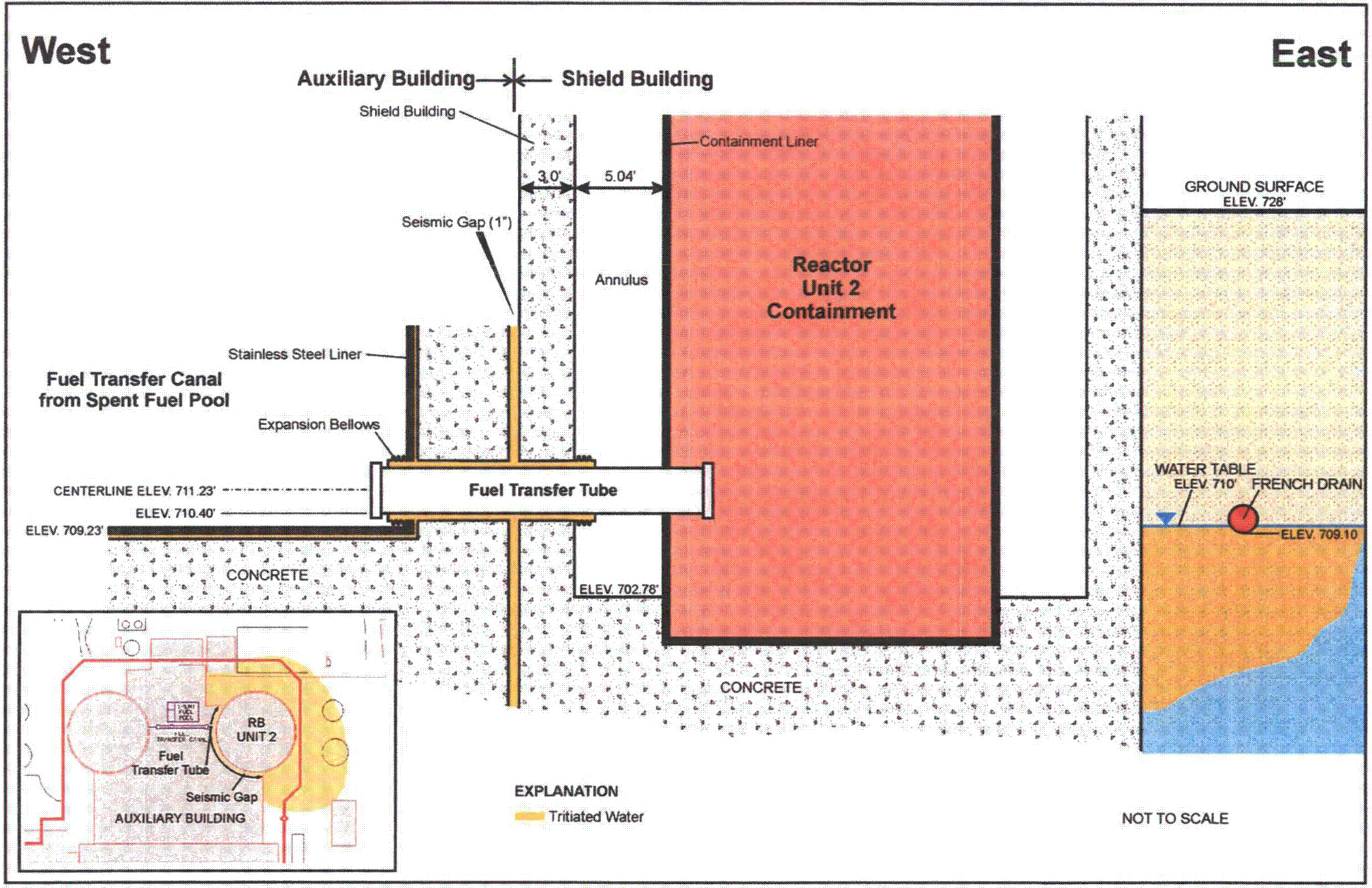
Exhibit ES-4
Source #2 - Schematic Cross-Section
TVA, Watts Bar Nuclear Plant, Spring City, Tennessee



1.0 Introduction

ARCADIS, on behalf of Tennessee Valley Authority (TVA), has prepared this Groundwater Investigation Report to document the findings of a site investigation conducted at the TVA Watts Bar Nuclear (WBN) Plant (Site) located near Spring City, Tennessee (Figure 1-1 and Attachment A). The plant is located just downstream of the Watts Bar dam, near the Tennessee River (Figure 1-2). The WBN Plant was constructed during the mid-1970s and contains substantial infrastructure for the generation of electricity (Figure 1-3 and Attachment B). The Unit 1 Reactor began operation in 1996 and the Unit 2 Reactor has never been brought online.

This report includes background to the investigation, data collected, findings, risk evaluation summary, remediation planning, and recommendations for the path forward.

The primary objectives of the investigation were to:

- Identify the potential source(s) of tritium releases;
- Characterize groundwater movement;
- Determine the nature and extent of tritium in the subsurface environment; and
- Determine preliminary remedial options to address tritium in groundwater.

This project was a collaborative effort between TVA and ARCADIS. TVA began researching the potential sources of tritium in early 2003. TVA retained ARCADIS after the fall 2003 refueling outage to aid in the investigation. During the early months of 2004, multiple project meetings and a sharing of resources resulted in identifying the sources of tritium release and accomplishment of project objectives. These findings were then presented to TVA management in April 2004. This report is meant to document the groundwater investigation, present the findings, and provide a path forward for the project.

2.0 Background

As part of planned plant modifications to produce tritium for the U.S. Department of Energy, TVA expanded the Radiological Environmental Monitoring Program (REMP) by installing four additional monitor wells (Wells A, B, C, and D) adjacent to the Liquid Radioactive Effluent Line (Rad Waste Line) and Cooling Tower Blowdown Lines in December 2002. Initial sampling in January 2003 indicated the presence of tritium in three of the four new monitor wells (Wells B, C, and D) (Tables 2-1, 2-2 and Appendix B).

Based on the tritium levels found in these newly-installed REMP wells, a team consisting of both site and corporate TVA personnel was established to locate the source of the tritium and eliminate the path to groundwater. The team's first task was to identify possible sources of tritium. The possible sources listed below were identified based on tritium concentration in the component or system, location within the plant, and relative tritium concentrations in the groundwater samples. These possible sources underwent evaluations utilizing visual inspections, testing, and sampling (Table 2-1).

The following components were considered as possible sources of tritium in the groundwater:

- Rad Waste and Cooling Tower Blowdown Lines;
- Fuel Transfer Canal (FTC), Fuel Transfer Tube (FTT), Spent Fuel Pool (SFP), and Cask Loading Pit (CLP);
- Refueling Water Storage Tank (RWST);
- Auxiliary Building Passive Sump;
- Various Auxiliary Building Tanks; and
- Reactor Refueling Cavity.

Work began immediately on source identification. This work included the following: leak testing of lines and storage components; evaporation calculations of the SFP and RWST; installation and sampling of groundwater wells; inspection of drain lines; and boroscopic investigation of SFP, CLP, and FTC leak collection system channels and drains (Tennessee Valley Authority 2003). After the most recent refueling outage (fall 2003), ARCADIS was retained in January 2004 to aid TVA in identifying the source(s) of tritium, define groundwater movement and tritium extent, and support remedial planning. Details of the tritium investigation completed by TVA throughout 2003 and early 2004 are provided in the following sections.

2.1 Rad Waste Line

The Rad Waste Line contains liquids from the radioactive waste system and steam generator blowdown, as well as the condensate demineralizers drain. This line leaves various buildings in the plant and is routed to the Cooling Tower Blowdown Line, where it is diluted prior to discharging into the Tennessee River through two diffusers.

Because of the proximity of Well C to the Rad Waste Line, this line was suspected as the source of the tritium release. During March and April 2003, the line was pressure tested and acoustically monitored to determine the location of possible leaks. While pressurized to 75 pounds per square inch gauge (psig), testing indicated a leak rate of 2 to 2.5 gallons per minute (gpm). Excavation on May 1, 2003, confirmed a leak located in the eastern portion of the Power Block near the cooling towers (Figure 1-3). The leak appeared to be caused by accelerated corrosion from the pipeline exterior due to a tear in the protective pipe wrap. The line was cut, inspected, and repaired on May 5, 2003. Internally, the pipe appeared to be in very good condition. The line was then pressurized to 80 psig with no further indications of leakage noted indicating a successful repair.

Additional acoustic and pressure testing occurred during the summer of 2003 to determine if additional leaks in the line were present. The testing indicated the possibility of small leaks in the line. Several areas were excavated in an attempt to locate additional leaks, however, no more leaks were observed along the Rad Waste Line during this investigation.

2.2 Fuel Transfer Canal

The FTC is part of the plant system used to move reactor fuel during a refueling outage. Because the FTC is normally only filled with water during refueling outages, any leakage from the FTC will be intermittent. Occasional FTC leakage has been identified over the past 5 to 6 years (WBN Plant began operation in 1996). Repairs to these leaks were attempted as they were discovered. Because monitoring of potential leakage during the time the FTC is filled is difficult, the team spent some time in May 2003 "brainstorming" possible methods to detect leaks in this area of the plant. All current methods of testing (pressurizing the back of the welds with air or nitrogen, etc.) have been ruled out due to concerns over stressing the liner welds to the point of failure.

Based on this, other physical inspections of the FTC were performed in lieu of a pressure test.

In early October 2003, during the most recent refueling outage, a mobile camera (submersible) was used to record the condition of the FTC walls and floor. This video was reviewed to determine possible inspection locations. The FTC has since been decontaminated in preparation for additional inspections and repair by coating or sealing methods.

2.3 Fuel Transfer Tube

As part of the equipment to refuel the reactor, a FTT is utilized along with other associated equipment to move fuel to and from the reactor. A bellows arrangement is utilized to separate the FTC and FTT from the Reactor Building. In January 2003, it was identified that the Unit 2 FTT bellows was leaking water into the Unit 2 Reactor Building annulus (Appendix A).

A catch basin was erected to catch the leakage and was routed to the appropriate tank. A boroscopic inspection of this bellows was performed on April 29, 2003. The inspection confirmed that the bellows to transfer tube weld was leaking. A repair method was developed which included removing the bellows and transfer tube and welding a plate over the remaining hole. This repair was completed in August 2003.

2.4 Unit 1 Refueling Water Storage Tank

The Unit 1 RWST is a large source of water used during refueling outages and is also a source of water to the reactor should there be a loss of coolant accident. The Unit 1 RWST is located just west of the Unit 1 reactor and is an above ground storage tank connected to the Unit 1 Auxiliary Building through an underground tunnel. The Unit 2 RWST is currently empty and has never been filled during the operation of the plant. The water from the Unit 1 RWST is used to fill the fuel transfer canal and the reactor cavity during refueling outages, and is returned to the RWST at the conclusion of the outage. As the water is mixed with reactor coolant during the time it is in the fuel transfer canal, it becomes a source of tritium.

Because the Unit 1 RWST is a large volume of water with elevated tritium concentrations [approximately 28 million picocuries per liter (pCi/L)], the integrity of the Unit 1 RWST was reviewed. The Unit 1 RWST was found to be losing water at a rate of approximately 150 to 200 gallons per day (gpd). Several valves associated with the piping to/from the Unit 1 RWST were examined and found to be leaking through the valve seat into interfacing systems. The valves were repaired, reducing the water loss to approximately 45 to 50 gpd in January 2004. Additional checks and repairs have been made since that time reducing the Unit 1 RWST leakage to approximately 15 gpd in early May 2004. This rate of loss is believed to be well within the range of loss that would be expected due to evaporation.

2.5 Spent Fuel Pool and Cask Loading Pit

The SFP is a large concrete pool with a stainless-steel liner, and is the in-plant storage location for fuel after it has been removed from the reactor core. The SFP is approximately 30 feet (ft) wide and 40 ft long and is located within the Auxiliary Building between the two reactors. The SFP depth is approximately 40 ft, with a bottom elevation of 709.23 ft msl and a maximum water elevation of 749.79 ft above mean sea level (msl) (the ground elevation around the Power Block is approximately 728 ft msl). The CLP is located immediately west of, and is connected to, the SFP. The CLP is an approximate 10 ft square with a bottom elevation of 706 ft msl. The remaining portion of the Cask Loading Area is immediately south of, and connected to, the CLP. It is approximately 20 ft long and 10 ft wide with a bottom elevation of 731 ft msl.

During refueling outages, the entire core is offloaded and stored in the SFP. Spent fuel which has reached the end of useful life remains stored in the SFP, while the remainder of the core, along with new fuel, is returned to the reactor vessel prior to restart. The tritium concentration in the SFP is approximately 95 million pCi/L. The SFP and the adjacent CLP have individual tell-tale drain systems to detect any leakage through the liner welds. Neither of these drains has exhibited any recent evidence of water leakage.

On June 16, 2003, and other occasions, boroscopic inspections were made of the drain lines and leak collection channels for the SFP and CLP to determine if there is any borated water leakage. Although the inspection area was limited due to piping configuration, the piping was not blocked and appeared to be free of any boron deposits. The CLP showed no signs of leakage, while the SFP showed minor signs of past leakage near the isolation valve. No recent leakage indications were identified. Most leak channels for SFP, FTC, and the Cask Loading Area were drilled, inspected, and no leakage was found. Water was poured down all leak channels indicating the FTC now drains while the SFP is still blocked.

Over a period of several months beginning in December 2003, water levels/makeup to the SFP was compared to measured level loss and estimates from an evaporation calculation. The water levels were measured using a pressure transducer. Also, data loggers were used to record spent fuel pool temperature and refueling area supply/exhaust air temperature and relative humidity. Results of this effort revealed that the makeup rate was approximately the same as the evaporation rate, indicating that there is either no leak in the SFP, or the leak is too small to be measured by this method.

2.6 Reactor Cavity

During the fall 2003 refueling outage, it was noted that when water was added to the Unit 1 Reactor Cavity, water was observed to be leaking into adjacent areas. A visual inspection revealed what appeared to be a tear in the liner. This tear was inspected at the end of the outage and found to be a non-penetrating welding arc-strike. Additional inspections will be required prior to adding water to the Unit 1 Reactor Cavity for the next refueling outage in the spring of 2005. However, it is noted that a cavity liner leak would be contained within the reactor containment by design, which would rule this out as a potential tritium pathway.

3.0 Summary of Groundwater Investigation Data

The following sections detail the various sources of data used for the tritium investigation.

3.1 Site Infrastructure

Because of the nature of building and operating nuclear plants, a large amount of information was available and was reviewed related to the construction and operation of site infrastructure. This information was not only used in identifying and eliminating possible sources, but was used to develop an understanding of the lithologic character of disturbed areas, and construct the various figures and plates used in this report. The following information was reviewed relating to site infrastructure:

- Site plans;
- Final Safety Analysis Report - Sections 2.4 and 2.5 related to hydrology and geology (Tennessee Valley Authority 1980);
- Construction photos (Appendix A);
- Groundwater Tritium Monitoring Status Report (Tennessee Valley Authority 2003); and
- Information obtained from TVA site personnel.

Native soil and bedrock have been extensively excavated and reworked in the Power Block area. In general, native soil was removed to expose the bedrock surface beneath category I features. Category I features were installed several feet to tens of feet into bedrock. Both category I and non-category I features were backfilled with engineered fill (Class A and Class B, respectively). Many subsurface infrastructure lines were backfilled with material such as crushed stone. Because materials used to backfill these lines is more transmissive than the engineered backfill, they provide a preferential groundwater flow pathway.

3.2 Geology/Hydrogeology

The Site is located within the Valley and Ridge Physiographic Province of the Appalachian Highlands. The Valley and Ridge province is characterized by linearly continuous valleys and corresponding ridges formed in part due to horizontally extensive and typically parallel low-angle thrust faults. The local drainage patterns are typically trellis in nature, being influenced regionally by underlying bedrock structural features. The Site is located within a floodplain of the northeast-southwest trending portion of the Tennessee River.

The Site is underlain by unconsolidated soil and fill overlying the Middle Cambrian-aged Conasauga Shale Formation, present at an average depth of 706 ft msl (Attachment C) (Tennessee Valley Authority 1980). The unconsolidated zone is composed of alluvial deposits (Tennessee River flood plain) and underlying terrace deposits. The alluvium is characterized by fine-grained, well-sorted silts and clays, and minor quartz sand. The thickness of the unit is variable, averaging approximately 25 ft (Figure 3-1 and Attachments D through G).

The older terrace deposits can be subdivided into upper and lower units. Terrace sediments were deposited when the ancestral river was flowing at higher velocities in the past. The upper unit is characterized by sandy and silty clays, while the lower unit is composed of coarse grained pebbles, cobbles, and boulders within a sandy matrix (Tennessee Valley Authority 1980). The terrace deposits exhibit bench topography (approximately 30 ft in elevation change), which is evident 200 to 1,000 ft northwest of the river. The terrace deposits are variable in thickness, ranging from 30 to 46 ft. Trends within the basal gravel terrace deposits suggest that the main course of the river historically was near the northwest margin of the Site, based on the presence of courser grained deposits in that area (Tennessee Valley Authority 1980).

There is little *in-situ* saptrolite (weathered bedrock) overlying the competent Conasauga Shale Formation (Tennessee Valley Authority 1980). The Conasauga Shale is characterized by folded red, grey, or blue-grey fissile and calcareous shale with interbedded glauconitic and/or argillaceous limestone seams. At the Site, the estimated ratio of shale to limestone is 5.25:1 (Tennessee Valley Authority 1980). The regional strike of the Conasauga Formation is N35°E, and the beds generally dip at 16° toward the southeast (Tennessee Valley Authority 1980). Complex folding at the Site yields localized variations in bedding strike and dip from this average.

Category I structures are constructed into the Conasauga Shale after the removal of all unconsolidated material in the vicinity of these structures. The elevation of bedrock ranges from approximately 690 to 702 ft msl (Attachment C) in the Power Block area indicating that bedrock surface variations are minor (Tennessee Valley Authority 1980). The Conasauga Formation is approximately 2,000 ft in thickness in the vicinity of the Site.

The alluvium and upper terrace deposits (finer grained) have been removed in the main plant area (excavated to an elevation of approximately 728 ft msl) (Tennessee Valley Authority 1980). Therefore, non-category I features are underlain by engineered backfill.

The Site is situated within the Tennessee River watershed (Figure 3-2), with the Tennessee River located to the south and east of the main plant. Local groundwater flow within the unconsolidated zone is toward the south, discharging to the Tennessee River (Figure 3-2 and Attachment H). An on-site groundwater drainage system, connected to a sump, surrounds the perimeter of the Power Block. This system influences shallow groundwater near the Power Block Building by creating an artificial groundwater divide (Figure 3-3 and Attachment I). Shallow groundwater to the north of this divide flows in a radial pattern toward the Power Block, due to the drawdown influence of the continuously-operating sump and drainage system (Figure 3-3 and Attachment I). South of the groundwater divide, flow is generally toward the Tennessee River (south) (Figure 3-2 and Attachment H).

The characteristics of various site infrastructure components have a significant impact on groundwater flow. The Yard Holding Pond (YHP), as an example, influences shallow groundwater flow by generating a groundwater mounding effect in the surrounding area. Underground piping and excessive cut and backfill during infrastructure construction also influences groundwater flow by providing preferential flow regimes within the transmissive backfill surrounding these pipes. Groundwater occurrence and movement within the Conasauga Formation bedrock is confined to small openings along fractures and bedding planes, but generally flows southward toward the Tennessee River also (Tennessee Valley Authority 1980).

3.3 Well Installation

As part of planned plant modifications to produce tritium for the U.S. Department of Energy (USDOE), TVA committed to modify the REMP by installing additional monitor wells around the WBN Plant. Four additional monitor wells (Wells A through D) were installed at Watts Bar along the existing Rad Waste and Cooling Tower Blowdown Lines. These wells were installed in December 2002.

Additional monitor wells and Geoprobe wells were installed throughout 2003 and early 2004 to delineate the extent of tritium impact to shallow groundwater. In March 2003, three additional monitor wells (Wells E, F, and G) were installed to further assess potential sources of tritium in the site groundwater. Wells H through S were installed during September and October 2003 and wells T through X were installed during

December 2003. These wells were typically drilled to bedrock and screened over the bottom 10-ft interval.

Wells Y, Z, and AA through LL were installed using a direct-push Geoprobe rig. Geoprobe wells are ¾-inch inner diameter and 1-inch outer diameter polyvinyl chloride casings. Wells Y, Z, and AA through DD were installed during the final week of January 2004 and first week of February 2004. Geoprobe Wells EE through LL were installed at the end of February 2004. All Geoprobes were installed to refusal and screened over the bottom 10-ft interval.

3.4 Hydrology

WBN Plant is located within the Tennessee River watershed (Figure 3-2). The Tennessee River, particularly above Chattanooga, Tennessee, is one of the most highly regulated rivers in the United States. The TVA reservoir system is operated for flood control, navigation, and power generation, with flood control a prime purpose with particular emphasis on protection for Chattanooga, 64 miles downstream from the WBN Plant. The WBN Plant sits on the west bank of the Tennessee River, 57 miles upstream of Chickamauga Dam. Watts Bar Dam is 1.9 miles upstream of the plant. At the WBN Plant, The river is approximately 1,100 ft wide with depths ranging between 18 ft and 26 ft at the normal pool elevation of 682.5 ft msl (Tennessee Valley Authority 1980).

Based upon Watts Bar Dam discharge records since 1942, average daily stream flow at the plant is 27,800 cubic feet per second (cfs). Flow data for water years 1960 through 1987 indicate average summer flow rates (May to October) of 23,700 cfs and average winter flow rates (November to April) of 31,900 cfs. Channel velocities at WBN Plant average about 2.3 feet per second (fps) under normal winter conditions. Because of lower flows and higher reservoir elevations in the summer months, channel velocities average about 1.0 fps (Tennessee Valley Authority 1980).

The climate of the watershed is humid temperate. The area receives approximately 50 inches of precipitation per year. Based on a 30-year average (1971 through 2000), the wettest month of the year is March (5.71 inches) and the driest month of the year is October (2.65 inches). The wettest 3-month average is 4.58 inches/month for January through March and the driest 3-month average is 2.86 inches/month for August through October (National Weather Service 2004).

The local watershed surrounding the plant is relatively small because the plant is approximately 2,000 ft from the Tennessee River. The watershed divide is located north and northeast of the plant along a ridge (Figure 3-2). Precipitation that falls south of the ridge in the local watershed collects in numerous small streams that drain towards the Tennessee River. Precipitation collected by the Site's storm sewer system drains to the YHP before eventually being discharged to the river.

3.5 Tritium Distribution

Tritium was detected in the initial baseline groundwater samples taken from three of the four new groundwater monitor wells (Wells B, C, and D) installed as part of the REMP in January 2003. The maximum tritium detection during this initial sampling was 12,453 pCi/L at Well B (Appendix B). As described in Section 3.3, additional monitor wells and Geoprobe wells were installed throughout 2003 and the beginning of 2004 to delineate tritium in groundwater.

The most comprehensive and current tritium data set was collected on March 1, 2004, as a snapshot in time of plume distribution (Table 3-1). Based on this data, tritium is not present along the northern (Wells T, U, V, W, and X) and western (Wells Q, P, O, and N) sides of the Power Block and switchyard. Geoprobe Wells Y and Z (west and north, respectively, of the Unit 1 Reactor Building) were not sampled during this event, but previous sampling events indicate no detectable tritium concentrations at these locations. Based on the March 2004 and previous data sets, two distinct areas of tritium exist (Figures 3-5 through 3-7 and Attachment J and K).

The largest area of tritium concentrations in groundwater extend from the east side of the Turbine Building at Well R east to approximately Well K and then south to the YHP, with the southernmost extent of tritium being approximately Well B. The maximum tritium concentration during the March 2004 sampling event was located at Well K at 109,000 pCi/L. The maximum historical tritium concentration was also located at Well K on October 1, 2003 at 353,700 pCi/L. Monitor wells and Geoprobe wells with tritium concentrations greater than 10,000 pCi/L during the March 2004 sampling event include Wells K, L, R, GG, and KK (Figures 3-5 and 3-6). Maximum tritium concentrations in this area appear to follow preferential groundwater pathways created by underground piping infrastructure and their associated backfill. The Condenser Cooling Water (CCW) Discharge Pipes, particularly for Unit 1, Waste Heat Park Lines, Rad Waste Line, Storm Sewer Lines, and the Cooling Tower Blowdown Lines have the greatest affect on plume distribution. Tritium concentrations at Well L indicate a portion of tritium is moving toward the YHP, likely due to a set of abandoned waste heat lines that are positioned east/west along the northern portion of the YHP. Additional wells near the Intake Pump

Station and Tennessee River (Wells F, J, D, H, B, E, and A) indicate tritium is migrating toward the river and has extended as far south as Well B.

The second area of tritium concentrations in groundwater is located surrounding the Unit 2 Reactor Building. Well BB is the only location with detectable concentrations of tritium (2,120 pCi/L) during the March 2004 sampling event. Wells CC and DD have also recently had detectable tritium concentrations, but these wells were dry during the March 2004 sampling event.

3.6 French Drain/Groundwater Sump

A perimeter drain encompasses the entire Power Block area (i.e., Reactor, Auxiliary, Control, Turbine, and Service Buildings) and was installed at foundation depths to prevent groundwater from entering the lower levels of the plant. The French drainpipe is a porous 8-inch concrete pipe set in crushed stone, which is approximately 2 ft in thickness. The highest elevation for the perimeter drain (French drain) is located at the southwest corner of the Service Building at 710 ft msl (ground elevation surrounding the plant is approximately 728 ft msl). Hence, groundwater entering the drain moves by gravity in two directions at a slope of 0.1% from this southwest corner. Each leg of the French drain is 1,250 ft in length and ends at an elevation of 708.75 ft msl along the east side of the Auxiliary Building. The two legs of the drain empty into a groundwater sump with a bottom elevation of approximately 700 ft msl. Groundwater collected in the sump is then normally pumped to Catch Basin (CB) 50 of the stormwater sewer system where it drains to the YHP.

Beginning in March 2003, tritium samples have been collected from the groundwater sump where the two legs of the French drain discharge. Tritium samples were periodically collected from this location through the remainder of 2003 and beginning of 2004 (Figure 3-8). During April and May 2003, groundwater sump concentrations were consistently between 10,000 and 15,000 pCi/L. Since that time, concentrations have steadily decreased from approximately 10,000 pCi/L to 4,000 pCi/L in February 2004 (Figure 3-7).

With elevated tritium concentrations discovered during 2003, groundwater from the sump was rerouted to the station sump, which is a monitored release point, instead of CB 50 on April 25, 2003. Groundwater pumped from the sump was returned to the normal discharge operation to the YHP via CB 50 on February 27, 2004, following installation of runtime meters on the sump pumps to allow characterization of the discharge from this release point.

To further define the source of tritium, the two inputs were sampled (north and south leg of the French drain at the discharge point) periodically in December 2003 and January 2004. Both legs of the French drain system are collecting water with tritium. The northern French drain input to the groundwater sump consistently discharges more water (53.1 gpm) and a lower concentration (4,700 pCi/L) than the southern leg of the French drain (19.4 gpm and 8,200 pCi/L) (Figure 3-8).

3.7 Fate and Transport

Quantification of solute migration requires specification of various transport parameters and processes that control the rate, movement, mixing, sorption, and degradation of a contaminant in the subsurface. Advection defines the process of contaminant migration due to the movement of groundwater. Dispersion accounts for the spreading and mixing of the constituent due to heterogeneities and non-ideal flow paths in the soil that cause variations in the groundwater velocity, as well as Fickian diffusion driven by concentration gradients. Sorption refers to the partitioning of a contaminant between the liquid and solid phases of the aquifer. Degradation is the mass decay of a contaminant as a result of physical, chemical, and biological activity within the aquifer. Each of these processes and their effect on the movement of site-related constituents along flow pathways are summarized in the following sections.

3.7.1 Advective Water Movement

Water-level measurements taken in monitor wells and Geoprobes distributed spatially across the Site provide the necessary information to describe the direction of groundwater movement. These water-level measurements are combined with effective porosity and hydraulic conductivity information to determine the rate or speed of groundwater movement. In general, water-level measurements are used to define the slope of the water table (gradient) and direction of movement; groundwater moves down the slope or gradient from high water-table elevations to lower water-table elevations. Based upon both water levels and constituent concentrations, the primary flow pathways are toward the French drain near the power block and toward the Tennessee River once out of the influence of the French drain (Figures 3-2 and 3-3).

The movement of a solute with the groundwater, or advective transport, can be computed using Darcy's Law. Darcy's Law is written as follows:

$$q = K\,i \qquad (1)$$

where, q is the Darcian flux ($ft^3/day/ft^2$ or ft/day), K is the hydraulic conductivity (ft/day), and i is the hydraulic gradient (ft/ft). Since water can only move through the pore spaces, the Darcian flux is not the velocity at which groundwater is moving. The average linear velocity of groundwater is higher as water moves only through the voids or pore spaces of the soil:

$$v = {}^{q}\!/_{\theta_e} \qquad (2)$$

where v is the velocity (ft/day) and θ_e is the effective porosity (ft^3/ft^3). The effective porosity for the unconsolidated sediments and engineered backfill at the Site was assumed to be 0.20. The average gradient from the groundwater divide to the river is 0.018 and the average gradient to the French drain is 0.02 based on the March 2004 water-level information. Aquifer testing was not conducted as part of this investigation. Therefore, hydraulic conductivity was determined using two different methods using the flow from the French drain and by assuming a known velocity of the existing tritium plume.

The known flow in the French drain can be used to calculate the hydraulic conductivity by computing the flux of groundwater into the drain assuming all water flowing in is from groundwater. The average linear velocity of the groundwater into the French drain multiplied by the area through which the groundwater flows will yield the flow in the French drain. The average flow in the French drain (both legs combined) for the six sampling events is 72.5 gpm or 13,956 ft^3/day (Figure 3-8). The area through which groundwater flows into the French drain is the length of the French drain (both legs, 2,500 ft) multiplied by the height of the saturated interval emptying into the drain (approximately 10 ft). Also, groundwater is assumed not to flow to the French drain from inside the loop because the plant was built on bedrock (i.e., not unconsolidated deposits). The hydraulic conductivity calculated using an effective porosity of 0.20 and an average gradient of 0.02 is 5.6 ft/day.

The hydraulic conductivity can also be calculated by assuming tritium is moving at the same velocity of groundwater and the tritium leak began in 1996 when the plant first went to criticality. The length of the plume (from Geoprobe JJ to just south of Well B) is 2,000 ft, and this plume was assumed to be created over a timeframe of 7 years (Figure 3-4). This results in a groundwater/plume velocity of 285.7 ft/year or

0.78 ft/day. The hydraulic conductivity using this method is 8.7 ft/day by assuming an effective porosity of 0.20 and an average gradient during that timeframe of 0.018.

These two methods resulted in relatively similar hydraulic conductivities and provide confidence in the average hydraulic conductivity of the unconsolidated sediments and engineered backfill, the age of the plume, and the velocity of the plume. Based on these results, the edge of the plume (defined as 1,000 pCi/L) will reach the Tennessee River (a distance of approximately 600 ft) in slightly more than 2 years.

3.7.2 Sorptive Processes and Degradation

The term sorption refers to the removal of a solute from solution through association with a solid surface. This attraction between a soil surface and a solute can result from a number of forces. The effects of these forces or processes are commonly described by sorption isotherms. These isotherms assume that when a solution contacts a solid, the solute will tend to transfer from liquid to solid until the concentration of solute in solution is in equilibrium with the soil concentration. These processes, especially for inorganic compounds, tend to be pH dependent, not always completely irreversible, and site specific. With respect to the constituents found in groundwater at the WBN site, this process has no effect on the movement of tritiated water and only a minor effect on the movement of boron; therefore, this process is not important to understanding the fate and transport of tritium. Tritium is a radioactive form of hydrogen and has a half-life of 12.33 years. Tritium is not susceptible to either biological or chemical degradation enhancement.

3.7.3 Dispersion

Dispersion is the process whereby contaminants spread over a greater region than would be predicted solely from the average linear groundwater velocity. Dispersion occurs at multiple scales. The primary cause of dispersion is variations in groundwater velocity, on a microscale by variations in pore size and on a macroscale by variations in hydraulic conductivity. The hydrodynamic dispersion tensor is complex. For isotropic media, the dispersion coefficient written to incorporate molecular diffusion (described by Fick's Law), is calculated as follows:

$$D_c = \alpha_d v + D \tag{3}$$

where D_c is the dispersion coefficient $[L^2/T]$, α_d is the dispersivity [L], v is the groundwater velocity [L/T], and D the molecular diffusion coefficient $[L^2/T]$.

While the general process of dispersion is understood, the dispersivity of a formation is not easily measured or quantified at the field scale. Therefore, as dispersion is related to porewater velocities, plume travel distance is the single most important factor that can be correlated to dispersivity. For the WBN site, the advective transport of tritium will far exceed the effects of dispersivity and its effects can therefore be considered negligible.

If tritiated groundwater were to discharge into the Tennessee River, the tritium would significantly be diluted. Assuming a 400-ft wide tritium plume discharging into the Tennessee River at a rate of 5.8 gpm, a tritium concentration of 1,000 pCi/L results in a surface-water concentration of 0.0024 pCi/L. A 10,000 pCi/L tritium concentration would result in a surface-water concentration of 0.024 pCi/L and a 100,000 pCi/L tritium concentration would result in a surface-water concentration of 0.24 pCi/L. Background tritium concentrations are approximately 150 pCi/L. Although these concentrations would not pose an unacceptable risk or even be detectable, TVA is going forward with plans to ensure tritium does not reach the Tennessee River (Section 6.0).

4.0 Source Assessment

Based on the distribution of tritium in groundwater and refined understanding of groundwater flow conditions, the tritium plumes observed at WBN are likely associated with two separate sources. This conclusion is bolstered by the differing, yet consistent, tritium concentrations discharging from the north and south legs of the French drain. The investigation and data collected indicate that Source #1 is the result of a leak in the Rad Waste Line near Geoprobe Well JJ, and Source #2 is a result of a leak in the FTT Sleeve through the Unit 2 Shield Building seismic gap. Source #1 is partially controlled by groundwater discharge from the French drain and Source #2 is completely controlled by the French drain. The following sections detail each of the two sources.

4.1 Source #1 – Rad Waste Line

Documented leaks from the Rad Waste Line appear to have resulted in tritium extending in dual branch fashion west from the Well K vicinity to the southeast edge of the Turbine Building, and south from the Well K vicinity towards the Tennessee River (Figure 4-1). The Rad Waste Line was pressure tested, acoustically monitored, and excavated at several locations to identify potential leak locations. A leak was identified east of the Power Block (Figure 4-1) after overburden was excavated on May 1, 2003. The leak appeared to be caused by accelerated corrosion from the pipeline exterior due to a tear in the protective pipe wrap. The line was cut, inspected, and repaired. Through the fall of 2003, possible additional leaks in the line were investigated, but no additional leaks have been found.

The Rad Waste Line leak, identified and repaired in May 2003, is suspected of being the primary source of tritium. A portion of the tritium originating from the leak location has migrated toward the south leg of the French drain system along preferential pathways associated with the CCW Lines and relatively permeable bedding material. Another portion of the tritium originating from the leak appears to follow major subsurface lines (i.e., Cooling Tower Blowdown Line, Waste Heat Park Lines, and storm drains) towards the Tennessee River. Again, this directional behavior is likely associated with preferential groundwater movement associated with the higher permeability bedding material surrounding subsurface piping.

When the WBN Plant was constructed, engineered fill was placed over a majority of the Site. The tighter hydraulic properties make the fill more difficult for groundwater to flow through than the gravel packs surrounding the numerous pipe systems associated with facility infrastructure. Tritium migration towards the Turbine Building appears to be influenced by the south CCW Discharge Line running from the Turbine Building to the Unit 1 Cooling Tower. Tritium migration toward the river is strongly influenced by the Cooling Tower Blowdown Line, Waste Heat Park Lines, and other piping infrastructures, as their position within the subsurface is coincident with the groundwater table along portions of their length. Based on calculations of tritium in the south leg of the French drain, it is likely that a majority of the activity is not being observed in groundwater monitor wells and is within the more permeable gravel packs of the discharge CCW Line and Raw Cooling Water Lines. A majority of the groundwater monitor wells has shown decreasing concentrations of tritium, indicating that the primary source has been eliminated.

4.2 Source #2 – Unit 2 Fuel Transfer Tube Seismic Gap

In February 2003, it was identified that water was leaking into the Unit 2 Shield Building annulus through the Unit 2 FTT sleeve connection between the Auxiliary and Unit 2 Shield Buildings. All of these units (SFP, CLP, and FTC) have the potential to be inter-connected behind the stainless-steel liner since the liner is not continuously bound in the concrete. A 1-inch seismic gap exists between the Auxiliary Building and Unit 2 Shield Building where the FTT passes through these buildings (Figures 4-2 and 4-3). Tritiated water, between the steel tube (20-inch diameter) and the Concrete Building, was observed flowing into the Unit 2 Shield Building annulus in February 2003. This water must flow across the seismic gap to get from the Auxiliary Building to the Unit 2 Shield Building, which provides a pathway to groundwater. This gap is filled with fiberglass and is glued on one side to the Unit 2 Shield Building. Potentially, water from the SFP, CLP, or FTC that has leaked behind the stainless-steel liner could migrate to the Unit 2 FTT sleeve.

Leaks through the FTT sleeve and seismic gap have resulted in groundwater impact surrounding the Unit 2 Shield Building (Figures 4-2 and 4-3). Occasional FTC leakage has been identified over the past 5 to 6 years. The SFP and adjacent CLP, along with the FTC, have individual "tell-tale" drain systems to detect leakage through the liner welds. Neither of these drain systems has exhibited recent leakage, although recent investigations indicate that the drain system for the SFP and FTC is clogged, so evidence of leakage by this method is problematic. Subsequent efforts to clear these drain systems have resulted in a functioning drain system for the FTC. The SFP system continues to not drain and additional efforts are under way. The Cask Loading Area drain system appears to be functioning as designed. Inspection of the "tell-tale" drain system is further complicated due to its piping configuration.

The difference in potential head between the bottom of the FTT sleeve and the French drain directly north of the seismic gap is approximately 1.25 ft, indicating that water would flow towards the French drain from this point (either to the north or to the east). Calculations using the tritium concentrations in these areas of nearly 100 million pCi/L indicate it would take a small volume of tritiated water to result in the concentrations being observed in the north leg of the French drain, and in groundwater monitoring points around the Unit 2 Shield Building.

5.0 Risk Summary

Risk analysis is the process of organizing and systematically evaluating information pertaining to the likelihood and magnitude of adverse effects. In the context of environmental contamination, this typically includes separate analyses of the risks to human health and the risks to ecological receptors. However, both human health and ecological risk assessment consist of fundamentally similar elements. These elements include a problem formulation (description), exposure analysis, effects analysis (i.e., toxicity), and risk characterization. These elements are implicitly included in this risk summary, but only the most essential factors are discussed.

5.1 Site Conceptual Exposure Model

Exposure, in the context of human health and ecological risk, is defined as the contact of a receptor with a chemical or physical agent. For exposure to occur, a source of contamination or contaminated media must exist which serves as either 1) a point of exposure or 2) transports contaminants away from the exposure unit to a point where exposure could occur. In addition, a receptor must come into either direct contact (i.e., ingestion, inhalation, dermal contact, or external exposure) or indirect contact (ingestion of foodstuffs that have bioaccumulated contaminants within their systems) with the contaminant. This concept, exposure pathway, includes the elements of a contaminant source, contaminated environmental media, exposure point, exposure route, and receptor.

Based on the activity patterns of a population, any given individual may be exposed to more than one exposure pathway. Therefore, the exposure assessment must also evaluate the activity patterns of the potential receptors and determine what combination, if any, of exposure pathways an individual might be exposed to. This evaluation results in the generation of exposure scenarios. Exposure scenarios represent the combination (if applicable) of exposure pathways that an individual could be exposed to based on their activity patterns. The result of an exposure pathways analysis is the development of a site conceptual exposure model (Figure 5-1).

5.2 Human Health

The site conceptual exposure model (Figure 5-1) indicates that currently no completed exposure pathways are known or suspected. Surface soil was not affected by the release and does not serve as a contaminant source. Releases of tritium initially affected subsurface soil and subsequently groundwater. The contaminated environmental media, groundwater, is not used as a source of potable water nor for process applications. No residential drinking water wells are located within the area of impact nor are anticipated to be installed.

Anticipated future maintenance or construction activities at the facility (on site) related to operation/upgrades of plant infrastructure could result in potential exposure of construction/excavation workers to impacted groundwater. This is considered a viable exposure pathway based on the known extent of the groundwater plume, the existence of preferential flow pathways (i.e., underground piping/conduits), and the relatively shallow depth to groundwater. Human exposure to tritium in groundwater could occur via incidental ingestion, inhalation, or dermal contact.

Potential future off-site exposure to receptors could occur as a result of the migration of affected groundwater to surface water. The Tennessee River is immediately downgradient of the facility and is used for recreational and navigational purposes. Human exposure to tritium in surface water during recreational activities could occur via incidental ingestion, inhalation, and dermal contact.

An analysis of potential adverse effects is the counterpart to a review of potential exposure pathways. Two important effects-based values for the protection of human health are drinking water standards and preliminary remediation goals. The drinking water Maximum Contaminant Level (MCL) for gross beta emissions is 4 millirems per year which equates to 20,000 pCi/L of tritium. The preliminary remediation goal based on exposure via incidental ingestion of water as part of a recreational scenario is 290,000 pCi/L (U.S. Department of Energy 2002). Based on these screening values, it is unlikely that the existing tritium contaminated groundwater will pose an unacceptable risk to future human receptors. This is especially true given the substantial dilution that would occur if the tritiated groundwater were to discharge to the river. As noted above, there currently are no known or suspected completed exposure pathways.

5.3 Ecological

The site conceptual exposure model (Figure 5-1) indicates that currently there are no known or suspected completed exposure pathways for ecological receptors. Future completed exposure pathways may exist for off-site receptors. However, any potential exposures for ecological receptors are likely to be well below typical levels of concern.

Aquatic biota are the ecological receptors of primary concern at this site, based on the constituent of concern, affected media, and environmental setting. Terrestrial animals are not expected to be exposed to tritium in groundwater and the terrestrial vegetation in the area is part of the maintained facility, rather than a natural environment. Natural populations of aquatic biota do not occur on-site (i.e., the YHP is a treatment facility and is not maintained as an ecological habitat). Therefore, there are no known current or future on-site exposure pathways for aquatic biota.

Off-site ecological exposures could occur in surface water at the downgradient boundary of the Site. This exposure pathway is not believed to be a completed exposure pathway under current conditions. However, the groundwater tritium plume has the potential to reach the site boundary in the future. This could lead to a completed exposure pathway for aquatic biota in the river (Figure 5-1).

Although an ecological risk assessment is not warranted at this time, a brief review of the available screening values for tritium can provide a valuable perspective on the potential for future ecological impacts. The USDOE recently developed "A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota" (U.S. Department of Energy 2002). This peer-reviewed USDOE technical standard is the first and only comprehensive guidance document on this topic and is the basis for the discussion of potential ecological impacts that follows.

The USDOE graded approach (U.S. Department of Energy 2002) provides screening values for water, sediment, and soil called Biota Concentration Guides (BCGs). A BCG is the concentration of a radioactive isotope (e.g., pCi/L) that is estimated to result in a dose rate (e.g., Rad/d) equivalent to the consensus safe exposure level for the receptor being evaluated (i.e., 1.0 Rad/d for aquatic animals and terrestrial plants and 0.1 Rad/d for terrestrial animals). BCGs are available for four classes of ecological receptors: aquatic animals, riparian animals, terrestrial animals, and terrestrial plants. The BCGs for tritium in water are presented on Table 5-1.

Based on these conservative screening values, potential ecological impacts due to exposure to the existing tritium contaminated groundwater are highly unlikely. It is also noteworthy that tritium does not bioaccumulate. For example, the USDOE Graded Approach used conservative uptake factors (concentration ratios) for tritium that ranged from 0.2 to 1.0 (U.S. Department of Energy 2002). A value less than or equal to 1.0 indicates that receptor organism will have the same or lower concentration of the contaminant than does the media to which it is exposed. Therefore, there is no indication of potential ecological impacts via food chain exposure pathways for tritiated groundwater.

5.4 Risk Conclusions

Actual risks to human and ecological receptors are acceptable based on available environmental data and existing radiological screening criteria. However, risks may be perceived by the public to be higher than actual because the constituent of concern is a radionuclide. Therefore, risk managers must rigorously demonstrate that remedial measures are adequate to ensure protection of human health and the environment. Additionally, risk management activities should include a risk communication component.

6.0 Remediation Planning Summary

Recent assessment activities indicate that site groundwater has been impacted by tritiated process water. Two potential tritium sources have been identified;
1) Rad Waste Line, which appears to have resulted in a dual branch tritium plume that extends from the Rad Waste Line toward the river and toward the Turbine Building; and 2) Unit 2 FTT sleeve, which appears to have resulted in a tritium plume that is localized in the vicinity of the Unit 2 Shield Building. Repairs of the component infrastructure responsible for the release are already underway. All of Source #2 and a portion of Source #1 are captured by ongoing recovery at the French drain groundwater sump. The portion of the plume not captured has resulted in migration of tritiated groundwater southward toward the YHP and to the Tennessee River. This portion of the plume, and associated groundwater movement, appears to be preferentially following the bedding material surrounding the utilities, which run downgradient from the plant to the river. Since tritium does not sorb to soil, the plume is migrating at the same rate as groundwater velocity.

Remedial action objectives (RAOs) must be established to guide remedial planning and any resulting actions. RAOs are typically selected based on removing unacceptable risk to receptors, both current and potential future. The RAOs for the Site are designed to remove unacceptable risk to human receptors, protect ecological resources in the Tennessee River, and control/prevent plume growth. RAOs for the Site include:

- Protect ecological receptors in the Tennessee River from impacted groundwater;
- Prevent groundwater plume growth to ensure it does not migrate off site;
- Protect human health of plant workers from exposure to impacted groundwater; and
- Remove tritium mass in plume core to assist in natural attenuation of remaining plume.

Since the discharge from the YHP is monitored and tritium levels are very low (<1,000 pCi/L), no mitigation measures are likely necessary. However, additional migration of the plume toward the river should be monitored or controlled. Minimizing continued downgradient migration of the plume toward the river can only be achieved through some type of hydraulic control. An example of this commonly used technique would involve constructing a series of extraction wells (or trench) along the downgradient edge of the plume. Alternatively, hydraulic control can be accomplished by using phreatophytic vegetation to transpire tritiated water to the atmosphere, however, this approach would take longer to be effective and may not be appropriate for the WBN site (i.e., deep water table and preferential flow).

Tritium has a half life of 12.33 years. Aside from this natural decay, tritiated water has the same physical characteristics as normal water. As a result, treatment technologies (e.g., ion exchange, adsorption, precipitation, etc.) normally used to remove chemicals or compounds from water will not separate or remove tritiated water from normal water. Therefore, options for integrating extracted groundwater into the plant process stream need to be evaluated. Although the water is not "treated", downgradient receptors are protected as concentrations are sufficiently reduced such that the associated risk is neglible.

Control and/or management of plume migration can be accomplished through a complete understanding of site conditions. This would allow quantification of tritium flux into the Tennessee River and permit design of a hydraulic containment system to prevent a release of tritium to surface water. Prior to designing a hydraulic control system, refinement of the plume extent, a fate and transport model, and a better understanding of the engineered fill along the utility corridor would be required. Once this is completed, hydraulic testing would be conducted to develop the necessary data to design the recovery wells and size the system.

7.0 Recommendations

Based on these initial findings, the following observations/recommendations are made to correct the tritium releases.

- *Unit 2 FTT Sleeve Repair*: Tritiated water must be prevented from crossing the seismic gap in the Unit 2 FTT sleeve, or prevent water from entering the FTT sleeve. WBN is currently investigating the application of a coating/sealing system for the transfer canal liner to preclude leakage into this area. This is documented in the Site Problem Evaluation Report (PER) number 12430.
- *Replacement of Rad Waste Line Sections*: Because the existing Steam Generator Blowdown/Rad Waste Lines likely have minor existing leaks, continuing releases could be occurring from this line system. In order to prevent these possible current or future leaks, WBN is replacing this line under the Design Change Notice (DCN) number 51690.
- *Monitoring Program Development*: Groundwater sampling procedures have been refined over time to make improvements when necessary. These should be further revised to examine the sequence of well sampling and use of dedicated sampling equipment. A monitoring program should be designed to continue to collect those data that will provide information on current site conditions, and what is necessary to evaluate a remedial solution/progress. Once the monitoring program has met these needs, it should be reduced or eliminated.
- *Refinement of Plume Extent*: Additional groundwater monitor wells are needed to better define the tritium plume and to monitor its movement at the distal end near the Tennessee River.
- *Source #1 Remedial Measures*: Source #1 is somewhat controlled by inducing groundwater flow to the plant buildings by the French drain and actively pumping the groundwater sump. A hydraulic control system may be used to capture the entire plume by installing recovery wells in the downgradient leading edge of the plume, south of the plant. Aquifer testing and a fate and transport model may be used to design the hydraulic control system.
- *Source #2 Remedial Measures*: Source #2 is completely contained by the French drain and actively pumping the groundwater sump. The extent of tritium in groundwater at Source #2 has likely been influenced by moderate to large storm events and underground infrastructure (i.e., RWST tunnel). Nevertheless, the plume around the Unit 2 Shield Building remains focused and contained, and no additional remedial actions are needed.

8.0 References

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Table 2-1. Chronology of Events

Tennessee Valley Authority Watts Bar Nuclear Plant Spring City, Tennessee

Date	Activity
August 2002	- Low levels of tritium were detected in a scheduled sample drawn from an on-site radiological monitor well (Monitor Well 1)
December 2002	- Additional REMP wells (Wells A, B, C, and D) were installed as part of the plant modifications to produce tritium
January 2003	- Groundwater samples collected from new monitor wells (A through D) indicated tritium in 3 of the 4 wells (Wells B, C, and D)
January 2003	- It was identified that the Unit 2 FTT bellows was leaking water into the Unit 2 Reactor Building
March 2003	- TVA team formed to determine and eliminate the source(s) of tritium in groundwater
March/April 2003	- Pressure testing and soil sampling around the Rad Waste Line
May 2003	- Leak identified in Rad Waste Line and line was cut, inspected, and repaired
June 2003	- Boroscopic inspections were made of the drain lines for the SFP and the CLP
August 2003	- Repair method was developed for FTT by removing the bellows and transfer tube and placing a plate over the remaining hole
October 2003	- Refueling outage/initiation of tritium program
October 2003	- Mobile camera (submersible) was used to record the condition of the FTC walls and floor
December 9, 2003	- Initial Site Meeting (TVA and ARCADIS)
January 9, 2004	- Project Kick-Off Meeting (TVA and ARCADIS)
January 23, 2004	- Team Progress Meeting (TVA and ARCADIS)
February 13, 2004	- Team Progress Meeting (TVA and ARCADIS)
March 1, 2004	- Comprehensive "snapshot" sampling of all wells for tritium and measurement of all well water levels
March 11, 2004	- Team Progress Meeting to present findings (TVA and ARCADIS)
April 16, 2004	- Presentation to TVA plant management of tritium investigation findings

CLP - Cask Loading Pit
FTC - Fuel Transfer Canal
FTT - Fuel Transfer Tube
REMP - Radiological Environmental Monitoring Program
SFP - Spent Fuel Pool
TVA - Tennessee Valley Authority

ARCADIS

Table 2-2. Well Summary and Water Levels

Tennessee Valley Authority Watts Bar Nuclear Plant Spring City, Tennessee

Well	Coordinates TN Lambert (ft)		TOC (ft msl)	10/8/03		12/12/03		1/14/04		3/1/04		3/11/04	
	East	North		Level (ft)	Water Level (msl)	Level (ft)	Water Level (msl)	Level (ft)	Water Level (msl)	Level (ft)	Water Level (msl)	Level (ft)	Water Level (msl)
A	2360776	440131	704.52	20.33	684.19	20.61	683.91	37.0	667.52	28.4	676.12	NM	NM
B	2360769	440887	709.64	25.25	684.39	26.10	683.54	26.4	683.24	27.9	681.74	NM	NM
C	2360754	442317	726.17	12.75	713.42	11.60	714.57	12.2	713.97	12.2	713.97	NM	NM
D	2360717	441161	714.71	28.33	686.38	Dry	Dry	29.8	684.91	DRY	DRY	NM	NM
E	2360204	440566	738.71	53.25	685.46	55.80	682.91	55.6	683.11	54.5	684.21	NM	NM
F	2360870	441509	723.88	22.17	701.71	20.60	703.28	22.7	701.18	21.6	702.28	NM	NM
G	2361666	441932	723.03	36.75	686.28	37.00	686.03	36.7	686.33	19.4	703.63	NM	NM
H	2360682	441013	712.18	26.50	685.68	30.50	681.68	28.4	683.78	28.8	683.38	NM	NM
I	2360558	442289	725.53	12.08	713.45	11.10	714.43	11.4	714.13	11.3	714.23	NM	NM
J	2360834	441341	711.77	20.25	691.52	22.10	689.67	20.5	691.27	20.4	691.37	NM	NM
K	2360525	442600	728.01	14.17	713.84	13.00	715.01	13.4	714.61	13.1	714.91	12.6	715.41
L	2360510	441772	725.48	27.25	698.23	16.60	708.88	17.6	707.88	17.3	708.18	NM	NM
M	2359974	441652	729.20	24.33	704.87	16.00	713.20	25.9	703.30	25.9	703.30	NM	NM
N	2359448	441557	726.65	27.67	698.98	24.50	702.15	24.2	702.45	26.5	700.15	NM	NM
O	2359379	442244	727.95	14.33	713.62	22.00	705.95	12.9	715.05	13.1	714.85	NM	NM
P	2359440	442658	727.27	14.58	712.69	18.10	709.17	14.6	712.67	14.3	712.97	NM	NM
Q	2359353	443147	725.35	4.33	721.02	3.90	721.45	4.4	720.95	4.2	721.15	NM	NM
R	2360060	442616	726.59	16.33	710.26	16.00	710.59	16.0	710.59	15.1	711.49	NM	NM
S	2360330	442595	724.49	11.58	712.91	9.90	714.59	10.2	714.29	NM	NM	9.5	714.99
T	2359511	443167	726.70	NI	NI	NI	NI	12.8	713.90	13.1	713.60	NM	NM
U	2359641	443190	727.22	NI	NI	NI	NI	15.9	711.32	15.8	711.42	NM	NM
V	2359847	443234	727.89	NI	NI	NI	NI	15.1	712.79	15.9	711.99	NM	NM
W	2359950	443252	727.60	NI	NI	NI	NI	13.6	714.00	14	713.60	NM	NM
X	2360046	443261	728.09	NI	NI	NI	NI	14.4	713.69	13.9	714.19	NM	NM
Y	NA	NA	NA	NI	NI	NI	NI	NI	NI	NM	NM	NM	NM
Z	NA	NA	NA	NI	NI	NI	NI	NI	NI	NM	NM	NM	NM
AA	2359992	442954	729.49	NI	NI	NI	NI	NI	NI	20.8	708.69	NM	NM
BB	2359995	443017	732.07	NI	NI	NI	NI	NI	NI	23.8	708.27	NM	NM
CC	2359973	443118	730.83	NI	NI	NI	NI	NI	NI	DRY	DRY	NM	NM
DD	2360043	442970	732.26	NI	NI	NI	NI	NI	NI	DRY	DRY	NM	NM
EE	2360112	442827	731.78	NI	NI	NI	NI	NI	NI	20.5	711.28	NM	NM
FF	2360035	442738	729.32	NI	NI	NI	NI	NI	NI	20	709.32	NM	NM
GG	2360036	442638	731.62	NI	NI	NI	NI	NI	NI	21.2	710.42	NM	NM
HH	2360294	442683	727.14	NI	NI	NI	NI	NI	NI	14	713.14	13.3	713.84
II	2360550	442932	729.03	NI	NI	NI	NI	NI	NI	13.4	715.63	NM	NM
JJ	2360567	442734	728.90	NI	NI	NI	NI	NI	NI	12.7	716.20	NM	NM
KK	2360561	442654	729.74	NI	NI	NI	NI	NI	NI	14.8	714.94	NM	NM
LL	2360279	442994	731.07	NI	NI	NI	NI	NI	NI	17.1	713.97	NM	NM
MW-1	2360289	443209	726.99	8.11	718.88	7.90	719.09	7.9	719.09	7.6	719.39	NM	NM
MW-2	2360109	443072	727.86	15.94	711.92	15.70	712.16	15.9	711.96	15.9	711.96	NM	NM
MW-3	2360286	442873	727.34	13.96	713.38	13.70	713.64	13.7	713.64	13.4	713.94	NM	NM
MW-4	2360193	443149	727.86	17.74	710.12	12.70	715.16	12.7	715.16	12.5	715.36	NM	NM
GW Sump	2359991	442920	728.50	26.09	702.41	NM	NM	NM	NM	NM	NM	NM	NM

ft - feet
GW - groundwater
msl - mean sea level
NA - not available
NI - not installed
NM - not measured
TOC - Top of Casing

Table 3-1. Groundwater Tritium Concentrations (September 2003 - March 2004)

Tennessee Valley Authority Watts Bar Nuclear Plant Spring City, Tennessee

Date	Well A	Well B	Well C	Well D	Well E	Well F	Well G	Well H	Well I	Well J	Well K	Well L
9/2/03	--	11,200	19,300	--	--	--	--	NI	NI	NI	NI	NI
9/4/03	--	--	--	--	--	1,140	--	NI	NI	NI	NI	NI
9/15/03	--	--	--	--	--	--	--	5,620	NI	NI	NI	NI
9/17/03	--	--	--	--	--	--	--	--	32,100	NI	NI	48,700
9/18/03	--	--	21,300	--	--	1,230	--	6,370	36,060	NI	NI	49,240
9/24/03	--	10,900	18,500	--	--	--	--	--	30,200	NI	NI	40,800
9/26/03	--	--	--	--	--	--	--	--	--	NI	NI	--
9/27/03	--	--	--	--	--	--	<531	--	--	NI	NI	--
9/30/03	--	--	21,180	--	--	--	--	--	--	1,830	92,500	--
9/30/03	--	--	--	--	--	3,055	--	--	--	--	324,700	--
10/1/03	--	--	--	--	--	--	2,731	--	23,240	--	353,700	--
10/2/03	--	--	--	--	--	--	--	--	--	--	297,900	--
10/3/03	--	--	26,090	--	--	--	--	6,438	19,630	--	291,200	--
10/5/03	--	--	--	--	--	--	--	--	--	--	218,300	--
10/7/03	--	--	20,700	--	--	1,210	1,140	--	20,300	--	204,800	43,300
10/8/03	2,930	--	--	--	--	--	3,270	--	--	--	--	--
10/9/03	<513	--	--	--	<520	--	--	--	--	--	--	--
10/10/03	1,370	--	28,280	--	<568	--	--	--	--	--	194,500	--
10/12/03	<547	--	--	--	<555	--	<554	--	--	--	189,000	--
10/13/03	970	--	23,590	--	723	--	<561	--	--	--	247,000	--
10/15/03	--	--	--	--	<573	--	<575	--	--	--	--	--
10/17/03	885	--	--	--	--	--	--	--	--	--	--	--
10/19/03	--	--	22,320	--	--	--	--	--	--	--	256,800	39,730
10/20/03	--	--	--	--	--	--	--	--	--	2,812	--	--
10/23/03	--	--	21,980	--	--	--	--	--	--	--	229,300	--
10/24/03	2990	--	--	--	--	--	--	--	--	--		--
11/1/03	--	--	--	--	--	--	--	--	--	--	226,600	--
11/7/03	<544	--	--	--	<544		<544	--	--	--	319,400	--
11/10/03	--	--	--	--	--	--	--	--	--	--	--	--
11/11/03	--	--	--	--	--	--	--	--	--	--	--	--
11/12/03	--	--	--	--	--	--	--	--	--	--	--	--
11/13/03	--	--	23,260	--	--	--	--	--	--	--	--	--
11/21/03	<501	--	22,200	--	903	--	<544	--	--	--	272,000	--
12/1/03	--	--	--	--	--	--	--	--	16,000	--	72,100	32,100
12/3/03	--	--	--	--	--	--	--	--	--	--	91,900	--
12/4/03	--	--	17,000	--	--	--	--	--	--	--	118,000	--
12/5/03	--	--	--	--	--	1,360	--	--	--	2,710	--	--
12/8/03	--	--	--	--	--	--	--	--	--	--	--	--
12/10/03	--	--	--	--	--	--	--	--	--	--	--	--
12/11/03	--	--	--	--	--	--	--	--	--	--	--	--
12/12/03	--	--	--	--	--	--	--	--	--	--	--	--
12/17/03	--	--	10,400	--	--	--	--	--	12,910	--	53,340	--
12/19/03	--	--	--	--	--	--	--	--	--	--	--	--
12/22/03	--	--	7,040	--	--	--	--	--	--	--	63,500	--
12/29/03	--	--	8,250	--	--	--	--	--	--	--	85,600	--
12/30/03	--	--	--	--	--	--	<498	--	--	--	--	--
12/31/03	--	--	--	--	--	--	--	--	--	--	--	--
1/5/04	--	--	9,563	--	--	--	--	--	--	--	128,100	--
1/12/04	--	--	8,500	--	--	--	--	--	--	--	123,500	--
1/20/04	--	--	8,500	--	--	--	--	--	--	--	144,000	--
1/26/04	--	--	--	--	--	--	--	--	4,302	--	116,500	47,830
1/30/04	--	--	--	--	--	--	--	--	6,090	--	121,000	50,700
2/2/04	--	--	--	--	--	--	--	--	--	--	--	--
2/9/04	--	--	--	--	--	--	--	--	1,250	--	114,000	58,100
2/16/04	--	--	--	--	--	--	--	--	2,061	--	102,200	53,240
2/23/04	--	--	--	--	--	--	--	--	5,890	--	95,500	50,400
2/24/04	--	--	--	--	--	--	--	--	--	--	--	--
2/26/04	--	--	--	--	--	--	--	--	--	--	--	--
3/1/04	<490	6,920	7,520	Dry	<484	1,170	<486	3,200	9,480	1,710	109,000	52,900
3/5/04	--	--	--	--	--	--	--	--	--	--	--	--

Note: all values in picocuries per liter

NI - not installed

-- - not measured

Table 3-1. Groundwater Tritium Concentrations* (September 2003 - March 2004)

Tennessee Valley Authority Watts Bar Nuclear Plant Spring City, Tennessee

Date	Well M	Well N	Well O	Well P	Well Q	Well R	Well S	Well T	Well U	Well V	Well W
9/2/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
9/4/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
9/15/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
9/17/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
9/18/03	<558	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
9/24/03	--	<559	--	NI	NI	NI	NI	NI	NI	NI	NI
9/26/03	<549	--	<549	NI	NI	NI	NI	NI	NI	NI	NI
9/27/03	--	--	--	<519	<519	NI	NI	NI	NI	NI	NI
9/30/03	--	--	--	--	--	NI	NI	NI	NI	NI	NI
9/30/03	--	--	--	--	--	NI	NI	NI	NI	NI	NI
10/1/03	--	--	--	--	--	NI	NI	NI	NI	NI	NI
10/2/03	--	--	--	--	--	NI	NI	NI	NI	NI	NI
10/3/03	--	--	--	--	--	18,450	11,200	NI	NI	NI	NI
10/5/03	--	--	--	--	--	18,490	10,520	NI	NI	NI	NI
10/7/03	--	--	--	--	--	23,060	9,440	NI	NI	NI	NI
10/8/03	--	--	--	--	--	--	--	NI	NI	NI	NI
10/9/03	--	--	--	--	--	--	--	NI	NI	NI	NI
10/10/03	--	--	--	--	--	--	--	NI	NI	NI	NI
10/12/03	--	--	--	--	--	--	--	NI	NI	NI	NI
10/13/03	--	--	--	--	--	--	--	NI	NI	NI	NI
10/15/03	--	--	--	--	--	--	--	NI	NI	NI	NI
10/17/03	--	--	--	--	--	--	--	NI	NI	NI	NI
10/19/03	--	--	--	--	--	18,120	16,360	NI	NI	NI	NI
10/20/03	--	--	--	--	--	--	--	NI	NI	NI	NI
10/23/03	--	--	--	--	--	--	--	NI	NI	NI	NI
10/24/03	--	--	--	--	--	--	--	NI	NI	NI	NI
11/1/03	--	--	--	--	--	--	--	NI	NI	NI	NI
11/7/03	--	--	--	--	--	--	--	NI	NI	NI	NI
11/10/03	--	--	--	--	--	--	--	NI	NI	NI	NI
11/11/03	--	--	--	--	--	--	--	NI	NI	NI	NI
11/12/03	--	--	--	--	--	--	--	NI	NI	NI	NI
11/13/03	--	--	--	--	--	--	--	NI	NI	NI	NI
11/21/03	--	--	--	--	--	--	--	NI	NI	NI	NI
12/1/03	--	--	--	--	--	19,800	11,000	NI	NI	NI	NI
12/3/03	--	--	--	--	--	--	--	NI	NI	NI	NI
12/4/03	--	--	--	--	--	--	--	NI	NI	NI	NI
12/5/03	--	--	--	--	--	--	--	NI	NI	NI	NI
12/8/03	--	--	--	--	--	--	--	NI	NI	NI	NI
12/10/03	--	--	--	--	--	--	--	NI	NI	NI	NI
12/11/03	--	--	--	--	--	--	--	<588	<588	NI	NI
12/12/03	--	--	--	--	--	--	--	--	--	<587	<587
12/17/03	--	--	--	--	--	22,030	9,166	--	--	--	--
12/19/03	--	--	--	--	--	--	--	--	--	--	--
12/22/03	--	--	--	--	--	20,000	7,720	--	--	--	--
12/29/03	--	--	--	--	--	22,800	7,500	--	--	--	--
12/30/03	--	--	--	--	--	--	--	--	--	--	--
12/31/03	--	--	--	--	--	--	--	--	--	--	--
1/5/04	--	--	--	--	--	22,560	8,579	--	--	--	--
1/12/04	--	--	--	--	--	22,400	9,900	--	--	--	--
1/20/04	--	--	--	--	--	18,900	7,360	--	--	--	--
1/26/04	--	--	--	--	--	18,750	8,267	--	--	--	--
1/30/04	--	--	--	--	--	21,700	8,670	--	--	--	--
2/2/04	--	--	--	--	--	--	--	--	--	--	--
2/9/04	--	--	--	--	--	18,000	7,510	--	--	--	--
2/16/04	--	--	--	--	--	19,420	5,172	--	--	--	--
2/23/04	--	--	--	--	--	18,800	6,280	--	--	--	--
2/24/04	--	--	--	--	--	--	--	--	--	--	--
2/26/04	--	--	--	--	--	--	--	--	--	--	--
3/1/04	<494	<533	<533	<537	<529	19,600	6,070	<526	<524	<496	<496
3/5/04	--	--	--	--	--	--	--	--	--	--	--

Note: all values in picocuries per liter
NI - not installed
-- - not measured

Table 3-1. Groundwater Tritium Concentrations* (September 2003 - March 2004)
Tennessee Valley Authority Watts Bar Nuclear Plant Spring City, Tennessee

Date	Well X	Well Y	Well Z	Well #1	Well #2	Well #3	Well #5	Well #6	MW 1	MW 2	MW 3	MW 4
9/2/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
9/4/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
9/15/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
9/17/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
9/18/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
9/24/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
9/26/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
9/27/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
9/30/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
9/30/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
10/1/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
10/2/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
10/3/03	NI	NI	NI	--	--	<578	--	<578	--	--	--	--
10/5/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
10/7/03	NI	NI	NI	--	--	--	--	--	<580	<580	<580	<580
10/8/03	NI	NI	NI	--	<538	--	--	--	--	--	--	--
10/9/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
10/10/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
10/12/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
10/13/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
10/15/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
10/17/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
10/19/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
10/20/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
10/23/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
10/24/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
11/1/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
11/7/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
11/10/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
11/11/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
11/12/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
11/13/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
11/21/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
12/1/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
12/3/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
12/4/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
12/5/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
12/8/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
12/10/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
12/11/03	NI	NI	NI	--	--	--	--	--	--	--	--	--
12/12/03	<523	NI	NI	--	--	--	--	--	--	--	--	--
12/17/03	--	NI	NI	--	--	--	--	--	--	--	--	--
12/19/03	--	<551	NI	--	--	--	--	--	--	--	--	--
12/22/03	--	--	NI	--	--	--	--	--	--	--	--	--
12/29/03	--	--	NI	--	--	--	--	--	--	--	--	--
12/30/03	--	--	NI	--	--	--	--	--	--	--	--	--
12/31/03	--	--	<593	--	--	--	--	--	--	--	--	--
1/5/04	--	--	--	--	--	--	--	--	--	--	--	--
1/12/04	--	--	--	--	--	--	--	--	--	--	--	--
1/20/04	--	--	--	--	--	--	--	--	--	--	--	--
1/26/04	--	--	--	--	--	--	--	--	--	--	--	--
1/30/04	--	--	--	--	--	--	--	--	--	--	--	--
2/2/04	--	--	--	--	--	--	--	--	--	--	--	--
2/9/04	--	--	--	--	--	--	--	--	--	--	--	--
2/16/04	--	--	--	--	--	--	--	--	--	--	--	--
2/23/04	--	--	--	--	--	--	--	--	--	--	--	--
2/24/04	--	--	--	--	--	--	--	--	--	--	--	--
2/26/04	--	--	--	--	--	--	--	--	--	--	--	--
3/1/04	<496	--	--	--	--	--	--	--	--	--	--	--
3/5/04	--	--	--	--	--	--	--	--	835	<478	627	<493

Note: all values in picocuries per liter
NI - not installed
-- - not measured

Table 3-1. Groundwater Tritium Concentrations* (September 2003 - March 2004)
Tennessee Valley Authority   Watts Bar Nuclear Plant   Spring City, Tennessee

Date	Well AA	Well BB	Well CC	Well DD	Well EE	Well FF	Well GG	Well HH	Well II	Well JJ	Well KK	Well LL
9/2/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
9/4/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
9/15/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
9/17/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
9/18/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
9/24/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
9/26/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
9/27/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
9/30/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
9/30/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
10/1/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
10/2/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
10/3/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
10/5/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
10/7/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
10/8/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
10/9/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
10/10/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
10/12/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
10/13/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
10/15/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
10/17/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
10/19/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
10/20/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
10/23/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
10/24/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
11/1/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
11/7/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
11/10/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
11/11/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
11/12/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
11/13/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
11/21/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
12/1/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
12/3/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
12/4/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
12/5/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
12/8/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
12/10/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
12/11/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
12/12/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
12/17/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
12/19/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
12/22/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
12/29/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
12/30/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
12/31/03	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
1/5/04	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
1/12/04	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
1/20/04	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
1/26/04	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
1/30/04	<522	1,434	NI	NI	NI	NI	NI	NI	NI	NI	NI	NI
2/2/04	<550	<520	4,300	NI	NI	NI	NI	NI	NI	NI	NI	NI
2/9/04	317	1,624		6,064	NI	NI	NI	NI	NI	NI	NI	NI
2/16/04	--	--	--	--	NI	NI	NI	NI	NI	NI	NI	NI
2/23/04	--	--	--	--	NI	NI	NI	NI	NI	NI	NI	NI
2/24/04	--	--	--	--	669	<528	10,320	5,980	NI	NI	NI	NI
2/26/04	--	--	--	--	--	--	--	--	<533	901	26,800	661
3/1/04	<531	2,120	Dry	Dry	<530	<530	11,400	4,260	<534	<537	20,000	<536

Note: all values in picocuries per liter
NI - not installed
-- - not measured

Table 5-1. Water-Only Biota Concentration Guide for Tritium

Tennessee Valley Authority Watts Bar Nuclear Plant Spring City, Tennessee

Receptor Category	Example Receptors	BCG (pCi/L)
Terrestrial Animals	Mouse	270,000,000
Riparian Animals	Raccoon	300,000,000
Aquatic Animals	Fish	6,000,000,000
Terrestrial Plants	Trees	9,000,000,000

Source: U.S. Department of Energy 2002
BCG - Biota Concentration Guides
pCi/L - picocuries per liter

ARCADIS

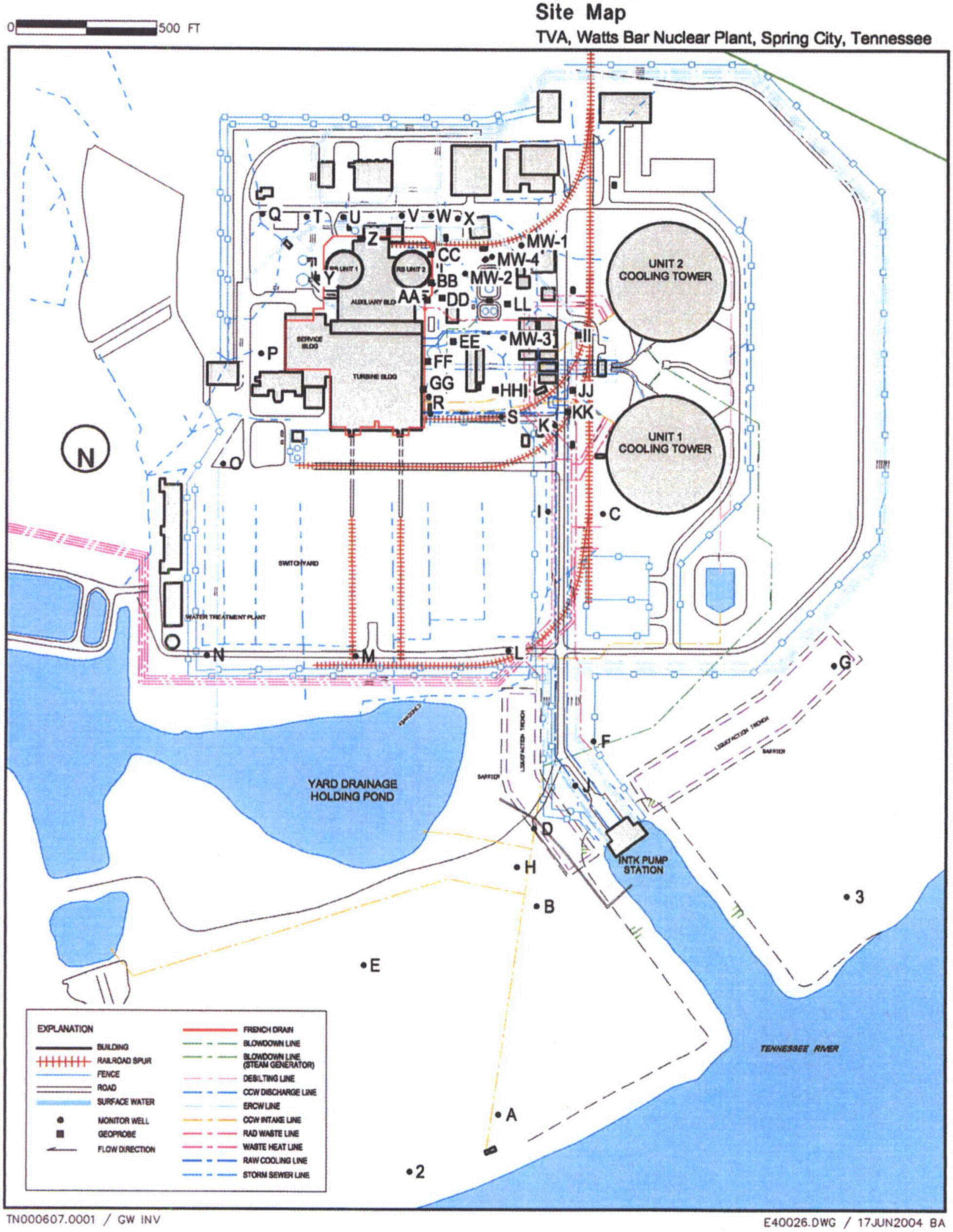
Figure 1-1
Regional Location Map
TVA, Watts Bar Nuclear Plant, Spring City, Tennessee

TN000607.0001 / GW INV

E40085.DWG / 17JUN2004 BA

ARCADIS

Figure 1-2
Site Map
TVA, Watts Bar Nuclear Plant, Spring City, Tennessee



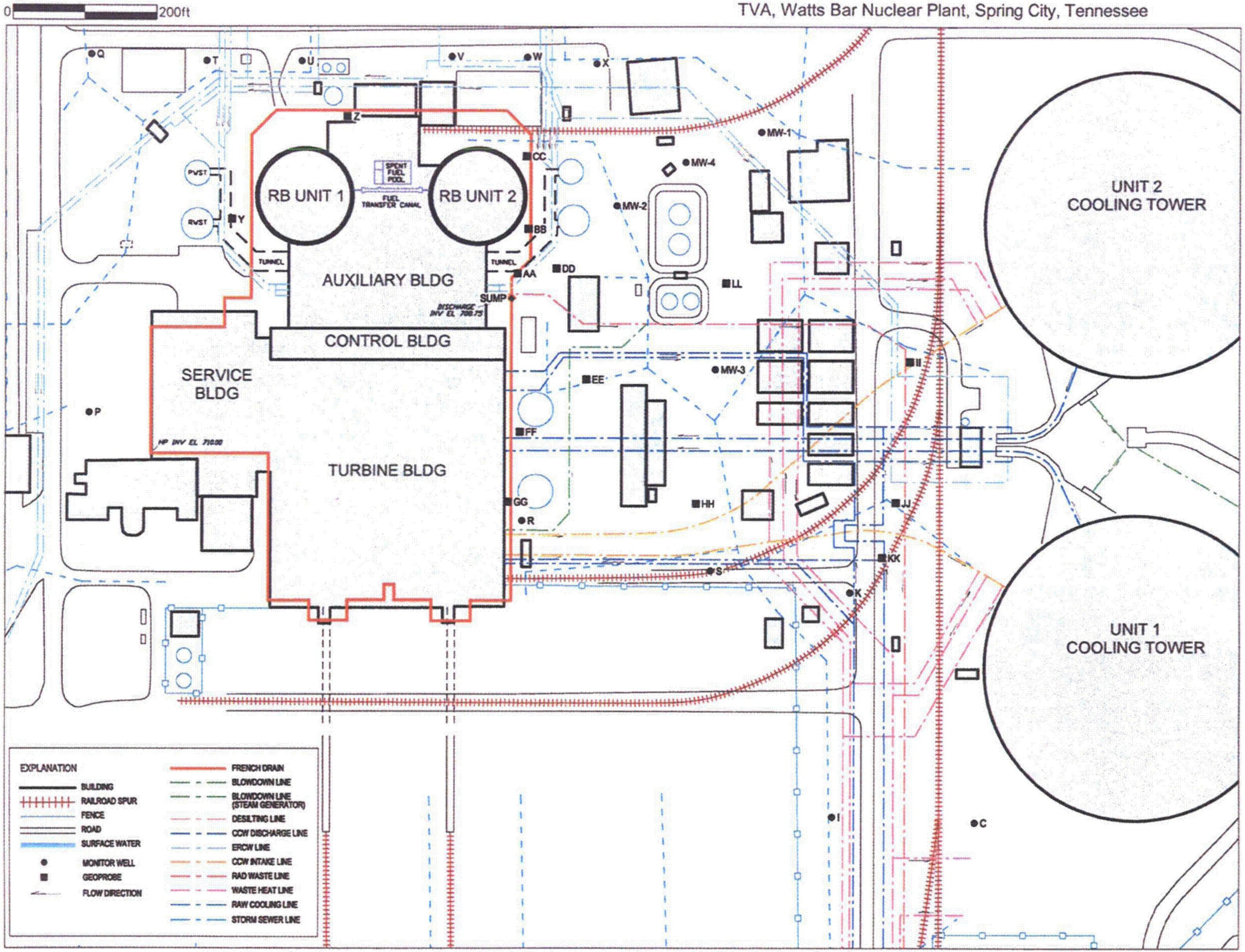
TN000607.0001 / GW INV

E40026.DWG / 17JUN2004 BA

ARCADIS

Figure 1-3
Power Block Site Map

TVA, Watts Bar Nuclear Plant, Spring City, Tennessee

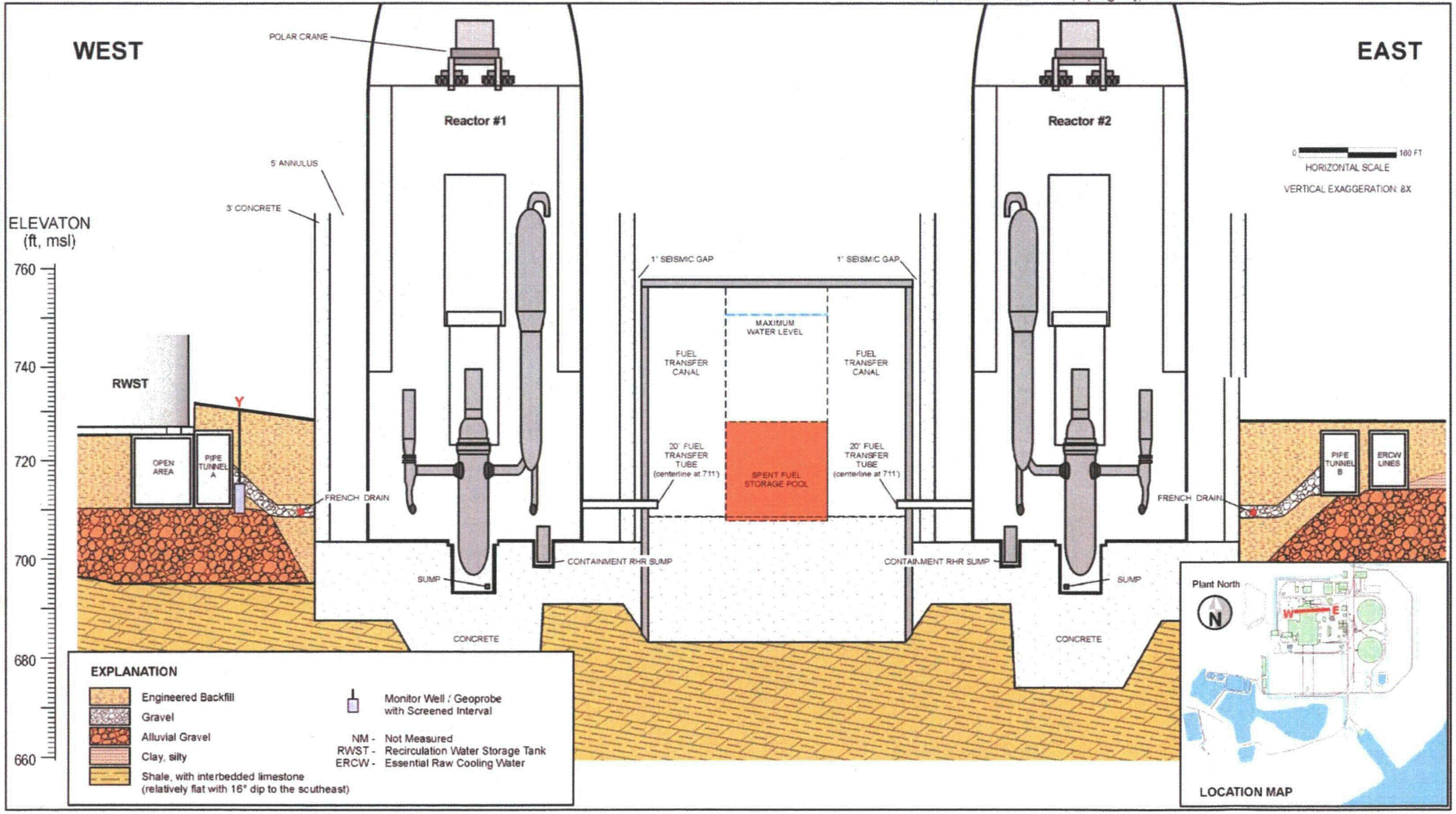


TN000607.0001 / GW INV

E40084DWG / 13AUG2004 BH

ARCADIS

Figure 3-1
East/West Geologic Cross-Section - North Power Block
TVA, Watts Bar Nuclear Plant, Spring City, Tennessee



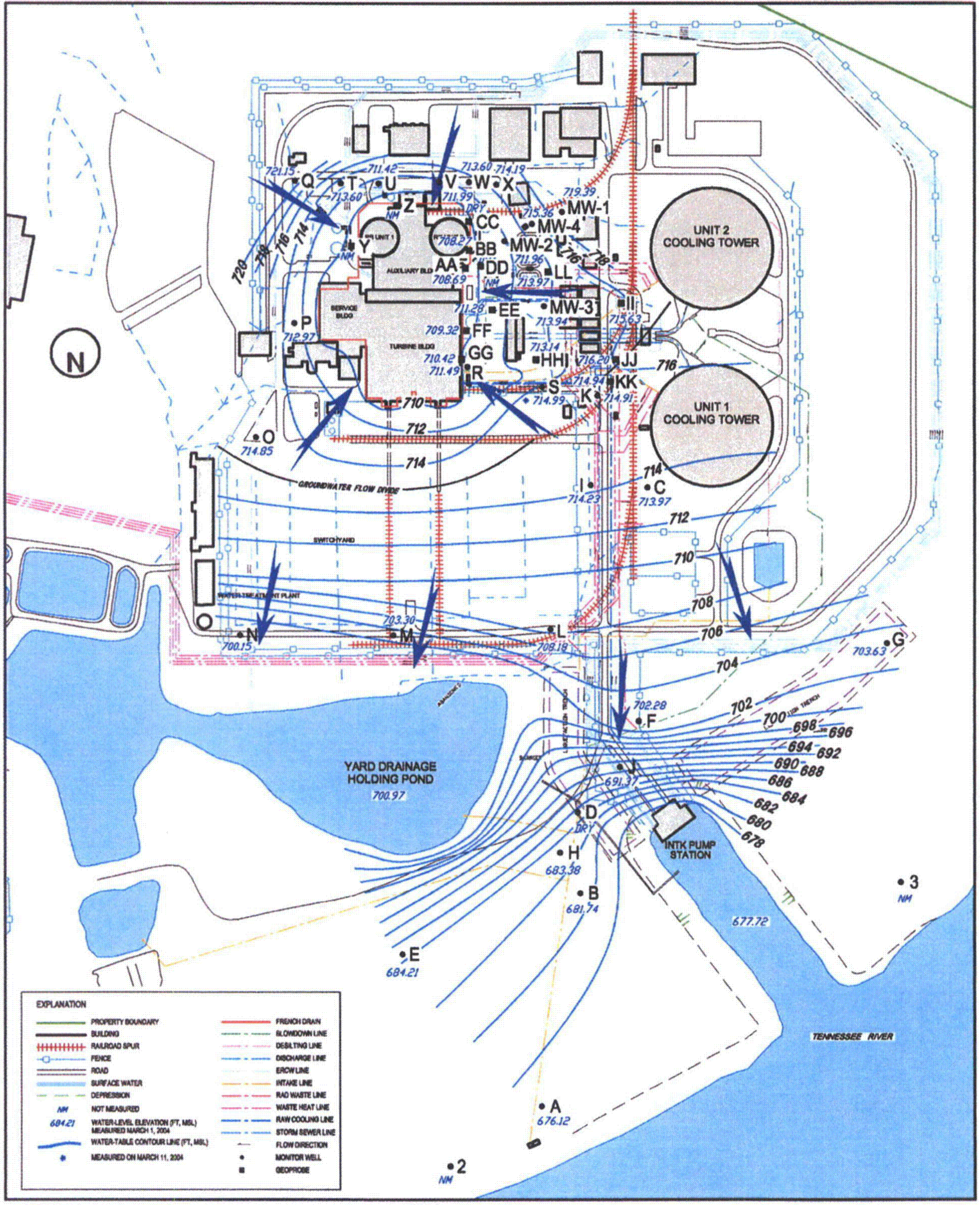
TN000607.0001 / GW INV

E40027 CDR / 16JUN2004 Ba

ARCADIS

0 500 FT

Figure 3-2
Water Table, March 2004
TVA, Watts Bar Nuclear Plant, Spring City, Tennessee



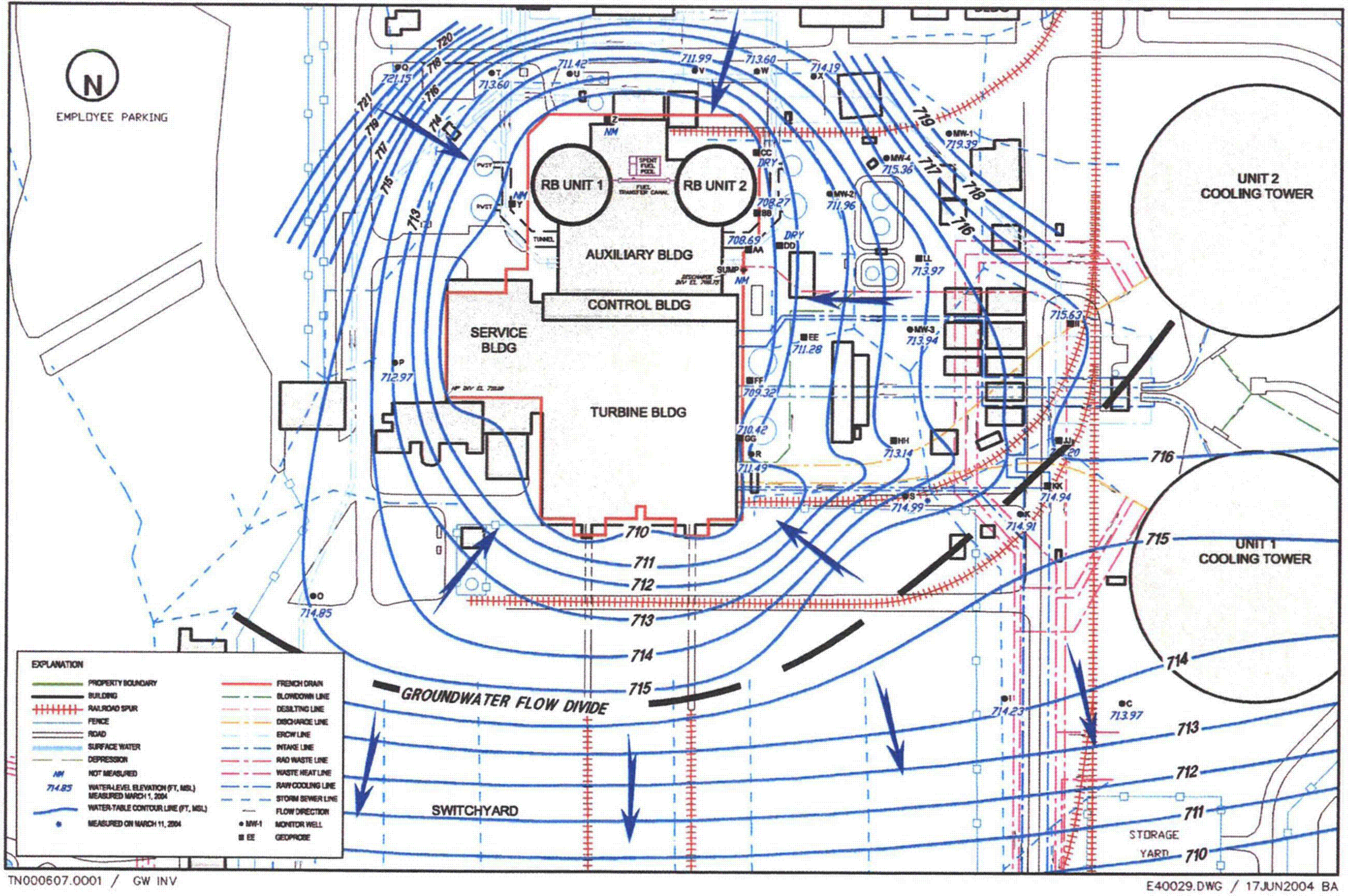
TN000607.0001 / GW INV

E40028.DWG / 17JUN2004 BA

ARCADIS

Figure 3-3
Water Table in Power Block, March 2004

TVA, Watts Bar Nuclear Plant, Spring City, Tennessee

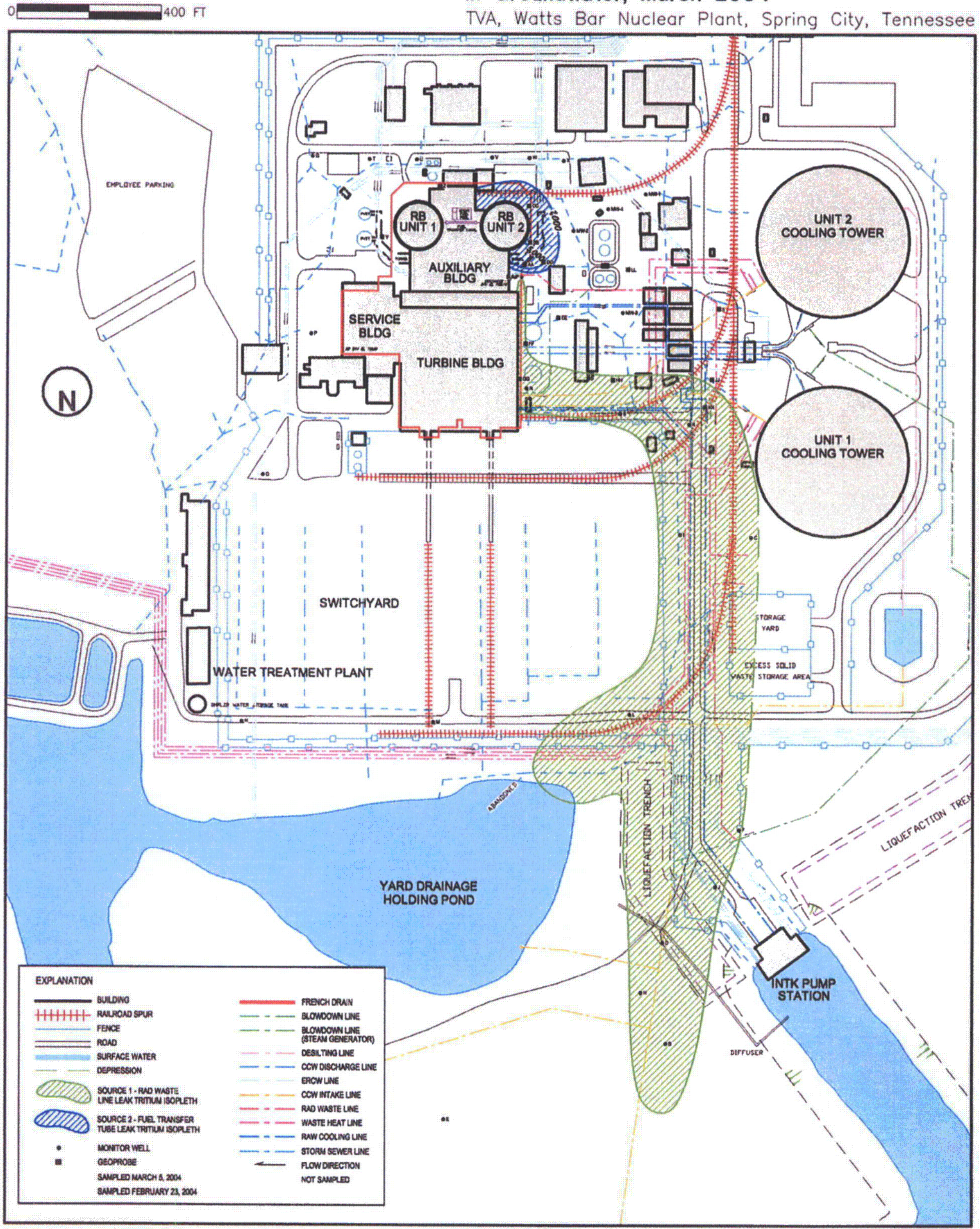


TN000607.0001 / GW INV

E40029.DWG / 17JUN2004 BA

ARCADIS

Figure 3-4
Distribution of Tritium Concentrations in Groundwater, March 2004
TVA, Watts Bar Nuclear Plant, Spring City, Tennessee

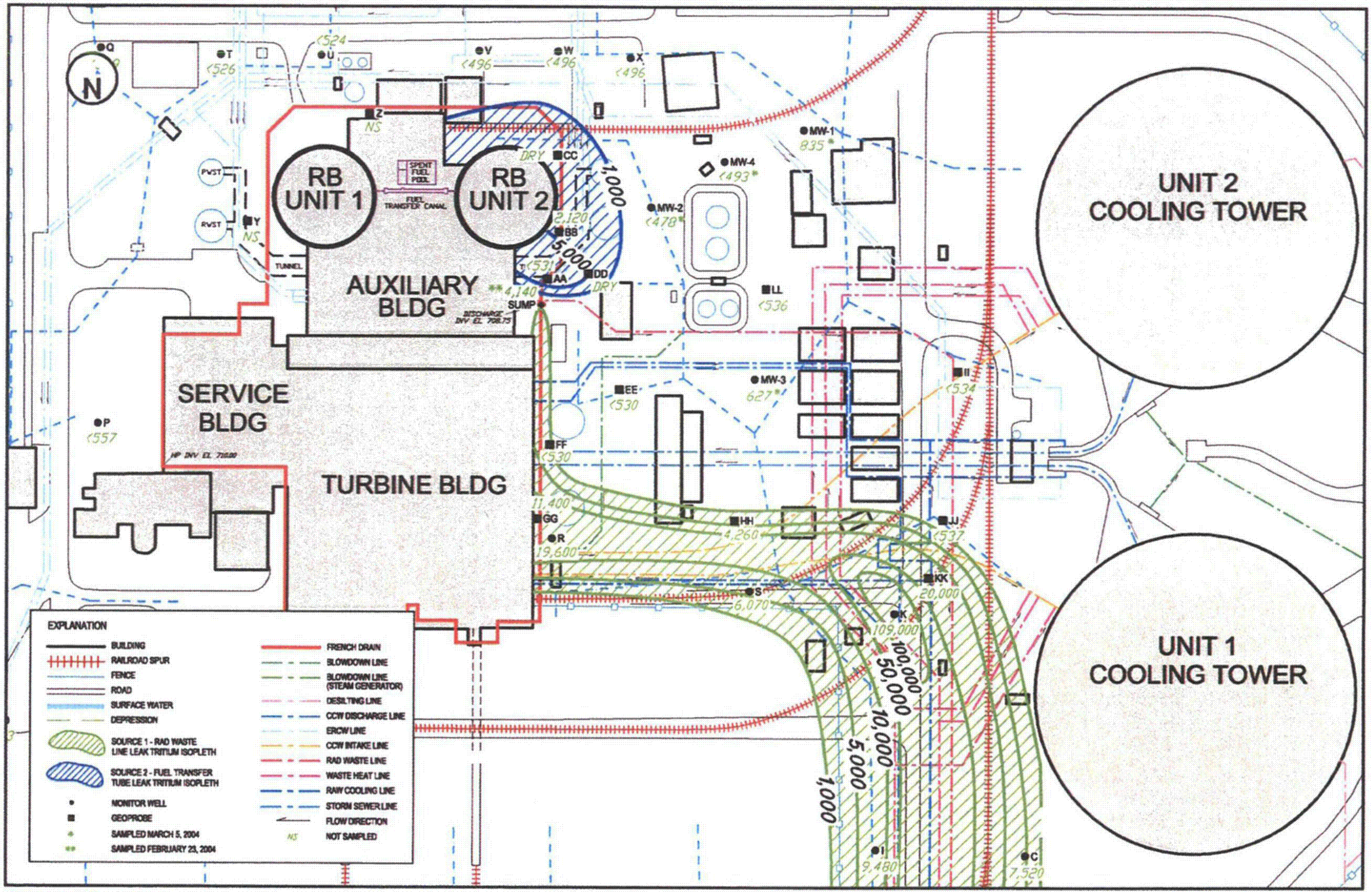


ARCADIS

Figure 3-5
Distribution of Tritium Concentrations in Groundwater at Power Block, March 2004

TVA, Watts Bar Nuclear Plant, Spring City, Tennessee

0 200 FT



TN000607.0001 / GW INV

E40033.DWG / 17JUN2004 Ba

ARCADIS

Figure 3-6

Three-Dimensional Representation of Tritium Plume

TVA, Watts Bar Nuclear Plant, Spring City, Tennessee

NOTE: Estimate total activity in plume is 1.6 curies.

NOT TO SCALE

ARCADIS

Figure 3-7
Tritium Concentrations in Sump Groundwater
TVA, Watts Bar Nuclear Plant, Spring City, Tennessee

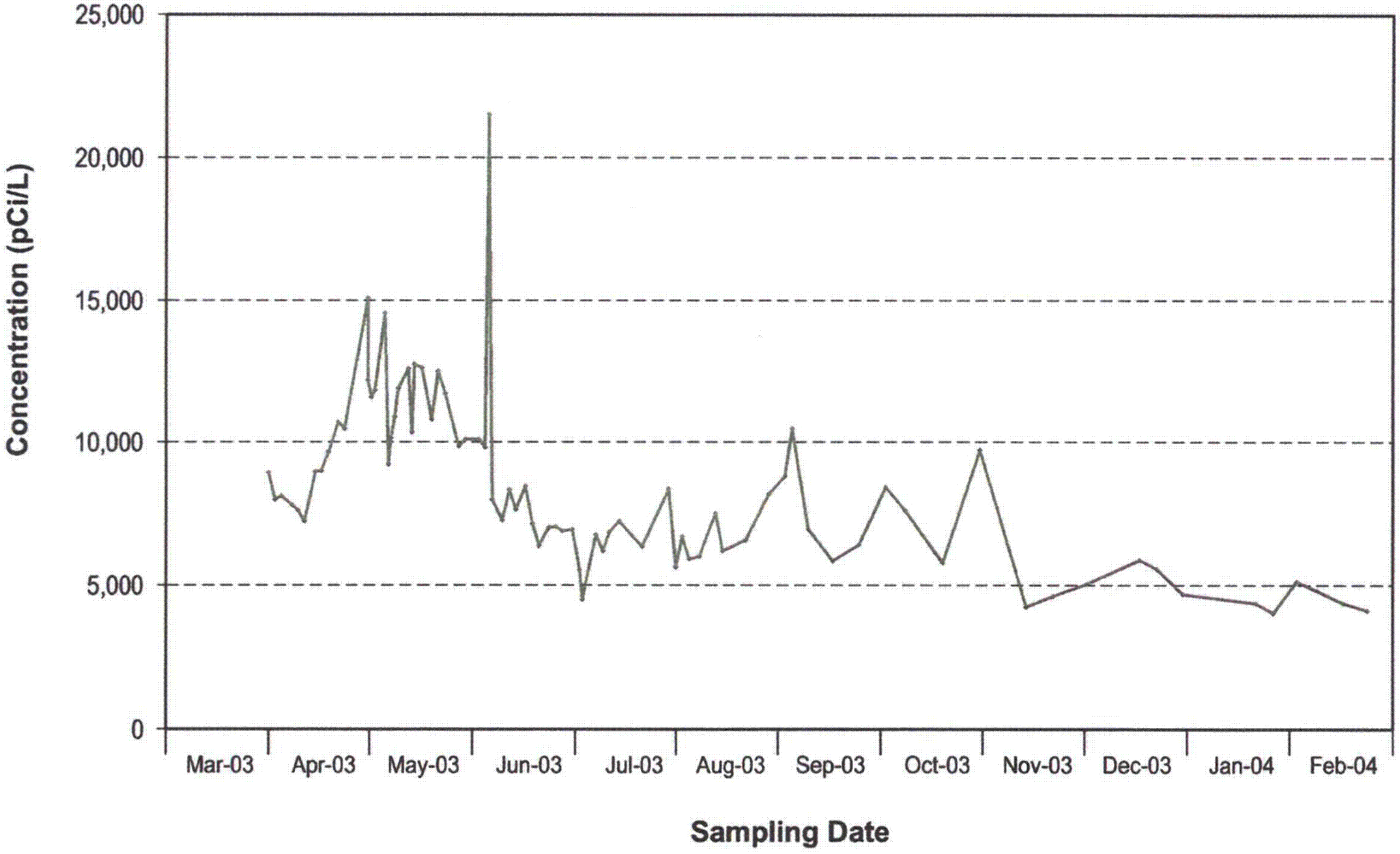
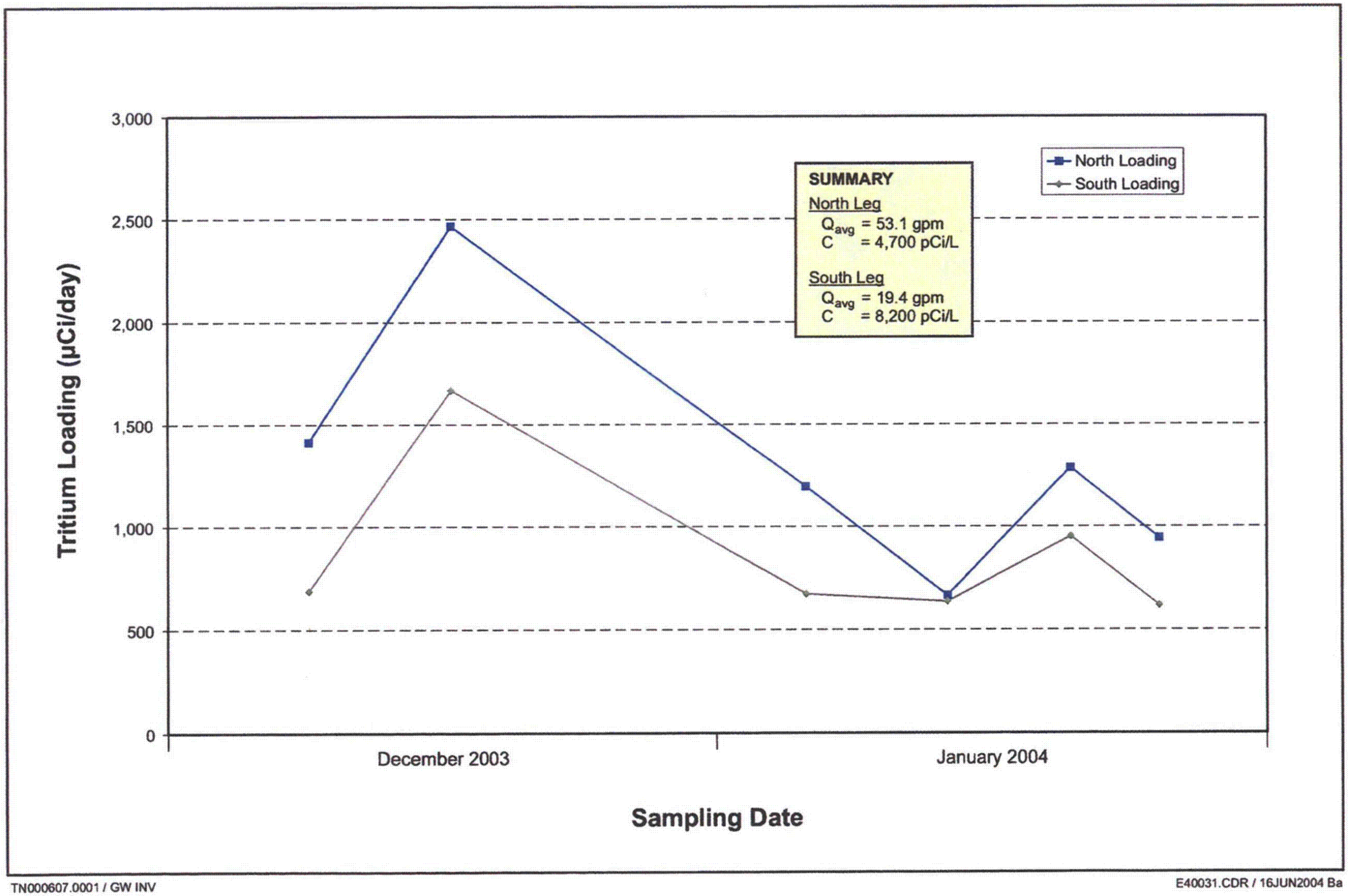
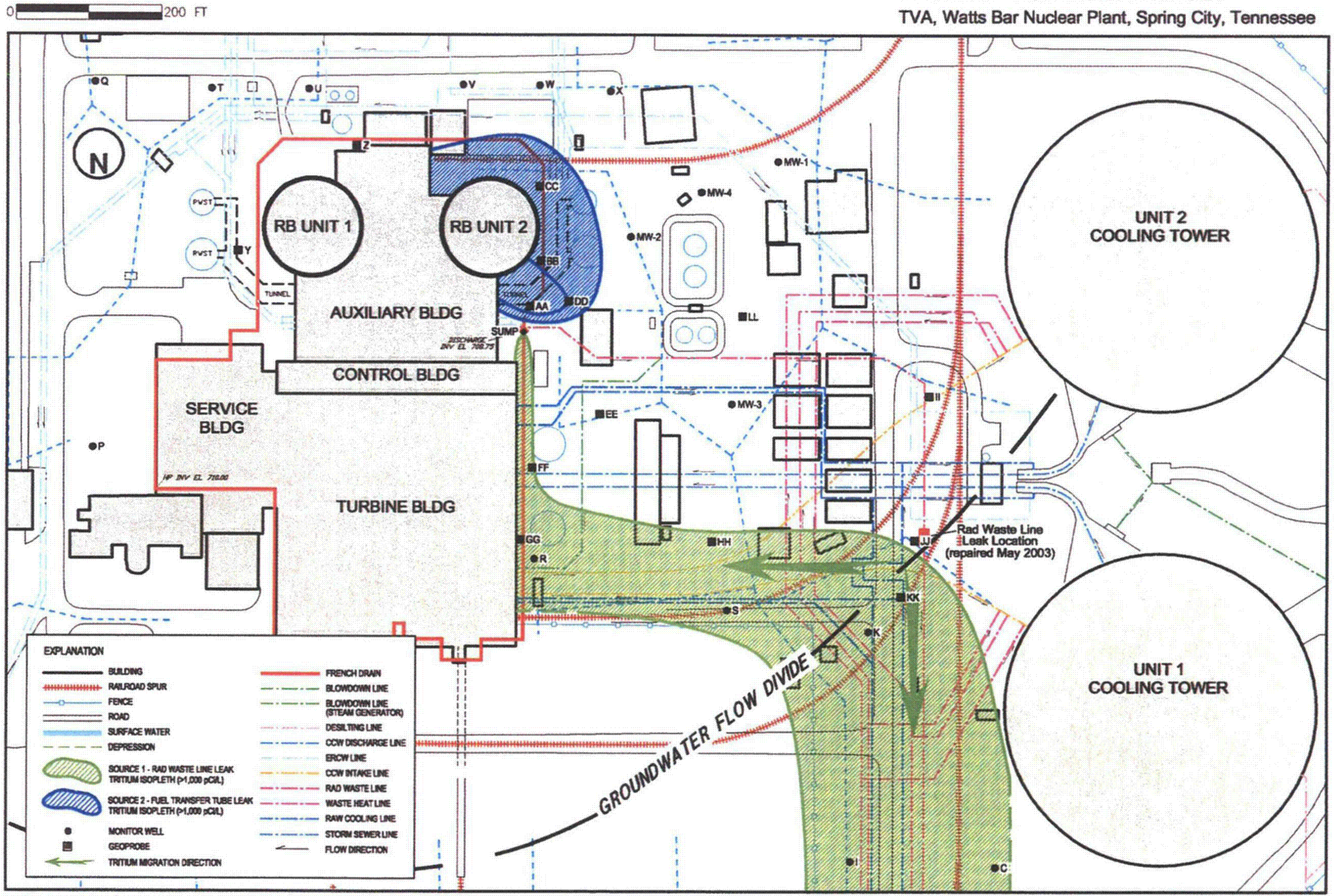


Figure 3-8
Tritium Loading in Sump Groundwater
TVA, Watts Bar Nuclear Plant, Spring City, Tennessee



ARCADIS

Figure 4-1
Source #1 - Rad Waste Line Leak
TVA, Watts Bar Nuclear Plant, Spring City, Tennessee

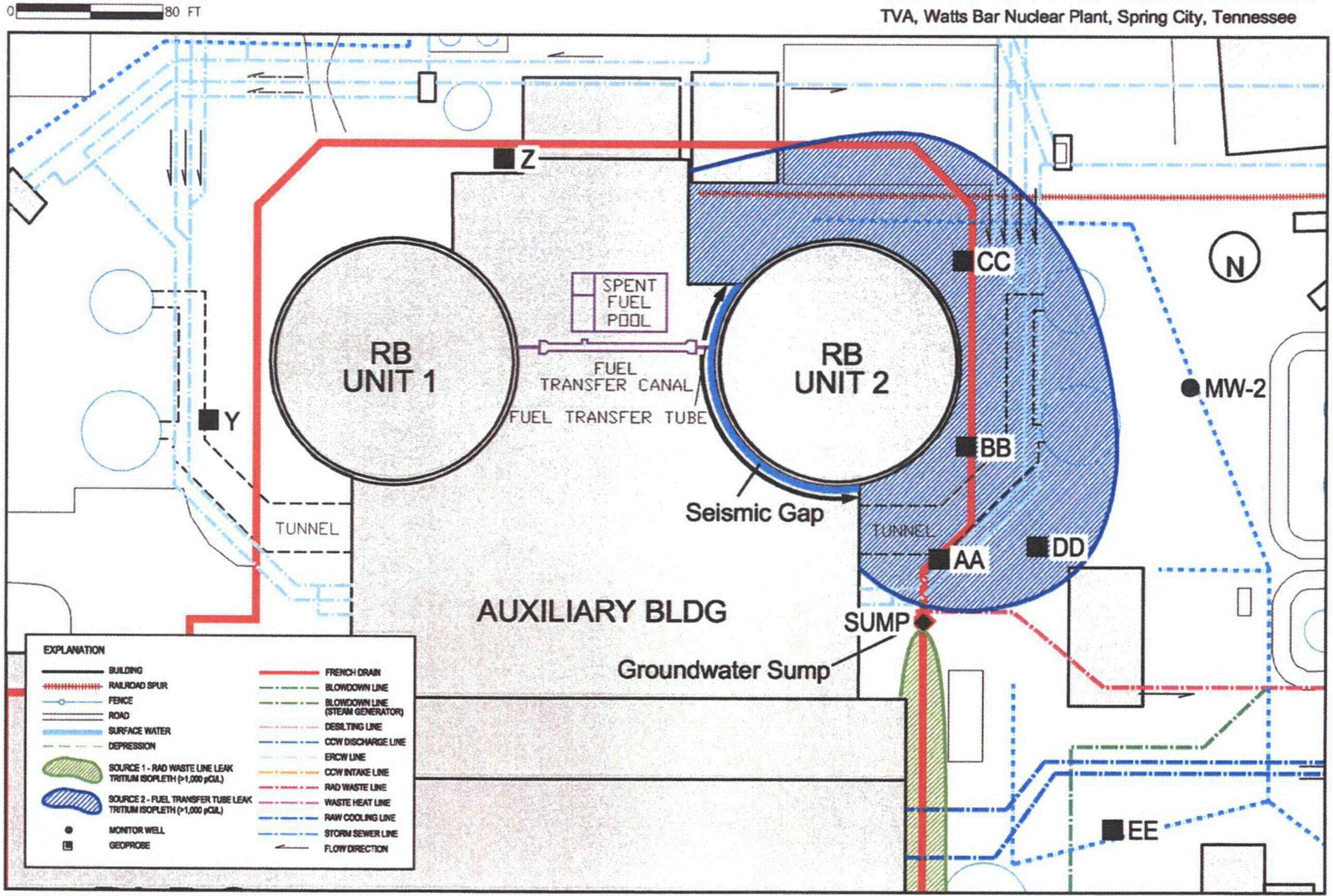


TN000607.0001 / GW INV

E40035.DWG / 17JUUN2004 Ba

ARCADIS

Figure 4-2
Source #2 - Unit 2 Fuel Transfer Tube Sleeve
TVA, Watts Bar Nuclear Plant, Spring City, Tennessee



TN000607.0001 / GW INV

E40036.DWG / 17JUN2004 Ba

ARCADIS

Exhibit 4-3
Source #2 - Schematic Cross-Section
TVA, Watts Bar Nuclear Plant, Spring City, Tennessee

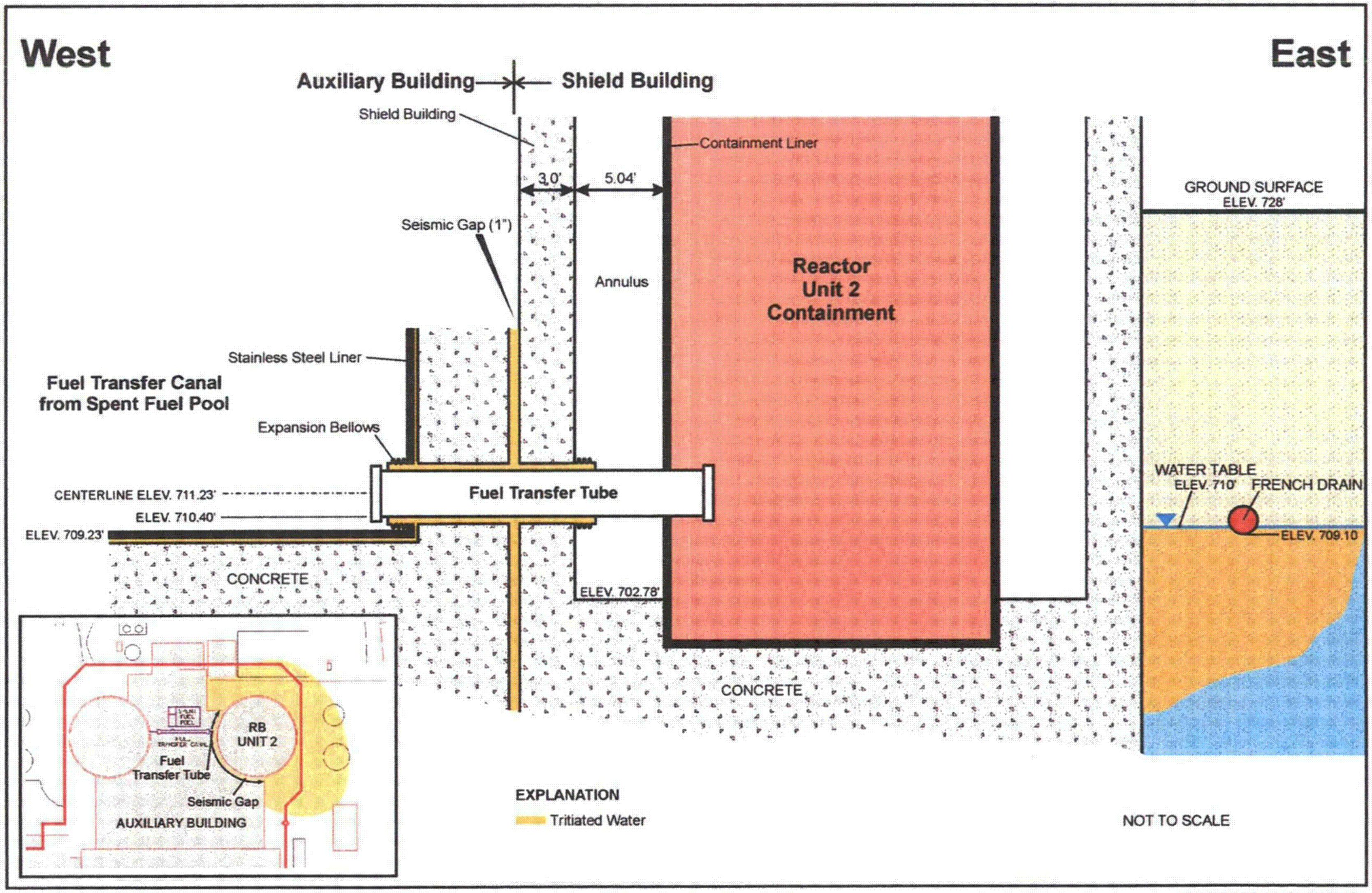
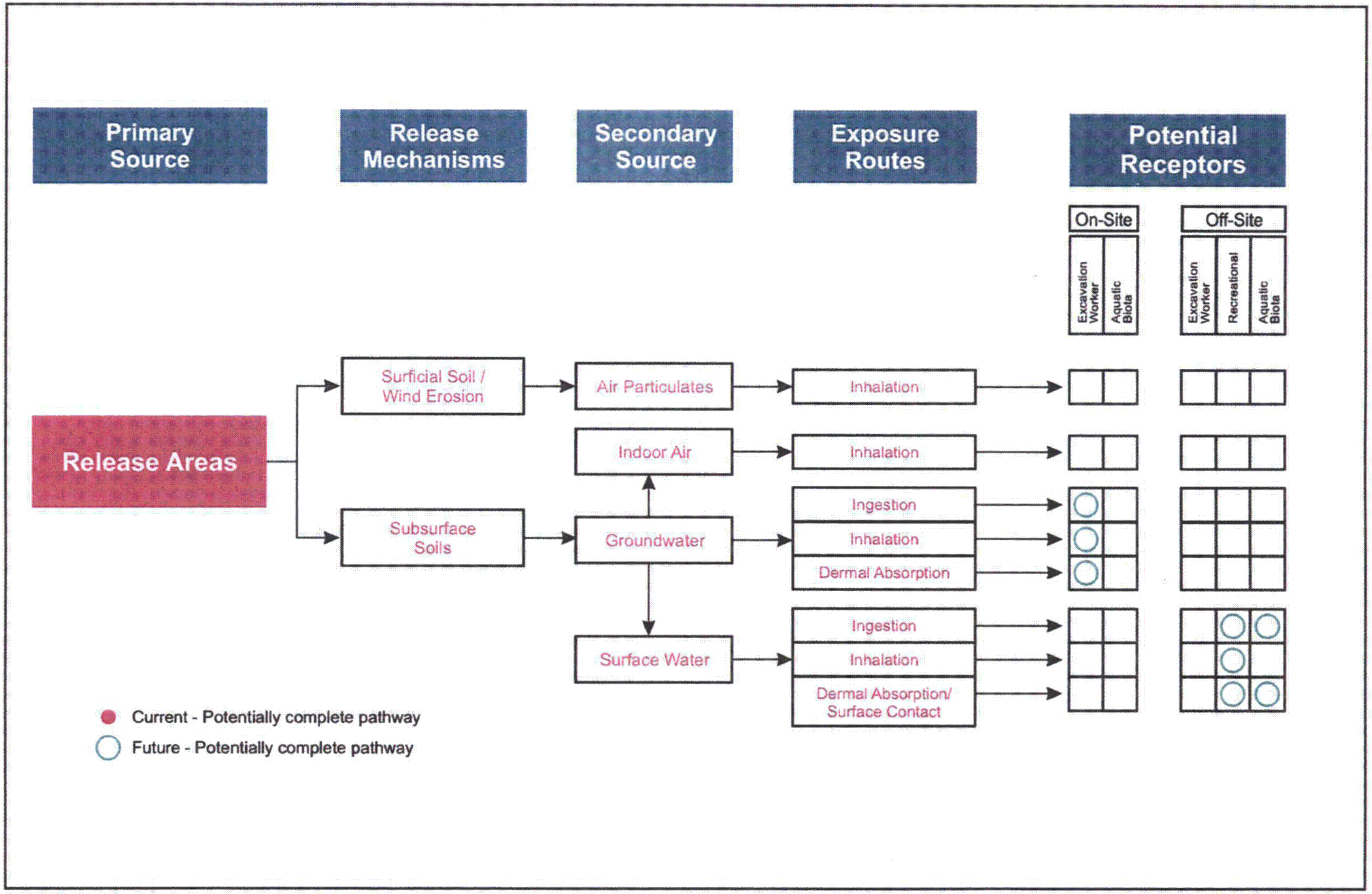


Figure 5-1

Site Conceptual Exposure Model

TVA, Watts Bar Nuclear Plant, Spring City, Tennessee

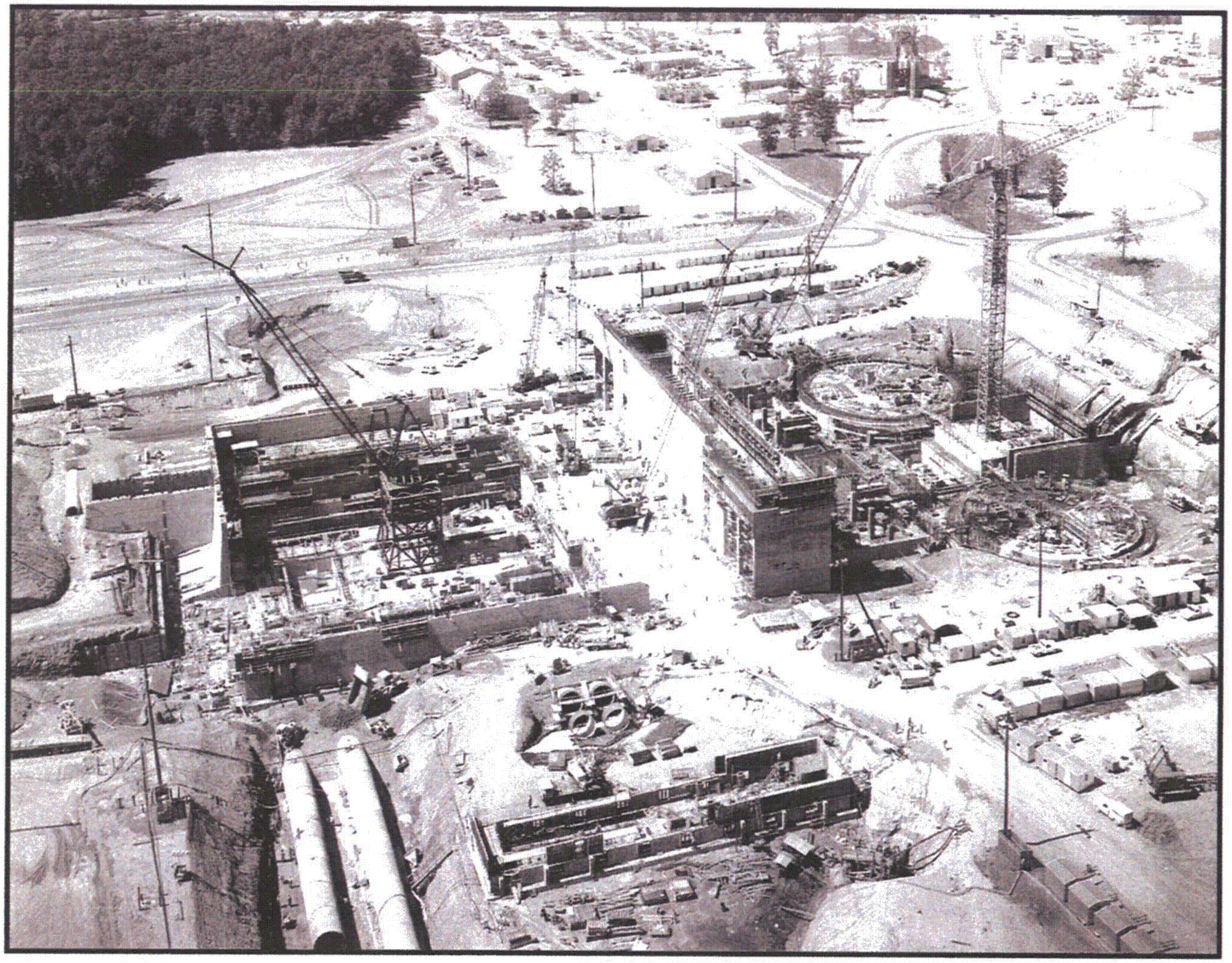


ARCADIS

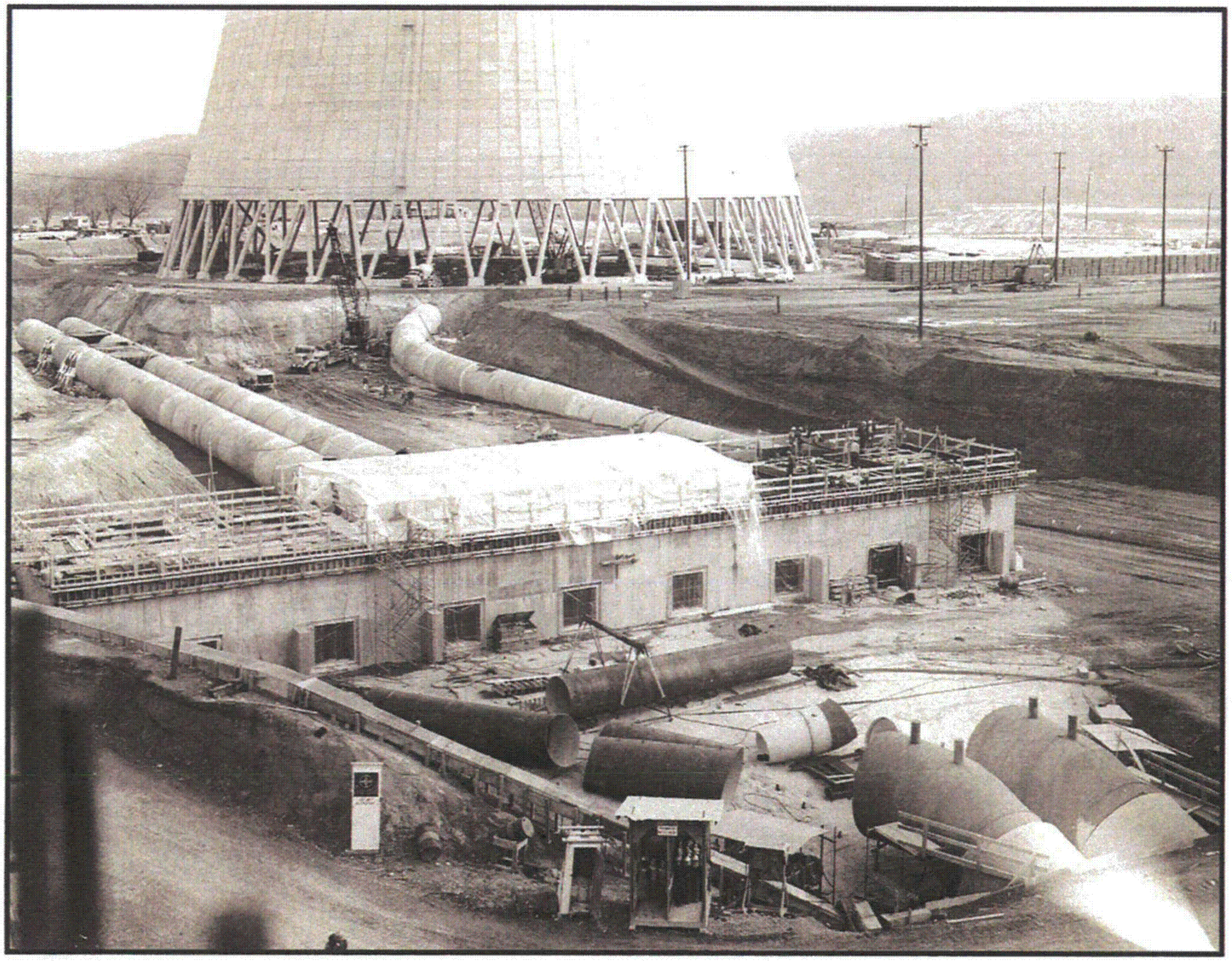
Appendix A

Site Photographs

Photograph A-1. Fuel Transfer Tube Sleeve Leak in Unit 2 Reactor Building
Photographed May 30, 2003.



Photograph A-2. View west from Unit 1 Cooling Tower of site construction. *Photographed April 1975.* Note condenser cooling water effluent lines, oriented east/west, emanating from south end of turbine building.



Photograph A-3. View east from Auxiliary Building toward Unit 1 Cooling Tower of the Condenser Cooling Water Intake and Discharge Pipe construction.
Photographed May 1975

Photograph A-4. View east from Auxiliary Building toward Unit 1 Cooling Tower of the Condenser Cooling Water Intake and Discharge Pipe construction.
Photographed June 1975

Appendix B

Historical Tritium Data

Table B-1. Groundwater Tritium Concentrations (August 2002 - August 2003)

Tennessee Valley Authority   Watts Bar Nuclear Plant   Spring City, Tennessee

Date	Well A	Well B	Well C	Well D	Well #6	MW 1	MW 2	MW 3	MW 4
8/20/02	NI	NI	NI	NI	--	--	--	--	--
11/12/02	NI	NI	NI	NI	--	--	--	--	--
12/10/02	NI	NI	NI	NI	--	--	--	--	--
1/7/03	--	12,453	4,339	4,409	--	--	--	--	--
1/27/03	--	13,356	7,356	NA	--	--	--	--	--
2/25/03	--	14,730	8,465	13,992	--	--	--	--	--
3/1/03	--	--	--	--	--	<584	<570	<575	<581
3/4/03	--	14,100	3,245	16,010	--	--	--	--	--
3/5/03	--	15,100	2,760	17,700	--	--	--	--	--
3/6/03	--	15,400	3,239	17,880	--	--	--	--	--
3/7/03	--	13,500	2,405	19,230	--	<577	<585	<587	<585
3/8/03	--	12,390	3,894	19,070	--	--	--	--	--
3/9/03	--	12,300	3,617	20,760	--	--	--	--	--
3/10/03	--	12,170	4,337	20,210	--	--	--	--	--
3/11/03	--	12,800	4,130	21,500	--	--	--	--	--
3/12/03	--	8,336	5,662	18,760	--	--	--	--	--
3/13/03	<556	8,540	3,980	17,300	<562	--	--	--	--
3/14/03	--	8,910	4,600	15,900	--	--	--	--	--
3/15/03	--	9,075	4,826	15,810	--	--	--	--	--
3/16/03	--	9,374	3,931	14,240	--	--	--	--	--
3/17/03	--	12,740	5,375	18,220	--	<585	<585	<585	<584
3/18/03	--	13,100	5,256	20,500	--	--	--	--	--
3/19/03	--	14,290	NA	20,090	--	--	--	--	--
3/20/03	--	14,700	6,650	21,100	--	--	--	--	--
3/21/03	--	13,300	6,048	19,270	--	--	--	--	--
3/22/03	--	15,350	6,323	18,600	--	--	--	--	--
3/23/03	--	13,770	7,043	15,970	--	--	--	--	--
3/25/03	--	14,230	7,280	--	--	--	--	--	--
3/26/03	--	14,750	--	--	--	--	--	--	--
3/28/03	--	14,160	--	--	--	--	--	--	--
3/31/03	--	14,760	--	--	--	--	--	--	--
4/2/03	--	17,390	--	--	--	--	--	--	--
4/3/03	--	15,480	--	--	--	--	--	--	--
4/4/03	--	14,260	--	--	--	--	--	--	--
4/7/03	--	14,050	--	--	--	--	--	--	--
4/7/03	--	--	13,330	--	--	--	--	--	--
4/8/03	--	--	13,730	--	--	--	--	--	--
4/9/03	--	13960	13,060	--	--	--	--	--	--
4/11/03	--	--	11,900	--	--	--	--	--	--
4/14/03	--	17,420	--	--	--	--	--	--	--
4/16/03	--	16,600	6,560	--	--	--	--	--	--
4/18/03	--	18,500	7,402	--	--	--	--	--	--
4/21/03	--	19,100	6,920	--	--	--	--	--	--
4/23/03	--	18,500	7,940	3,950	--	--	--	--	--
4/25/03	--	18,700	9,230	--	--	--	--	--	--
4/28/03	<580	18,050	9,124	4,990	--	--	--	--	--
4/30/03	--	19,770	9,251	5,119	--	--	--	--	--

Note: All values in picocuries per liter.

NI - not installed

-- - not measured

Table B-1. Groundwater Tritium Concentrations (August 2002 - August 2003)

Tennessee Valley Authority   Watts Bar Nuclear Plant   Spring City, Tennessee

Date	Well A	Well B	Well C	Well D	Well #6	MW 1	MW 2	MW 3	MW 4
5/2/03	--	17,500	10,800	4,740	--	--	--	--	--
5/5/03	--	18,550	9,998	3,493	--	--	--	--	--
5/6/03	--	20,170	12,020	3,514	--	--	--	--	--
5/7/03	--	18,240	8,981	3,540	--	--	--	--	--
5/8/03	--	19,310	7,557	3,316	--	--	--	--	--
5/9/03	--	18,370	6,965	2,268	--	--	--	--	--
5/12/03	--	18,350	4,478	2,405	--	--	--	--	--
5/13/03	<580	18,380	4,183	2,758	--	--	--	--	--
5/14/03	--	NA	5,190	--	--	--	--	--	--
5/15/03	--	16,970	NA	2,371	--	--	--	--	--
5/16/03	--	17,320	4,461	2,083	--	--	--	--	--
5/19/03	--	16,700	6,170	3,180	--	--	--	--	--
5/21/03	--	14,400	6,120	3,130	--	--	--	--	--
5/23/03	--	13,800	5,550	3,060	--	--	--	--	--
5/27/03	--	13,700	5,475	2,159	--	--	--	--	--
5/28/03	--	13,100	--	2,430	--	--	--	--	--
5/28/03	--	13,100	--	2,250	--	--	--	--	--
5/28/03	--	13,550	--	2,132	--	--	--	--	--
5/29/03	--	12,180	5,747	2,039	--	--	--	--	--
5/29/03	--	11,900	--	1,790	--	--	--	--	--
5/29/03	--	12,000	--	3,140	--	--	--	--	--
5/29/03	--	13,690	--	2,526	--	--	--	--	--
5/29/03	--	15,150	--	2,450	--	--	--	--	--
5/30/03	--	13,500	--	2,420	--	--	--	--	--
6/2/03	--	12,200	7,840	3,440	--	--	--	--	--
6/3/03	--		8,160	--	--	--	--	--	--
6/4/03	--	12,200	9,150	3,030	--	--	--	--	--
6/5/03	--	10,700	10,250	3,289	--	--	--	--	--
6/5/03	--	10,700	9,710	3,400	--	--	--	--	--
6/6/03	--	10,330	9,720	3,291	--	--	--	--	--
6/6/03	--	9,720	10,600	2,540	--	--	--	--	--
6/9/03	--	11,980	10,110	2,207	--	--	--	--	--
6/11/03	--	13,980	12,800	3,575	--	--	--	--	--
6/13/03	--	14,150	12,980	3,799	--	--	--	--	--
6/16/03	--	13,170	12,820	3,092	--	--	--	--	--
6/17/03	--	14,440	15,820	--	--	--	--	--	--
6/18/03	--	14,900	14,600	--	--	--	--	--	--
6/18/03	--	15,400	15,100	--	--	--	--	--	--
6/19/03	--	18,530	14,080	3,230	--	--	--	--	--
6/20/03	<515	17,420	13,200	2,768	--	--	--	--	--
6/23/03	--	15,400	7,360	3,360	--	--	--	--	--
6/25/03	--	18,130	7,464	3,578	--	--	--	--	--
6/26/03	--	14,800	7,710	--	--	--	--	--	--
6/27/03	--	12,780	7,927	4,050	--	--	--	--	--
6/30/03	--	--	8,417	5,560	--	--	--	--	--

Note: All values in picocuries per liter.
NI - not installed
-- - not measured

Table B-1. Groundwater Tritium Concentrations (August 2002 - August 2003)

Tennessee Valley Authority Watts Bar Nuclear Plant Spring City, Tennessee

Date	Well A	Well B	Well C	Well D	Well #6	MW 1	MW 2	MW 3	MW 4
7/2/03	--	--	8,251	5,512	--	--	--	--	--
7/7/03	--	15,620	5,010	5,799	--	--	--	--	--
7/9/03	--	15,600	5,800	4,920	--	--	--	--	--
7/10/03	--	16,200	7,200	5,830	--	--	--	--	--
7/10/03	--	16,600	5,350	5,230	--	--	--	--	--
7/11/03	--	16,100	6,128	4,892	--	--	--	--	--
7/11/03	--	16,100	6,220	5,210	--	--	--	--	--
7/12/03	--	17,300	6,180	6,060	--	--	--	--	--
7/13/03	--	15,140	5,475	5,846	--	--	--	--	--
7/14/03	--	17,200	6,760	5,630	--	--	--	--	--
7/21/03	--	11,500	7,710	5,590	--	--	--	--	--
7/24/03	--	--	--	--	--	--	--	--	--
7/25/03	--	14,000	10,100	5,200	--	--	--	--	--
7/29/03	--	15,510	12,530	7,310	--	--	--	--	--
7/31/03	--	15,200	12,800	3,280	--	--	--	--	--
8/2/03	--	--	--	--	--	--	--	--	--
8/3/03	--	--	--	--	--	--	--	--	--
8/5/03	--	15,200	15,100	4,060	--	--	--	--	--
8/7/03	--	12,900	16,600	4,330	--	--	--	--	--
8/12/03	--	10,400	18,100	4,810	--	--	--	--	--
8/14/03	--	11,200	17,400	3,460	--	--	--	--	--
8/21/03	--	12,020	20,480		--	--	--	--	--
8/22/03	--	--	--	--	--	--	--	--	--
8/25/03	--	--	--	--	--	--	--	--	--
8/26/03	--	--	--	--	--	--	--	--	--
8/28/03	--	10,200	20,300		--	--	--	--	--

Note: All values in picocuries per liter.

NI - not installed

-- - not measured

Table B-2. Groundwater Sump Tritium Concentrations

Tennessee Valley Authority Watts Bar Nuclear Plant Spring City, Tennessee

Date	Concentration
3/31/03	8,943
4/2/03	8,002
4/4/03	8,135
4/7/03	7,808
4/9/03	7,606
4/11/03	7,255
4/14/03	8,978
4/16/03	9,012
4/18/03	9,673
4/21/03	10,700
4/23/03	10,500
4/30/03	15,070
4/30/03	12,200
5/1/03	11,600
5/2/03	11,850
5/5/03	14,540
5/6/03	9,213
5/7/03	10,140
5/8/03	10,880
5/9/03	11,910
5/12/03	12,600
5/13/03	10,360
5/14/03	12,750
5/16/03	12,630
5/19/03	10,800
5/21/03	12,500
5/23/03	11,700
5/27/03	9,864
5/29/03	10,100
6/2/03	10,100
6/4/03	9,825
6/5/03	21,510
6/6/03	7,990
6/9/03	7,284
6/11/03	8,351
6/13/03	7,666
6/16/03	8,473
6/18/03	7,140
6/20/03	6,399
6/23/03	7,010
6/25/03	7,040
6/27/03	6,909
6/30/03	6,965

Note: All values in picocuries per liter.

Table B-2. Groundwater Sump Tritium Concentrations

Tennessee Valley Authority Watts Bar Nuclear Plant Spring City, Tennessee

Date	Concentration
7/2/03	5,552
7/3/03	4,496
7/7/03	6,757
7/9/03	6,200
7/11/03	6,866
7/14/03	7,240
7/21/03	6,360
7/29/03	8,370
7/31/03	5,630
8/2/03	6,700
8/4/03	5,930
8/7/03	6,010
8/12/03	7,530
8/14/03	6,190
8/21/03	6,589
8/28/03	8,200
9/2/03	8,820
9/4/03	10,500
9/9/03	6,950
9/16/03	5,870
9/24/03	6,430
10/2/03	8,453
10/8/03	7,619
10/19/03	5,803
10/30/03	9,734
11/13/03	4,256
11/21/03	4,640
12/1/03	5,040
12/17/03	5,881
12/22/03	5,560
12/30/03	4,680
1/21/04	4,390
1/26/04	4,020
2/2/04	5,120
2/9/04	--
2/16/04	4,378
2/23/04	4,140

Note: All values in picocuries per liter.

Table B-3. Manhole Tritium Concentrations

Tennessee Valley Authority Watts Bar Nuclear Plant Spring City, Tennessee

Date	MH #1	MH #6B	MH #7B	MH #18	MH #20	MH #21	MH #24	MH #25	MH #26	MH #27
6/25/03	--	--	--	--	--	--	--	--	--	<562
8/2/03	--	--	--	--	<575	<575	<575	--	--	--
8/3/03	<527	<527	<527	<527	--	--	--	<527	<527	--
11/10/03	1,430	882	882	882	--	--	--	--	--	--
11/11/03	--	1,580	22,300	--	--	--	--	--	--	--
11/12/03	--	--	--	--	--	--	--	--	<560	--

Note: All values in picocuries per liter.
-- - not measured

Table B-4. Catch Basin Tritium Concentrations

Tennessee Valley Authority　Watts Bar Nuclear Plant　Spring City, Tennessee

Date	CB #2	CB #30	CB #50	CB #52
7/24/03	--	--	--	1,404
8/21/03	--	<590	26,100	--
8/22/03	--	--	9,910	--
8/22/03	--	--	16,710	--
8/25/03	--	--	14,600	--
8/26/03	--	--	13,000	--
9/2/03	<590	--	16,400	--
9/4/03	--	--	8,070	--
9/18/03	--	--	Dry	--
9/24/03	--	--	Dry	--
9/25/03	--	3,973	--	--
11/7/03	--	562.8	686	--
12/10/03	--	820	765	--

Note: All values in picocuries per liter.
-- - not measured

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"Power Block Site Map"

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"Distribution of Tritium Concentrations in Groundwater, March 2004"

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D-10

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ATTACHMENT: K
"Distribution of Tritium
Concentrations in Groundwater
At Power Block,
March 2004"

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D-11

Attachment 2

Table G-5

Federal, State, and Local Authorizations

TABLE G-5
FEDERAL, STATE, AND LOCAL AUTHORIZATIONS

Agency	Authority	Phase/Requirement/Status	Activity Covered
U.S. Nuclear Regulatory Commission (NRC)	10 CFR Part 50	Preconstruction. Construction Permit CPPR-92 EXP: 31DEC2013	Permit for construction of a utilization facility.
NRC	10 CFR Part 50	OL Submittal. Updated license application filed 04MAR2009	Operation of a utilization facility for commercial purposes
U.S. Fish and Wildlife Service (FWS)	16 U.S.C. §§ 1531 *et seq.*	FSEIS. Concurrence. 1995 consultation with FWS, cited in FSEIS Appendix D, applied to WBN1 and WBN2. 2007 FSEIS also found no impacts.	Consultation concerning potential impacts to Federal threatened & endangered (T&E) species.
U.S. Department of the Interior (DOI)	42 U.S.C. § 1996; 25 U.S.C. § 3001 *et seq.*	FSEIS. Consultation. Consultation not required as FSEIS did not identify any items of cultural significance to Native American tribes.	Identification, protection, and repatriation of items of cultural significance to Native American tribes.
Federal Aviation Administration (FAA)	14 CFR Part 77	Preconstruction. Notification not required as no activities affect structures over 200ft.	Preconstruction letter of notification to FAA results in a written response certifying that no hazards exist or recommending project modification.
U.S Coast Guard	14 U.S.C. §§ 81, 83, 85, 633; 49 U.S.C. § 1655(b).	Preconstruction. Authorization not required as no activities affect navigation.	Navigation markers authorization to protect river navigation from hazards connected with temporary construction activities in a river.
Tennessee Department of Environment and Conservation (TDEC)	Water Quality Control Act, TCA §§ 69-3-101 *et seq.*	Preoperation. Certification. TVA will seek any required certification from TDEC prior to issuance of the OL.	Aquatic resource alteration permit (ARAP) for any alteration of the properties of state waters. This permit also serves as a section 401 water quality certification, which is required prior to seeking a Federal permit or license, including an operating license from the NRC.

TABLE G-5
FEDERAL, STATE, AND LOCAL AUTHORIZATIONS

Agency	Authority	Phase/Requirement/Status	Activity Covered
U.S. Army Corps of Engineers (USACE)	33 U.S.C. § 1344; 33 U.S.C. §§ 1341	Preconstruction. Permit. USACE stated, as listed in FSEIS Appendix D, that Section 404 permit not required as no work requires discharge of dredged or fill material.	Section 404 permit required for discharge of dredged and fill material. A section 401 certification that the action does not violate state water quality standards is required prior to obtaining a section 404 permit.
TDEC Air Division	Tennessee Air Quality Act, TCA §§ 68-201-101 *et seq.* 42 U.S.C. §§ 7401 *et seq.*	Preconstruction. Construction permit. Permit 957606P held by TVA. EXP: 01JAN2007 Renewal pending. Requested update and consolidation with operating permit 448529 on 23JAN2007.	Construction permit for prevention of significant deterioration of air quality required to construct an air contaminant source.
TDEC Air Division	TCA §§ 68-201-101 42 U.S.C. §§ 7401 *et seq.*	Preoperation. Operating permit. Permit 448529 held by TVA. EXP: 01SEP2010.	This permit covers emissions from the Watts Bar site for both Unit 1 and Unit 2 equipment. TVA - WBN opted out of major source - Not a Title V Permit.
TDEC Water Division	42 U.S.C. § 1342; TCA §§ 69-3-101 *et seq.*	Continuing permit requirement. NPDES Permit TN0020168 held by TVA. EXP: 04NOV2006 Permit administratively continued. Renewal filed 03MAY2006.	Facility permit for point source discharges of wastewater to surface waters and in-stream monitoring Unit 1 only - Permit modification request to include Unit 2 will be filed in June 2010.

TABLE G-5
FEDERAL, STATE, AND LOCAL AUTHORIZATIONS

Agency	**Authority**	**Phase/Requirement/Status**	**Activity Covered**
TDEC Water Division	33 U.S.C. §1342; TCA §§ 69-3-101 *et seq.*	Continuing permit requirement. Industrial Storm water Multi-Sector General Permit TNR050000 held by TVA. EXP: 14MAY2014	Permit for discharge of storm water associated with land disturbance and industrial activity.
TDEC Water Division	33 U.S.C. §1342; TCA §§ 69-3-101 *et seq.*	Preconstruction. Permit. Not required, as no construction activities planned that would result in storm water discharge.	Permit for discharge of storm water associated with construction involving clearing, grading or excavation that result in an area of disturbance of one or more acres, and activities that result in the disturbance of less than one acre if it is part of a larger common plan of development
TDEC Division of Solid and Hazardous Waste Management (SHW)	Tennessee Solid Waste Disposal Act, TCA §§ 68-211-101 *et seq.*	Preoperation. Permit. Permit number DML72-103-0025 held by TVA. EXP: N/A	Site Permit for operation of a Class IV disposal facility (onsite construction & demolition landfill)
TDEC Division of SHW	TCA §§ 68-212	EPA Facility ID TN2640030035 Construction Demolition Landfill Permit Number DML 721030025 EXP: N/A	Transportation of waste
Alabama Department of Environmental Management (ADEM)	ADEM Admin. Code R. 335-14	Ongoing. Permit. Operation Permit AL2-640-090-005 held by TVA. EXP: 06MAY2011	Storage of hazardous waste at the hazardous waste storage facility in Muscle Shoals, AL.

TABLE G-5
FEDERAL, STATE, AND LOCAL AUTHORIZATIONS

Agency	Authority	Phase/Requirement/Status	Activity Covered
TDEC Division UST or Solid and Hazardous Waste	TCA §§ 68-212	Preconstruction/operation. Permit. Not required as no underground storage tanks as defined by TDEC.	Installation/operation of underground storage tanks that store regulated substances.
Tennessee Historical Commission (THC) (State Historic Preservation Officer)	16 U.S.C. §§ 470 *et seq.* 36 CFR Part 800	Preoperation. Consultation. Consultation with THC completed and documented in FSEIS Appendix D.	Review and analysis of cultural and historic resources, including completion of NHPA Section 106 consultation.
Tennessee Public Service Commission		Operation. Certification not required.	Certificate of public convenience and necessity.
TVA	Executive Order 11514 (Protection and Enhancement of Environmental Quality) 40 CFR Parts 1500-1508	FSEIS. Completed.	Protect and enhance the quality of the environment; develop procedures to ensure the fullest practicable provision of timely public information and understanding of Federal plans and programs that may have potential environmental impacts that the views of interested parties can be obtained.
TVA	Executive Order 11988 (Floodplain Management) TVA Procedure for Compliance With NEPA, Section 5.7	FSEIS. Completed.	Floodplain impacts to be avoided to the extent practicable.
TVA	Executive Order 11990 (Protection of Wetlands) TVA Procedure for Compliance With NEPA, Section 5.7	FSEIS. Completed.	Requires federal agencies to avoid any short- and long-term adverse impacts on wetlands wherever there is a practicable alternative.

Attachment 3

TVA Nuclear Power Group Calculation

WBNTSR-008 R11

Control Room Operator and Offsite Doses Due to a Steam Generator Tube Rupture

NPG CALCULATION COVERSHEET/CCRIS UPDATE

REV 0 EDMS/RIMS NO. B26 890410 001	EDMS TYPE: calculations(nuclear)	EDMS ACCESSION NO (N/A for REV. 0) T93100219003

Calc Title:
Control Room Operator and Offsite Doses Due to a Steam Generator Tube Rupture

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISION APPLICABILITY
CURRENT	CN	NUC	WBN	NTB	WBNTSR-008	10	11	Entire calc ☒ Selected pages ☐
NEW	CN	NUC						

ACTION	NEW ☐ REVISION ☒	DELETE ☐ RENAME ☐	SUPERSEDE ☐ DUPLICATE ☐	CCRIS UPDATE ONLY ☐ (Verifier Approval Signatures Not Required)	No CCRIS Changes ☐ (For calc revision, CCRIS been reviewed and no CCRIS changes required)

UNITS	SYSTEMS	UNIDS
1/2	NA	NA

DCN,EDC,N/A	APPLICABLE DESIGN DOCUMENT(S)	CLASSIFICATION
EDCR 54956	NA	E

QUALITY RELATED?	SAFETY RELATED? (If yes, QR = yes)	UNVERIFIED ASSUMPTION	SPECIAL REQUIREMENTS AND/OR LIMITING CONDITIONS?	DESIGN OUTPUT ATTACHMENT?	SAR/TS and/or ISFSI SAR/CoC AFFECTED
Yes ☒ No ☐	Yes ☒ No ☐	Yes ☐ No ☒	Yes ☐ No ☒	Yes ☐ No ☒	Yes ☒ No ☐

PREPARER ID	PREPARER PHONE NO	PREPARING ORG (BRANCH)	VERIFICATION METHOD	NEW METHOD OF ANALYSIS
MCBERG	603-926-3810	WorleyParsons/Polestar	Design Review	☐ Yes ☒ No

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
Marc C. Berg Marc C. Berg	1-14-10	Heather M. Lucek Heather M Lucek	1-14-10
VERIFIER SIGNATURE	**DATE**	**APPROVAL SIGNATURE**	**DATE**
Heather M. Lucek Heather M Lucek	1.14.10	DGF 2/18/2010 JSThompson JSThompson	02/19/10

STATEMENT OF PROBLEM/ABSTRACT

This analysis determines the control room operator and offsite dose due to a Steam Generator Tube Rupture accident. The steam releases (primary and secondary side) are from Westinghouse. The activities of the primary coolant are based on technical specification limits with a preexisting iodine spike of a factor of 21 μCi/gm I-131 equivalent (maximum 48 hour). Also analyzed are reactor coolant activities 0.265 μCi/gm I-131 equivalent with an accident initiated iodine spike of 500 times the release rate from the fuel. The secondary side activities come from WBNNAL3-003 and are set at 0.1 μCi/gm. Credit is taken for partial flashing of the reactor coolant as it enters the steam generator. For conservatism, no credit is taken for "scrubbing" of iodine in the steam bubbles as the bubbles rise through the water. The production rate of iodines is based on a pre-accident steady state reactor coolant leakage of 11 gpm (10 gpm known + 1 gpm unknown).

The released activities are used as input to computer code COROD which determines the control room operator dose. The base COROD model is taken from TI-RPS-198. The control room intake vent X/Q values are taken from WBNAPS3-104 and were determined using the ARCON96 code. The activities are used as input to the computer FENCDOSE which determines the offsite dose. The control room operator dose case is examined which considered the effect of slow closure times of 0-FCV-31-3, -4 (14 seconds) and the radiation monitor response time (6.6 sec) for a total closure time of 20.6 seconds.

The offsite doses (gamma, beta, thyroid and TEDE) due to a SGTR with a preexisting iodine spike does not exceed the 10CFR100 limits (25 rem gamma, 300 rem beta, and 300 rem thyroid per NUREG-0800). The SGTR with accident initiated iodine spike does not exceed a small fraction of the 10CFR100 limits (10% of the 10CFR100 limits of 25 rem gamma, 300 rem beta, and 300 rem thyroid per NUREG-0800).

The control room doses due to a SGTR do not exceed the 10CFR50 App.A GDC 19 limits (5 rem gamma, 30 rem beta and 30 rem thyroid).

This calculation impacts FSAR section 15.4 and 15.5.

MICROFICHE/EFICHE Yes ☒ No ☐ FICHE NUMBER(S) TVA-F-W001361

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NPG CALCULATION COVERSHEET/CCRIS UPDATE

Page 2

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	REV
	CN	NUC	WBN	NTB	WBNTSR-008	11

ALTERNATE CALCULATION IDENTIFICATION

BLDG	ROOM	ELEV	COORD/AZIM	FIRM	Print Report
				Polestar	Yes ☒

CATEGORIES

KEY NOUNS (A-add, D-delete)

ACTION (A/D)	KEY NOUN	A/D	KEY NOUN

CROSS-REFERENCES (A-add, C-change, D-delete)

ACTION (A/C/D)	XREF CODE	XREF TYPE	XREF PLANT	XREF BRANCH	XREF NUMBER	XREF REV
A	P	VD	WBN	MEB	LTR-CRA-09-153 R1	
A	P	VD	WBN	MEB	WBT-D-1015	
A	P	TS	WBN	MEB	TS 3.4.13	
A	P	TS	WBN	MEB	TS 3.4.16	
A	P	TS	WBN	MEB	TS 3.4.17	

CCRIS ONLY UPDATES:
Following are required only when making keyword/cross reference CCRIS updates and page 1 of form NEDP-2-1 is not included:

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE

PREPARER PHONE NO.

EDMS ACCESSION NO.

NPG CALCULATION RECORD OF REVISION

CALCULATION IDENTIFIER **WBNTSR-008**

Title **Control Room Operator and Offsite Doses Due to a Steam Generator Tube Rupture**

Revision No.	DESCRIPTION OF REVISION
0	Initial Issue
1	Revision 1 was performed because the base COROD model from TI-RPS-198 changed. pages changed: 1-6, 8, 9, 24-26, 30, 32-37, 39-60, 62, 63, 73-78 pages added: 24.1-24.3
2	Revision 2 was performed to incorporate the new steam releases as determined by Westinghouse with WBN specific parameters and to add the offsite dose to the analysis. pages changed: 1-24.2, 25-67 (old coversheet now page 1.1) pages deleted: none pages added: new cover (new page 1)
3	Revision 3 was performed because of revised steam releases as determined by Westinghouse. The entire calculation was rewritten. All pages were renumbered. Revision bars are shown only on areas of text which actually changed. Text which was reformatted does not show revision bars. pages changed: all pages deleted: none pages added: none
4	Revision 4 was performed because the X/Q values changed. pages added: 1 (new cover), 1.2 (abstract), 41.1, 41.2 pages deleted: none pages changed: 1.1 (old cover), 2-8, 17, 18, 20-22, 24-41
5	Revision 5 was revised because the control room intake flow was changed. pages added: none pages deleted: 41.1, 41.2 pages changed: 1, 1.2, 2-8, 18, 20-22, 24-41, 51-53
6	Revision 6 was performed because of revised reactor coolant and steam mass releases as determined by Westinghouse. pages added: 6.1 pages deleted: none pages changed: 1-8, 1.2, 11-14, 18, 20, 24-41
7	Revision 7 was performed as part of the corrective action of WBN PER 98-016506-000. The revision changed the basis of the source terms from the historical design values provided by Westinghouse which are located in the FSAR to the expected source terms based on ANSI/ANS-18.1-1984. No other modifications with respect to methodology were made. Other pending changes (such as alternate X/Q values, new Tech Spec limits, inclusion of the radiation monitor response time in the isolation time of the control room, impact of Tritium Production Core, and iodine spiking) will be dealt with in subsequent revision(s). There is no FSAR impact since there will be more changes in the near future, and the doses in this revision are less than R6. Pages added: 1 (new cover), 13.1, 50.1-50.3 Pages deleted: Attachment 3 Pages changed: 1a (old cover), 2, 3, 6, 6.1, 7-13, 18, 24-40, 46-50 R7: 75 total pages
8	Revision 8 is performed to increase the delay in the control room isolation time from 14.0 sec to 20.6 sec (= 14 sec damper closure + 6.6 sec instrument response) as part of the corrective action for WBN PER 01-000080-000. New X/Q values as determined by ARCON96 are incorporated. The Tritium Production Core (TPC) is included. The latest versions of COROD (R5) and FENCDOSE (R4) are used, which now determine the thyroid doses based on ICRP-2 and ICRP-30 dose conversion factors as well as the TEDE. Finally, the iodine spiking is treated differently. The preaccident iodine spike is the maximum Technical Specification limit (60 μCi/cc I-131 equivalent. Also 21 μCi/cc and 10 μCi/cc are analyzed). An accident initiated iodine spike with a factor of 500 increase in iodine release from the fuel with the initial activity at 1 μCi/cc, 0.265, or 0.177 μCi/cc I-131 equivalent with the baseline iodine production based on either 10 gpm, 5.75 gpm or 2.15 gpm, is now included in the analysis. Cases with the old Halitsky X/Q values are also performed. Additional justification for use of the ANS/ANSI-18.1-1984 spectrum was included. Finally, 3rd party review comments from Westinghouse and NISYS were incorporated. Due to the extent of the revision, all pages were renumbered. Text changes are marked with revision bars. Pages added: all Pages deleted: all Pages changed: all R8: 72 total pages The non-TPC results will affect FSAR section 15.5.5 and Tables 12.5-18 and 12.5-19, and the change will be processed in accordance with NADP-7 to reflect calculation results. A 10CFR50.59 evaluation is needed for these changes. In addition, Technical Specification LCO 3.4.16 and associated bases (RCS Iodine Concentration) will be affected by this calculation revision and a TS change will be required. These actions will be tracked under the corrective actions for PER 00-012545-000.

TVAN CALCULATION RECORD OF REVISION

CALCULATION IDENTIFIER **WBNTSR-008**

Title **Control Room Operator and Offsite Doses Due to a Steam Generator Tube Rupture**

Revision No.	DESCRIPTION OF REVISION
9	Revision 9 is performed for replacement steam generators (DCN 51754). The mass releases have been changed, resulting in different answers. The original steam generator results are retained. Also, the CREVS recirculation rate and time increments were corrected as part of the corrective action of PER 61493 and 94426. A 2 CREVS train operation for 2 hours is also performed. This calculation impacts FSAR section 15.4 and 15.5. The full impact to the FSAR and Technical Specifications will be addressed in the screening review of DCN 51754. Page numbers were redone, only actual text changes are marked with revision bars. Pages added: 4, Appendix F (p.36-37) Pages deleted: design verification form Pages changed: 1-3, 5-10, 14-29 R9: 63 total pages
10	Revision 10 is in support of DCN 51754. WBNNAL3003 has been revised to show the change in RCS volume due to the Replacement Steam Generators (RSG). R9 of this calculation used a RCS volume from a Westinghouse document (WB1RSG-TR-02) that has been revised since the issue of R9. Also, the 2 train CREVS cases have been deleted as it was determine to be beyond design basis. An assumption has been added to discuss this issue. Successor documents WBNAPS3048, WBNAPS3079, and WBNTSR028 were determined to be impacted by this revision. Impacts to the FSAR and TS's, if any, will be addressed in the screening review of DCN 51754. Pages Added: None Pages Deleted: None Pages Revised/Replaced: 1, 2, 4-7, 10, 14-17, 20, 23, 25-27, 29 R10: 63 total pages.
11	Revision 11 is performed to perform the SGTR analysis for Unit 2 (Appendix G). The steam generators are the same as the original Unit 1 steam generators, however the Westinghouse mass release calculations are different. SAR has been reviewed by _Marc Berg_____ and this revision of the calculation affects Unit 2 SAR section _Chapter 15 . A SAR change shall be processed in accordance with NGDC PP-10 to reflect the calculation results as part of EDCR 54956. Tech Specs have been reviewed and determined not to be affected. Pages added: Appendix G (p.39,40) Pages deleted: none Pages changed: 1,2,4-9, 21, 23 R11: 66 total pages

NPG CALCULATION TABLE OF CONTENTS

Calculation Identifier: **WBNTSR-008**	Revision: 11	

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NPG CALCULATION VERIFICATION FORM

Calculation Identifier WBNTSR-008 Revision 11

Method of verification used:

1. Design Review ☒
2. Alternate Calculation ☐
3. Qualification Test ☐

Heather Lucek
Verifier Heather Lucek Date 1-14-10

Comments:

I have reviewed WBNTSR-008 R11 and have found the calculation to have been completed in a technically sound an appropriate manner to address the Unit 2 Steam Generator Tube Rupture. In conducting the verification I reviewed the methodology, design input, and assumptions which I found to be valid and conservative. I verified the computer code inputs for correctness and confirmed they only contained the changes as specified in this document. I also confirmed the correct output values were compiled in the results.

LEGIBILITY EVALUATED AND
ACCEPTED FOR ISSUE. ALL PAGES
Scott Helm 2/18/10
SIGNATURE REV 11 DATE

NPG COMPUTER INPUT FILE
STORAGE INFORMATION SHEET

Document WBNTSR-008	Rev. 11	Plant: WBN	

Subject:
Control Room Operator and Offsite Doses Due to a Steam Generator Tube Rupture

☐ Electronic storage of the input files for this calculation is not required. Comments:

☒ Input files for this calculation have been stored electronically and sufficient identifying information is provided below for each input file. (Any retrieved file requires re-verification of its contents before use.)

The computer input for R6 is permanently stored in FILEKEEPER file # 300203.

The computer input for R7 is permanently stored in FILEKEEPER file # 303287

The computer input for R8 is permanently stored in FILEKEEPER file # 303581

The computer input for R9 is permanently stored in FILEKEEPER file # 307461 and 308002

The computer input for R10 is permanently stored in FILEKEEPER file # 308287

The computer input for R11 is stored in eFiche file TVA-F-W001361

☐ Microfiche/eFiche

TVA

NPG COMPUTER OUTPUT MICROFICHE INFORMATION SHEET			page 8
Document WBNTSR-008	Rev. 11	Plant: WBN	

Subject:

Control Room Operator and Offsite Doses Due to a Steam Generator Tube Rupture

Microfiche Number	Description
R5: TVA-F-C000107	
R6: 000244	R6: Name Code Description TSR008S6 STP 14sec delay source term TSR008F6 FENCDOSE offsite dose TSR008C6 COROD no damper delay control room operator dose
R7: TVA-F-C000322	R7: Name Code Description TSR008S7 STP 14sec delay source term TSR008F7 FENCDOSE offsite dose TSR008C7 COROD no damper delay control room operator dose
R8: TVA-F-C000356	R8: Name Code Description TSR8S8# STP 20.6 sec delay source term, TPC TSR8S8#N STP 20.6 sec delay source term, conventional core TSR8F8# FENCDOSE offsite dose, TPC TSR8F8#N FENCDOSE offsite dose, conventional core TSR8C8# COROD control room operator dose, TPC, ARCON96 X/Q TSR8C8#N COROD control room operator dose conventional core, ARCON96 X/Q TSR8C8#X COROD control room operator dose, TPC, Halitsky X/Q TSR8C8#Y COROD control room operator dose, conventional core, Halitsky X/Q where #=: A=60µCi/gm I spike, B=21µCi/gm I spike, C=10µCi/gm I spike, D=1µCi/gm I w/500I spike (10 gpm leak basis), E=0.265µCi/gm I with w/500I spike(10 gpm leak basis), F=0.177µCi/gm(10 gpm leak basis), G=0.265µCi/gm I with w/500I spike(2.15 gpm leak basis), H=0.177µCi/gm(2.15 gpm leak basis), I=0.265µCi/gm I with w/500I spike(5.75 gpm leak basis), J=0.177µCi/gm(5.75 gpm leak basis)
R9: TVA-F-W000500 and TVA-F-W000573	R9: Name Code Description TSR8S9# STP 20.6 sec delay source term, TPC TSR8F9# FENCDOSE offsite dose, TPC TSR8C9# COROD control room operator dose, TPC, ARCON96 X/Q where #=A,C, E, G=21 µCi/gm I spike, B,D, F, H=0.265µCi/gm w/500 I spike (10+1 gpm leak basis); A,B, E, F=1CREVS case, C,D, G, H=2 CREVS case; A,B,C,D=replacement steam generator, E,F,G,H=original steam generators
R10: TVA-F-W000613	TSR8S9A STP 20.6 sec delay source term, TPC, 21 uCi/g TSR8S9B STP 20.6 sec delay source term, TPC, 0.265 uCi/g TSR8F9A FENCDOSE offsite dose, TPC, 21 uCi/g TSR8F9B FENCDOSE offsite dose, TPC, 0.265 uCi/g c TSR8C9A COROD control room operator dose, TPC, 21 uCi/g TSR8C9B COROD control room operator dose, TPC, 0.265 uCi/g
R11: TVA-F-W001361	TSR8S11A STP 20.6 sec delay source term, TPC, 21 uCi/g TSR8S11B STP 20.6 sec delay source term, TPC, 0.265 uCi/g TSR8F11A FENCDOSE offsite dose, TPC, 21 uCi/g TSR8F11B FENCDOSE offsite dose, TPC, 0.265 uCi/g TSR8C11A COROD control room operator dose, TPC, 21 uCi/g TSR8C11B COROD control room operator dose, TPC, 0.265 uCi/g

Purpose

This analysis is performed to determine the control room operator dose following a design basis steam generator tube rupture accident (SGTR). Revision 9 is performed to address the replacement steam generators (DCN 51754, which changes the mass releases) and to correct CREVS recirculation flow (PER 61493) and time increments (PER 94423).

Introduction

This analysis determines the control room operator and offsite dose due to a Steam Generator Tube Rupture accident. The steam releases (primary and secondary side) are taken from reference 45 and 46. The activities of the primary coolant are based on technical specification limits with a preexisting iodine spike of 21 μCi/cc I-131 equivalent for a preaccident spike (note: all measurements are at STP, therefore 1 g=1cc water). An alternate accident initiated iodine spike case uses initial activity at 0.265 μCi/cc I-131 equivalent with a factor of 500 increase in iodine release rate from the fuel. The secondary side activities start at 0.1 μCi/cc I-131 equivalent. The secondary side activities come from WBNNAL3-003 R3 (ref.29). Credit is taken for partial flashing of the reactor coolant as it enters the steam generator. For conservatism, no credit is taken for "scrubbing" of iodine in the steam bubbles as the bubbles rise through the water, therefore it is unimportant if the break is above or below the water level at all times.

The computer code STP is used to determine the releases. The released activities are used as input to computer code COROD (ref.15) which determines the control room operator dose. The base COROD model is taken from TI-RPS-198 (ref.13, ingress and egress dose was not determined because the accident lasts less than 8 hours and the ingress/egress is after 8 hours). The control room operator dose considers the effect of slow closure times of 0-FCV-31-3, -4. The delay is 20.6 sec (which includes the 14 sec damper closure time and the 6.6 sec monitor response time). This is conservative because the delay in isolation allows a large slug of unfiltered radioisotopes into the control room. It is realistic because the isolation of the control room will most likely occur due to a high radiation signal in the control room intake HVAC. The control room intake vent X/Q values are taken from WBNAPS3-104 (ref.37) which are determined using ARCON96. These X/Q values are also found in WBNAPS3-104. The activities from STP are also used as input to the computer FENCDOSE (ref.30) which determines the offsite dose.

Revision 11 added the Unit 2 SGTR (Appendix G). The Unit 2 steam generators have are the same as the original Unit 1 steam generators, however the mass releases were reanalyzed by Westinghouse.

Assumptions

1. There is no iodine "scrubbing" by the water in the steam generator when the steam bubbles (formed due to the flashing of the primary water) rise to the surface of the water.
Technical Justification: This is conservative because this increases the amount of iodine released. Since the break may be below the water line, there will actually be some amount of scrubbing (removal) of iodine.
2. The maximum reactor coolant activities allowed under WBN Technical Specifications (ref.3) is assumed, with a distribution found in WBNNAL3-003 (ref.29), which are the expected source terms from ANSI/ANS-18.1-1984 modified for WBN.
Technical Justification: The maximum concentration is mandated by NUREG-0800 (ref.7). This assures maximum release of radioisotopes. See Attachment 2 for justification for using expected reactor coolant as the isotope distribution for establishing Technical Specification source terms.
3. The primary side to secondary side leakage is 150 gpd/steam generator, steady state.
Technical Justification: This is Technical Specification 3.4.13 (ref.33)
4. The maximum letdown of 120 gpm + 4.39 gpm = 124.39 gpm (ref.39, 41) is used.
Technical Justification: This value is used for calculation of iodine production/removal rates. This will maximize the removal rate of iodines from the primary coolant, and therefore will maximize the production rate of iodine (production = removal at steady state). See Calculation section for the formulas used. The letdown is assumed to be isolated at the beginning of the accident to maximize the reactor coolant inventories. The uncertainty of 4.39 gpm is determined in Appendix E.
5. The primary to secondary side leak rates and letdown flow rates are based on Standard Temperature and Pressure (STP).
Technical Justification: This is the method by which the plant measure leakage. Also, this will maximize the releases because the density is higher at STP, therefore more mass (and hence radioisotopes) will be released. For the letdown flow, this will increase the steady state iodine production rate, and therefore increase the iodine releases.
6. In the intact steam generators, the iodine partition factor is assumed to be 100. (see also assumption 12).
Technical Justification: The mass of primary to secondary leakage which occurs to the intact steam generators is small relative to the mass of secondary coolant. Therefore none of this leakage is assumed to flash and the release to the environment is through the steaming process. Reference 7 allows a partition factor of 100 for such cases.
7. In one case, a preaccident iodine spike of 21 μCi/gm I-131 equivalent is assumed at the start of the accident. In the other case, an accident initiated iodine spike of 500 increase in the iodine release rate from the fuel is assumed in the accident initiated case with the reactor coolant starting at 0.265 μCi/gm I-131 equivalent.
Technical Justification: SRP 15.6.3 subsection 6a specifies the maximum allowable preaccident spike is required (21 uCi/gm is permissible for 48 hours). SRP 15.6.3 subsection 6b specifies that following an accident, the iodine release rate from the fuel to the reactor coolant is increased by a factor of 500.
8. The letdown demineralizer efficiency is assumed to be 1 for iodines.
Technical Justification: This will maximize iodine removal (=production) rate, and therefore result in larger iodine spiking.
9. The tritium inventory in the reactor coolant is assumed to be for the case with 2 TPBAR failures (98.4 μCi/g, ref.29).
Technical Justification: This will give an upper bound for the tritium. Also, 2 TPBAR failure is considered to be an abnormal event. This will result in conservative doses.
10. It is assumed that there is no additional fuel damage due to the accident.
Technical Justification: There is no expected extreme temperatures expected in the core due to the accident, therefore there will not be any fuel damage.
11. Only the Tritium Production Core (TPC) inventories are analyzed.
Technical Justification: Except for tritium, the reactor coolant inventories for the conventional and tritium production cores are the same. Therefore using the TPC with the additional tritium in the coolant will be conservative.
12. Water that boils in the faulted steam generator has an iodine partition factor of 100.
Technical Justification: Normally, to take into account uncovery of the faulted steam generator, there is no iodine partitioning in the release to the environment (iodine partition coefficient = 1). However, the water that boils is allowed a partition of 100. This is consistent with assumption 6.

13.Only one train of CREVS is in operation. Normally, each CREVS train takes suction from separate intakes with no cross communication between trains. This leads to one contaminated train, and one uncontaminated train. The only way a 2 CREVS operation could result in higher doses would be for both trains to take suction from the same vent. For this to happen, one intake path would require a failed closed intake path **AND** a fail open of normally closed passive manual damper at the beginning of the accident. An active failure of a train plus a failure of a passive component in less than 24 hours is beyond design basis.

Special Requirements/Limiting Conditions

There are no special requirements or limiting conditions in this calculation.

Calculations

The following main text represents the replacement steam generator SGTR. The original steam generator results can be found in Appendix F. The details for the App.F calculations can be found in Revision 8 of this analysis, with the exception of the COROD control room doses (which were corrected with the proper recirculation rates and time increments).

Primary Coolant Activity Releases

In NUREG-0800 R2 Chapter 15.6.3 (ref.7), section III.5 states "The reviewer assumes the primary and secondary coolant activity concentrations allowed by the technical specifications." Reference 3 of NUREG-0800 states the following "The specific activity of the reactor coolant shall be limited to: a. Less than or equal to 1 microCurie per gram DOSE EQUIVALENT I-131, and b. Less than or equal to 100/E microCuries per gram of gross activity."

Given the above considerations, the isotopic spectrum found in WBNNAL3-003 (ref.29) was examined. The I-131 dose equivalent and 100/E values for this particular spectrum are determined in Tables 1 and 2.

Table 1: Determination of I-131 Dose Equivalent

	D/A mrads/Ci (ref.8)	Specific Activity µCi/gm	I-131 equivalent µCi/gm
I-131	1.48E+09	4.77E-02	4.77E-02
I-132	5.35E+07	2.25E-01	8.13E-03
I-133	4.00E+08	1.49E-01	4.03E-02
I-134	2.50E+07	3.64E-01	6.15E-03
I-135	1.24E+08	2.78E-01	2.33E-02
total		1.06E+00	1.255E-01

Table 2: Determination of 100/EBAR

Isotope	A(i) Activity [uCi/gm]	E(i) Beta Energy [MeV/dis]	E(i) Gamma Energy [MeV/dis]	E(i) Total	A(i)*E(i)
Kr-85m	1.71E-01	2.5290E-01	1.5862E-01	4.1152E-01	7.04E-02
Kr-85	2.66E-01	2.5060E-01	2.2102E-03	2.5281E-01	6.73E-02
Kr-87	1.61E-01	1.3237E+00	7.9284E-01	2.1165E+00	3.40E-01
Kr-88	3.00E-01	3.7500E-01	1.9629E+00	2.3379E+00	7.01E-01
Xe-131m	6.54E-01	1.4280E-01	2.0058E-02	1.6286E-01	1.06E-01
Xe-133m	7.17E-02	1.8980E-01	4.1559E-02	2.3136E-01	1.66E-02
Xe-133	2.53E+00	1.3540E-01	4.5385E-02	1.8079E-01	4.57E-01
Xe-135m	1.39E-01	9.5000E-02	4.3176E-01	5.2676E-01	7.35E-02
Xe-135	9.04E-01	3.1680E-01	2.4696E-01	5.6376E-01	5.10E-01
Br-84	1.72E-02	1.2842E+00	1.6816E+00	2.9658E+00	5.09E-02
Rb-88	2.04E-01	2.0617E+00	6.8631E-01	2.7480E+00	5.60E-01
Cs-134	7.39E-03	1.5690E-01	1.0361E+00	1.1930E+00	8.82E-03
Cs-136	9.08E-04	1.0140E-01	2.1985E+00	2.2999E+00	2.09E-03
Cs-137	9.79E-03	1.8840E-01	0.0000E+00	1.8840E-01	1.84E-03
Na-24	4.99E-02	5.5460E-01	4.1216E+00	4.6762E+00	2.33E-01
Cr-51	3.26E-03	3.7540E-03	3.2763E-02	3.6517E-02	1.19E-04
Mn-54	1.68E-03	4.1670E-03	8.3592E-01	8.4009E-01	1.41E-03
Fe-55	1.26E-03	4.1920E-03	1.5291E-03	5.7211E-03	7.22E-06
Fe-59	3.16E-04	1.1800E-01	1.1923E+00	1.3103E+00	4.14E-04
Co-58	4.84E-03	2.0490E-01	9.7586E-01	1.1808E+00	5.72E-03
Co-60	5.58E-04	9.6840E-02	2.5043E+00	2.6011E+00	1.45E-03
Zn-65	5.37E-04	6.8940E-03	5.8169E-01	5.8858E-01	3.16E-04
Sr-89	1.47E-04	5.7300E-01	1.3636E-04	5.7314E-01	8.44E-05
Sr-90	1.26E-05	1.9630E-01	0.0000E+00	1.9630E-01	2.48E-06
Sr-91	1.02E-03	6.5050E-01	6.9508E-01	1.3456E+00	1.37E-03
Y-90	1.26E-05	9.3610E-01	0.0000E+00	9.3610E-01	1.18E-05
Y-91m	4.93E-04	0.0000E+00	5.5557E-01	5.5557E-01	2.74E-04
Y-91	5.47E-06	6.0600E-01	3.6147E-03	6.0961E-01	3.34E-06
Y-93	4.46E-03	1.1721E+00	8.9414E-02	1.2615E+00	5.63E-03
Zr-95	4.10E-04	1.1990E-01	7.3474E-01	8.5464E-01	3.51E-04
Nb-95	2.95E-04	4.4970E-02	7.6430E-01	8.0927E-01	2.38E-04
Mo-99	6.75E-03	3.9570E-01	1.6238E-01	5.5808E-01	3.77E-03
Tc-99m	5.01E-03	4.8500E-03	1.4263E-01	1.4748E-01	7.38E-04
Ru-103	7.89E-03	6.7400E-02	4.8394E-01	5.5134E-01	4.35E-03
Ru-106	9.47E-02	1.0100E-02	0.0000E+00	1.0100E-02	9.57E-04
Rh-103m	7.89E-03	3.4620E-02	2.2148E-05	3.4642E-02	2.73E-04
Rh-106	9.47E-02	7.0960E-01	2.0348E-01	9.1308E-01	8.65E-02
Te-129m	2.00E-04	1.9150E-01	9.4832E-02	2.8633E-01	5.73E-05
Te-129	2.57E-02	5.2260E-01	5.9948E-02	5.8255E-01	1.50E-02
Te-131m	1.59E-03	2.1240E-01	1.4092E+00	1.6216E+00	2.57E-03

Table 2: Determination of 100/EBAR - continued

Isotope	A(i) Activity [uCi/gm]	E(i) Beta Energy [MeV/dis]	E(i) Gamma Energy [MeV/dis]	E(i) Total	A(i)*E(i)
Te-131	8.26E-03	7.5970E-01	4.1616E-01	1.1759E+00	9.71E-03
Te-132	1.79E-03	1.0020E-01	2.0507E-01	3.0527E-01	5.47E-04
Ba-137m	9.79E-03	6.4260E-02	5.9729E-01	6.6155E-01	6.48E-03
Ba-140	1.37E-02	3.1500E-01	1.9522E-01	5.1022E-01	6.98E-03
La-140	2.64E-02	5.4050E-01	2.3074E+00	2.8479E+00	7.52E-02
Ce-141	1.58E-04	1.6930E-01	1.0181E-01	2.7111E-01	4.28E-05
Ce-143	2.96E-03	3.8420E-01	3.4335E-01	7.2755E-01	2.15E-03
Ce-144	4.21E-03	9.1300E-02	3.2865E-02	1.2417E-01	5.23E-04
Pr-143	2.96E-03	3.1430E-01	0.0000E+00	3.1430E-01	9.30E-04
Pr-144	4.21E-03	1.2258E+00	3.1010E-02	1.2568E+00	5.29E-03
Np-239	2.32E-03	1.2380E-01	2.0845E+00	2.2083E+00	5.13E-03
Total	5.82E+00				3.44E+00
				EBAR	5.91E-01
			RCS Specific Activity Limit		169.14

The D/A values (rads/Curie) in Table 1 were obtained from reference 8, p.25 for each of the iodine isotopes of interest. The I-131 dose equivalence is calculated as follows:

$D.E_i. = A_i * (D/A)_i / (D/A)_{I131}$

As can be seen in Table 1, the resulting I-131 dose equivalency for the expected spectrum is 0.1255 μCi/g.

The definition of EBAR or E is as follows: "E shall be the average (weighted in proportion to the concentration of each radionuclide in the reactor coolant at the time of sampling) of the sum of the average beta and gamma energies per disintegration (in MeV) for isotopes, other than iodines, with half lives greater than 15 minutes, making up at least 95% of the total non-iodine activity in the coolant."

The values for E_i in Table 2 were obtained from reference 17 and the values for A_i are from WBNNAL3-003. The value of E is determined as follows:

$E = (\Sigma A_i E_i) / (\Sigma A_i)$

The value for E calculated in Table 2 is 0.591 MeV/dis. This results in a non-iodine specific activity limit (100/E) of 169.14 μCi/g. The total specific activity of the expected coolant is 5.82 μCi/g.

Therefore, the values for noble gasses in the design reactor coolant given in reference 29 will have to be increased by a factor of 169.14/5.82 = 29.06 and the values for iodines will have to be increased by a factor of 1/0.1255 = 7.965.

For the secondary side concentrations from WBNNAL3-003, the same procedure is performed to determine the I-131 equivalence:

	D/A mrads/Ci	μCi/gm secondary side,water ANSI 18.1	I-131 equivalent μCi/gm
1-131	1.48E+09	1.41E-06	1.41E-06
1-132	5.35E+07	3.37E-06	1.22E-07
1-133	4.00E+08	4.03E-06	1.09E-06
1-134	2.50E+07	2.93E-06	4.95E-08
1-135	1.24E+08	6.19E-06	5.19E-07
total		1.79E-05	3.189E-06
		inverse	3.136E+05

To convert to I-131 equivalence, the secondary side I-131 equivalent conversion factor is (1/3.189E-6) = 3.136E5 gm/μCi. Note that this factor has been developed for iodines. There is no limit on noble gasses in the secondary side as there is for the primary side (100/Ebar). However, in order to maintain the proper ratio of isotopes, and for conservatism, the iodine factor will also be applied to the noble gasses.

Note: the secondary side water does not contain any noble gasses. For conservatism, the noble gas inventory is the inventory from the secondary side steam.

The STP models consist of a pre-accident iodine spike (see figure 1) model and an accident initiated iodine spike model (see figure 2). The model(s) consist of the following:

Volumes:
#1: Reactor Coolant: 5.78E5 lb (ref.29) = 2.622E8 gm
#2: Steam Generator w/Leak: 5.31E7 gm (ref.40)
#3: Steam Generators w/out Leak: 1.593E8 gm (ref.40)
#4: Environment: 1 gm (arbitrary) (This volume is made into an accumulator through the "A" card to suppress radioactive decay)

The step sources to initialize the reactor coolant and the secondary side activities are:
S=2.622E8 gm*1E-6 Ci/μCi=2.622E2 (tritium)
S=2.622E8 gm*1E-6 Ci/μCi * 29.06 = 7.620E3 (noble gasses)
Pre-accident iodine spike case (initial concentration = 21 μCi/gm):
S=2.622E8 gm*1E-6 Ci/μCi * 7.965 $[\mu Ci/gm\ I\text{-}131]^{-1}$ *21 μCi/gm = 4.386E4 (iodines)
Accident initiated iodine spike case (initial concentration = 0.265 μCi/gm):
S=2.622E8 gm*1E-6 Ci/μCi * 7.965 $[\mu Ci/gm\ I\text{-}131]^{-1}$*0.265 μCi/gm = 5.534E2 (iodines)
Secondary side, all cases, steam generator with leak (initial concentration = 0.1 μCi/gm):
S = 5.31E7 gm * 1E-6 Ci/μCi = 5.31E1 (tritium)
S = 5.31E7 gm*1E-6 Ci/μCi*3.136E5 $[\mu Ci/gm\ I\text{-}131]^{-1}$* 0.1 μCi/gm = 1.665E6 (noble gasses, iodines)
Secondary side, all cases, steam generators without leak (initial concentration = 0.1 μCi/gm):
S = 1.593E8 gm * 1E-6 Ci/μCi = 1.593E2 (tritium)
S = 1.593E8 gm*1E-6 Ci/μCi*3.136E5 $[\mu Ci/gm\ I\text{-}131]^{-1}$* 0.1 μCi/gm = 4.996E6 (noble gasses, iodines)

Continuous Sources:

For the accident initiated iodine spike case, the iodine spike is 500 times the iodine release rate from the fuel. At steady state conditions, the iodine release (production) rate is equal to the removal rate. The iodine removal is due to a) radioactive decay, b) removal by the letdown system, and c) removal through leakage to the secondary side. These terms are expressed as:

$P = \Sigma$removal rates = decay + letdown + leakage
or $P = \lambda + f_L\varepsilon/V + p_s/V$

where P = production rate $[hr^{-1}]$
λ = decay constant for the isotope in question $[hr^{-1}] = \ln(2)/T_{1/2}$
f_L = letdown flow rate = 120 gpm + 4.39 = 124.39 gpm
ε = letdown demineralizer efficiency = 1 (assumed so as to maximize removal/production rate)
V = volume of primary coolant = 5.78E5 lb
p_s =removal rate of iodine from primary side due to leakage = 11 gpm (= 10 gpm identified plus 1 gpm unidentified leakage)
$T_{1/2}$ = halflife taken from ref.42
Note: All flow rates are converted to mass flow rates at STP ($H2O$ = 1 g/cc) .

Production/Removal Rates for 11 gpm Leakage (=10 known +1 unknown)

	Half Life	λ [1/hr]	$f_L\varepsilon/V$[1/hr]	p_s/V [1/hr]	prod rate P	500*P
I-131	8.04 d	3.59E-03	1.08E-01	9.53E-03	0.1209	60.44
I-132	2.28 h	3.04E-01	1.08E-01	9.53E-03	0.4213	210.65
I-133	20.9 h	3.32E-02	1.08E-01	9.53E-03	0.1505	75.23
I-134	52.6 m	7.91E-01	1.08E-01	9.53E-03	0.9079	453.97
I-135	6.61 h	1.05E-01	1.08E-01	9.53E-03	0.2222	111.08

The accident initiated iodine spike of 500 times the increase in the iodine release (production) rate from the fuel is modeled as a continuous source:

C = Volume * 1E-6 Ci/μCi * Prod. Rate * 500 * 1 μCi/gm I-131 equivalent conversion factor
where Volume = 2.622E8 gm
Prod Rate = see table above
I-131 equiv. = 0.265 μCi/gm I-131 equivalent
1 μCi/gm I-131 equivalent conversion factor = 7.965 (value determined above, this is to get the ANSI/ANS-18.1-1984 source into 1 μCi/gm I-131 equivalent

Continuous Source [1/hr] for Accident Initiated Iodine Spike:

	11 gpm leak (10 known+1gpm unknown)
	0.265 μCi/gm
I-131	3.345E+04
I-132	1.166E+05
I-133	4.163E+04
I-134	2.512E+05
I-135	6.147E+04

The following table presents the variables that change for each case:

Case	Step Source S for iodine	Continuous Source C	Description
A	4.386E+04	Not Applicable	21 μCi/gm I-131
B	5.534E+02	Table above	0.265 μCi/gm I-131, 500 spiking, 11 gpm leak (10 known+1 unknown)

Flow Rates:

The following is for the replacement steam generators. The results for the original steam generators can be found in App.F (with the input details found in Revision 8 of this analysis). The amount of secondary side steam released from the ruptured steam generator is 108,200 lbm from 0-2 hours and 35,500 lbm from 2-8 hours (ref.45). The amount of secondary side steam released from the intact steam generators is 539,500 lbm from 0-2 hours and 925,000 lbm from 2-8 hours (ref.45, note that ref.45b, which is a draft, gives this values as 924,400 lbm. This is 0.06% less than ref.45a. It is conservative to use the higher value). The reactor coolant release to the steam generator was a total of 166,200 lb, of which 9189 lb flashed (ref.45,46). In order to account for the release during the 20.6 second interval when the control room is not isolated, the amount of reactor coolant released at 20.6 sec is needed. However, the release from the steam generators does not actually start until 176 sec post accident. Therefore, the releases at 176+ 20.6 = 196.6 sec are actually needed for release calculations. Using the releases from reference 46 and adding each time increment release, the reactor coolant release at 196.5 sec is 9732.826 lb and at 197.5 sec it is 9776.753 lb. For conservatism, 9776.743 lb is used at 196.6 sec. The amount that flashed at 196.5 sec is 1322.612 lb and at 197.5 sec is 1324.805 lb. Using linear interpolation, the amount of reactor coolant that flashed at 196.6 sec is 1322.795lb. The mass release rate from the ruptured steam generator is non-linear. However since the time frame for the release is short (20.6 sec), the average release rate can be used. From reference 45, the flashing of the reactor coolant stops at 2208.5 sec, and the break flow stops at 4670 sec.

The following flow rates/leakage rates for each component are:

Flow from Reactor Coolant #1 to Steam Generator Faulted #2 (non-flashed):
  0-196.6 sec: F = (9776.753 lb - 1322.795 lb)*(3600 sec/hr)/(196.6 sec) = 1.548E5 lb/hr = 7.0217E7 g/hr
  196.6 sec-4670 sec: F = (166,200 lb-9776.753 lb)-(9189lb-1322.612 lb)/(4670-196.6sec) = 33.209 lb/sec =
      = 5.423E7 g/hr
  4670+ sec: F=0
Flow from Reactor Coolant #1 to Environment #4 (flashed):
  176-196.6 sec: F = (1322.795 lb)*(3600 sec/hr)/(20.6 sec) = 2.312E5 lb/hr = 1.0486E8 g/hr
  196.6 sec-2208.5 sec: F = (9189 lb-1322.795 lb)/(2208.6-20.6 sec]) = 3.5953 lb/sec = 5.871E6 g/hr
  2208.5+ sec: F=0
Flow from Steam Generator Faulted #2 to Environment #4:
  176 sec-2 hr:(108,200 lb)/(2hr-[176sec/3600sec/hr])=5.548E4 lb/hr=2.516E7g/hr(noble gas and tritium)
      0.01*(108,200 lb)/ (2hr-[176sec/3600sec/hr])=5.548E2 lb/hr=2.516E5g /hr (iodine)*
  2-8 hr: (35500 lb)/(8hr-2hr) = 5916.67 lb/hr = 2.6837E6 g/hr (noble gas)
      0.01*(35500 lb)/(8hr-2hr) = 59.1667 lb/hr = 2.6837E4 g/hr (iodine)
Flow from Steam Generator Unfaulted #3 to Environment #4:
  176 sec-2 hr: (539,500 lb)/ (2hr-[176sec/3600sec/hr]) = 276509 lb/hr = 1.254E8 g/hr (noble gas)
      0.01*(539,500 lb)/ (2hr-[176sec/3600sec/hr]) = 2765.09 lb/hr = 1.254E6 g/hr(iodine)
  2-8 hr: (925,000 lb)/(8hr-2hr) = 1.542E5 lb/hr = 6.993E7 g/hr (noble gas)
      0.01*(925,000 lb)/(8hr-2hr) = 1.542E3 lb/hr = 6.993E5 g/hr (iodine)
Flow from Reactor Coolant #1 to Steam Generator Unfaulted #3:
  F = 3 steam generators * 150 gpd * 3785.48 cc/gal / 24 hr/day * 1g/cc= 7.098E4 g/hr

* Normally, to take into account uncovery of the faulted steam generator, there is no iodine partitioning in the release to the environment (iodine partition coefficient = 1). For conservatism, no iodine scrubbing of the bubbles in the flashed water is taken into account. However, the water that boils is allowed the iodine partition of 100 (see assumption 6).

The STP output is used as input to COROD (which determines control room operator dose) and FENCDOSE (which determines 30-day and 2-hour LPZ offsite dose).

Control Room Dose

With the exception of the source activities and X/Q's, all of the input and assumptions used in TI-RPS-198 (ref.13) to calculate the control room operator dose are considered valid for this calculation. The X/Q values are taken from reference 37.

Maintenance Request MR-482000 (Attachment 2) gives measured closure times for several flow control valves in the control building ventilation system as measured on 12/8/88. Examination of reference 14 in conjunction with MR-482000 revealed that the worst case involved valves 0-FCV-31-3, -4 with closure times of 12.43 sec and 13.15 sec respectively. Therefore, it was conservatively assumed, and per reference 35, that these valves would be full open for 14 sec following the SGTR. (This is conservative since in actuality, as the valve closes, the flow decreases). In addition, the radiation monitor response time is 6.6 seconds (ref.38). This leads to a total unisolated control room time of 20.6 seconds. During this time the intake flow is 3200 cfm (reference 14). No filtration is provided for this stream.

Offsite Dose

The same source terms used in the COROD run are used in the FENCDOSE run. The base FENCDOSE model comes from TI-RPS-197 (ref.34). Some pertinent information from the COROD and FENCDOSE models used in this analysis are (from ref.34) with the control room X/Q values from ref.37:

30-day LPZ Offsite X/Q values [sec/cum]: 1.41E-4 0-2hr, 6.68E-5 2-8 hr, 4.59E-5 8-24 hr, 2.04E-5 1-4 day, 6.35E-6 4-30 day
2-hr EAB X/Q values: 6.07E-4
Control Room ARCON96 X/Q:4.03E-3 0-2hr, 3.35E-3 2-8hr, 2.27E-4 8-24hr, 1.81E-4 1-4day, 1.45E-4 4-30day
Control Room volume: 257198 cuft
Control Room makeup/pressurization flow: 711 cfm , 3200 cfm prior to isolation (ref.44*)
Control Room total flow: 3600 cfm
Control Room recirculation flow: 2889 , for normal operation (unisolated) each pass is at 3200 cfm (same as intake flow)
Control Room unfiltered intake: 51 cfm
Control Room filter efficiency: 95% first pass, 70% second pass for iodine, 0% for everything else
Control Room occupancy factors: 100% 0-24 hr, 60% 1-4 days, 40% 4-30 days
ICRP-2 and ICRP-30 dose conversion factors, as well as TEDE

* 3200 cfm has been deleted from 1-47W866-4 R36 (ref.10), and has been measured to be approximately 2500 cfm (0-SI-31-31-A). The value comes from 1-47W866-4 R20. The 3200 cfm will be retained in this calculation revision since this value produces conservative results.

Figure 1: STP Model

Pre-accident Iodine Spike

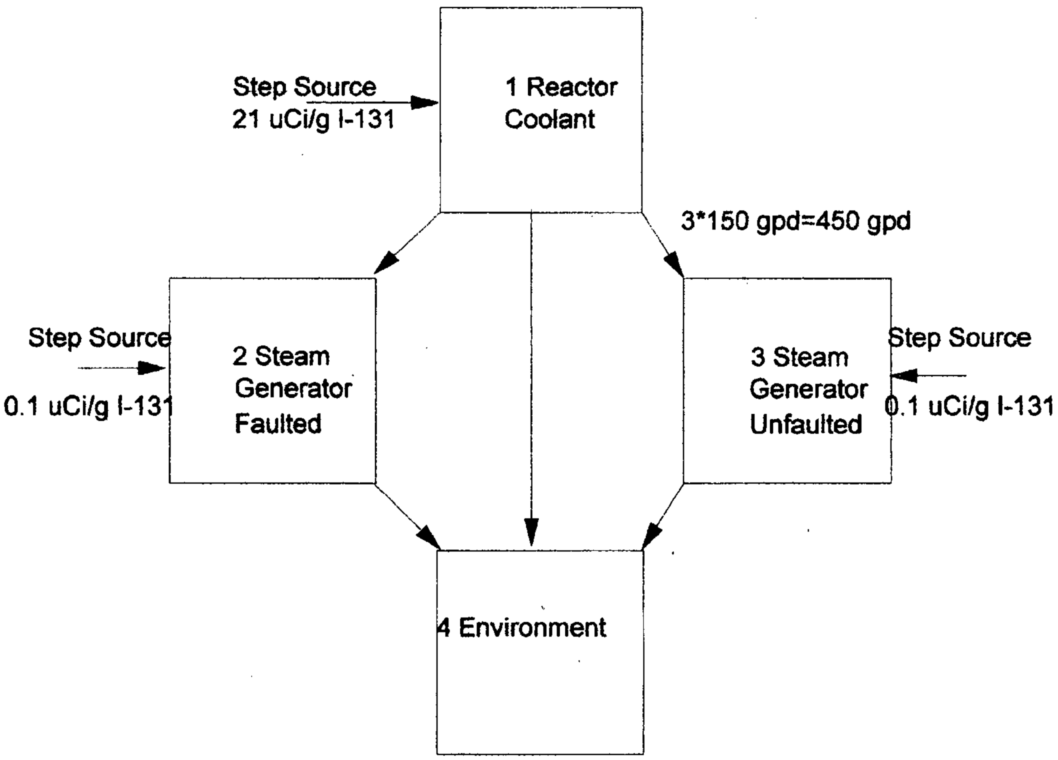
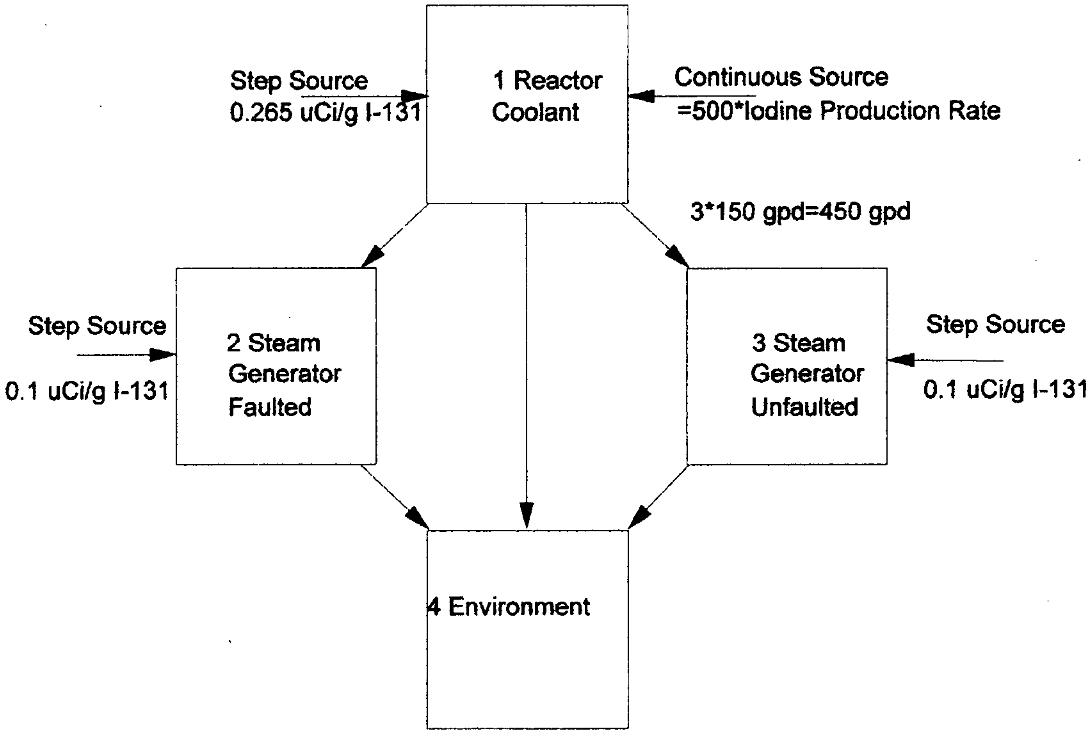


Figure 2: STP Model

Accident Initiated Iodine Spike



Results

The following Unit 1 doses were calculated for the Tritium Production Core (the Unit 2 results are found in Appendix G):

Control room (rem)	21 uCi/g	0.265 uCi/g	Limit
Gamma	8.91E-02	8.14E-02	5
Beta	9.88E-01	9.42E-01	30
Thyroid (ICRP-30)	2.31E+01	2.31E+00	30
TEDE	1.22E+00	5.27E-01	5

Pre-accident iodine spike of 21 uCi/c I-131 equivalent

Offsite (rem)	2 hr EAB	30 day LPZ	limit
Gamma	3.30E-01	8.06E-02	25
Beta	1.92E-01	4.87E-02	300
Thyroid (ICRP-30)	1.25E+01	2.97E+00	300
TEDE	1.14E+00	2.72E-01	25

Accident initiated iodine spike of 500 at 0.265 uCi/g I-131 equivalent

Offsite (rem)	2 hr EAB	30 day LPZ	limit
Gamma	3.58E-01	8.74E-02	25
Beta	1.93E-01	4.92E-02	300
Thyroid (ICRP-30)	3.94E+00	9.64E-01	300
TEDE	7.03E-01	1.71E-01	25

Conclusion

The offsite doses (gamma, beta, thyroid and TEDE) due to a SGTR with a preexisting iodine spike does not exceed the 10CFR100 limits (25 rem gamma, 300 rem beta, and 300 rem thyroid per NUREG-0800). The SGTR with accident initiated iodine spike does not exceed a small fraction of the 10CFR100 limits (10% of the 10CFR100 limits of 25 rem gamma, 300 rem beta, and 300 rem thyroid per NUREG-0800). The control room doses due to a SGTR do not exceed the 10CFR50 App.A GDC 19 limits (5 rem gamma, 30 rem beta and 30 rem thyroid).

The reactor coolant parameters for this conclusion is based on a pre-accident spike of 21 μCi/gm I-131 equivalent and an accident initiated iodine spike with the initial activity at 0.265 μCi/gm I-131 equivalent. The secondary side activity is 0.1 μCi/gm I-131 equivalent. The primary to secondary leak rate (prior to the accident) is 11 gpm (10 gpm identified plus 1 gpm unidentified) with a maximum of 150 gpd leak in the steam generators.

Note on methodologies used:

This calculation determined the doses using 3 different methodologies. The gamma, beta and Thyroid (ICRP-2) doses are all based on TID-14844 methodologies utilizing the ICRP-2 iodine dose conversion factors found in TID-14844. The second methodology is the Thyroid (ICRP-30) dose, which is also based on TID-14844, but uses the ICRP-30 iodine dose conversion factors. The ICRP-30 iodine dose conversion factors are less conservative than the ICRP-2 factors. Finally, the third methodology used is the TEDE (Total Effective Dose Equivalent). The TEDE presents an overall weighted dose and is more representative of the impact of all isotopes on the body as a whole. The TEDE dose is presented for potential future use, however is not currently part of the design basis of the plant. It is important to note that tritium does not impact the thyroid doses utilizing the TID-14844 methodology, because only iodine is applied to the thyroid dose. However, in fact tritium does contribute to the thyroid dose, as well as other organs of the body. This is why the TEDE is a more representative dose when discussing the impact of tritium. It is up to the end user to choose the dose which is to be used, with the understanding that each methodology has a different meaning.

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2b. "Study of Reactor Shutdown Radioactivity 'Spiking' at Three Mile Island Nuclear Power Station During February 20-21, 1976" J.E.Cline and E.D.Barefoot, July 1976
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19. WBN drawing 41N718-1 RE
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21. WBN drawing 47W930-2 RP
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23. WBN drawing 47W930-5 RE
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27. deleted R6
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31. Computer code STP R6, code I.D.262165
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35. N3-30CB-4002 R6 "Control Building Heating, Ventilating, Air Conditioning, and Air Cleanup System"
36. WBN PER 01-000080-000
37. WBNAPS3-104 R0 "WBN Control Room X/Q"
38. 0-RE-90-125 R10 "Demonstrated Accuracy Calculation For Main Control Room Air Intake Radiation Monitor 0-RE-90-125,-126, and Emergency Air Intake Radiation Monitor 0-RE-90-205, -206"

39. N3-62-4001 R5 "System Description for Chemical and Volume Control System"
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48. Unit 2 TS 3.4.13 Rev.A (developmental) "RCS Operational Leakage"
49. Unit 2 TS 3.4.16 Rev.A (developmental) "RCS Specific Activity"
50. Unit 2 TS 3.4.17 Rev.A (developmental) "Steam Generator (SG) Tube Integrity"
51. WBNAPS3-053 R2 "Steam Generator Leakage Detection with the Condenser Vacuum Pump Air Exhaust Monitor (1,2-RM-90-119)" note: this revision is out of date, however the pertinent data, the mass of water in a SG is relevant

Appendix A: Example of STP Model (preaccident Iodine spike)

```
//TSR8S9A JOB 264313,9MBERG.BIN111,MSGLEVEL=1,MSGCLASS=T
//*MAIN ORG=KNXLCL01,CLASS=MB
//JCL JCLLIB ORDER=(APB.NEN.PS264460.PROCLIB)
//    EXEC STP,SOUT='*'
//GO.FT07F001 DD DSN=$KBI988.TSR8S9A.OUT,DISP=(NEW,CATLG,DELETE),
//        SPACE=(TRK,(5,5)),UNIT=ALLOC,
//        DCB= (RECFM=FB,LRECL=80,BLKSIZE=3200)
//GO.SYSIN1 DD *
NV= 4  MS= 2
//GO.SYSIN2 DD *
$    CLASS         DESCRIPTION
$      1               NOBLE GASES
$      2               IODINE
$      3               TRITIUM
NI= 23  NK= 3  NG= 0  NL= 3
   1KRM   83 1 1.0352E-04   10.0            10.0            10.0
   2KRM   85 1 4.2978E-05   10.0            10.0            10.0
   3KR    85 1 2.0470E-09   29.8849E-06     10.0            10.0
   4KR    87 1 1.5141E-04   10.0            10.0            10.0
   5KR    88 1 6.8765E-05   10.0            10.0            10.0
   6KR    89 1 3.6328E-03   10.0            10.0            10.0
   7XEM  131 1 6.7414E-07  131.3039E-08   181.3039E-08    10.0
   8XEM  133 1 3.5656E-06  152.0365E-07   202.0365E-07    10.0
   9XE   133 1 1.5165E-06   83.5656E-06   159.0531E-06   209.0531E-06
  10XEM  135 1 7.3818E-04  174.8062E-06   224.8062E-06    10.0
  11XE   135 1 2.1043E-05  107.3818E-04   172.4322E-05   222.4322E-05
  12XE   138 1 8.1528E-04   10.0            10.0            10.0
  13I    131 2 9.9536E-07   10.0            10.0            10.0
  14I    132 2 8.4448E-05   10.0            10.0            10.0
  15I    133 2 9.2568E-06   10.0            10.0            10.0
  16I    134 2 2.1963E-04   10.0            10.0            10.0
  17I    135 2 2.9129E-05   10.0            10.0            10.0
  18I*   131 2 9.9536E-07   10.0            10.0            10.0
  19I*   132 2 8.4448E-05   10.0            10.0            10.0
  20I*   133 2 9.2568E-06   10.0            10.0            10.0
  21I*   134 2 2.1963E-04   10.0            10.0            10.0
  22I*   135 2 2.9129E-05   10.0            10.0            10.0
  23H      3 3 1.7785E-09   10.0000E+00     10.0000E+00     10.0000E+00
//GO.SYSIN3 DD *
1  'REACTOR COOLANT ANS/ANSI-18.1-1984 UCI/GM, WBNAPS3-003 R3'
 1 0.0 2 1.71E-1 3 2.66E-1 4 1.61E-1 5 3.00E-1 6 0.0
 7 6.54E-1 8 7.17E-2 9 2.53E0  10 1.39E-1 11 9.04E-1 12 1.29E-1
 13 4.77E-2 14 2.25E-1 15 1.49E-1 16 3.64E-1 17 2.78E-1
 18 0.0  19 0.0  20 0.0  21 0.0  22 0.0  23 9.84E1
0
2  'SECONDARY COOL  ANS/ANSI-18.1-1984 UCI/GM, WBNAPS3-003 R3'
 1 0.0 2 3.63E-8 3 5.51E-8 4 3.22E-8 5 6.31E-8 6 0.0
 7 1.34E-7 8 1.54E-8 9 5.25E-7 10 2.90E-8 11 1.91E-7 12 2.68E-8
 13 1.41E-6 14 3.37E-6 15 4.03E-6 16 2.93E-6 17 6.19E-6
 18 0.0  19 0.0  20 0.0  21 0.0  22 0.0  23 9.84E-2
0
T
STEAM GENERATER TUBE RUPTURE ACCIDENT
NJ= 4
1 'REACTOR COOLANT'
2 'STEAM GEN FAULTED'
3 'STM GEN UNFAULTED'
4 'ENVIRONMENT'
-1
INITIAL ACTIVITY
V 1 2.622E8 GM
V 2 5.31E7 GM
V 3 1.593E8 GM
V 4 1.0
S 1 1 3 2.622E2
S 2 2 0 1.665E6
S 2 3 0 4.996E6
S 2 2 3 5.31E1
S 2 3 3 1.593E2
S 1 1 1 7.620E3
S 1 1 2 4.386E4
F 1 2 0 7.0217E7
```

```
F 1 3 0 7.098E4
A 4
176 SEC
TIME TO 176 SEC
196.6 SEC
TIME TO 196.6 SEC
F 1 4 0 1.0486E8
F 2 4 0 2.516E7
F 2 4 2 2.516E5
F 3 4 0 1.254E8
F 3 4 2 1.254E6
N 4 0
P 1 0 4
2208.5 SEC
TIME TO 2208.5 SEC
F 1 2 0 5.423E7
F 1 4 0 5.871E6
4670 SEC
TIME TO 4670 SEC
F 1 4 0 0.0
2 HR
TIME TO 2 HOUR
F 1 2 0 0.0
N 4 0
P 1 0 4
8 HR
TIME TO 8 HOUR
F 2 4 0 2.6837E6
F 2 4 2 2.6837E4
F 3 4 0 6.993E7
F 3 4 2 6.993E5
N 4 0
P 1 0 4
T
T
/*
```

Appendix B: Example of STP Model (Accident Initiated Iodine Spike)

```
//TSR8S9B JOB 264313,9MBERG.BIN111,MSGLEVEL=1,MSGCLASS=T
//*MAIN ORG=KNXLCL01,CLASS=MB
//JCL JCLLIB ORDER=(APB.NEN.PS264460.PROCLIB)
//    EXEC STP,SOUT='*'
//GO.FT07F001 DD DSN=$KBI988.TSR8S9B.OUT,DISP=(NEW,CATLG,DELETE),
//       SPACE=(TRK,(5,5)),UNIT=ALLOC,
//       DCB= (RECFM=FB,LRECL=80,BLKSIZE=3200)
//GO.SYSIN1 DD *
NV= 4  MS= 2
//GO.SYSIN2 DD *
$    CLASS        DESCRIPTION
$      1              NOBLE GASES
$      2              IODINE
$      3              TRITIUM
NI= 23  NK= 7  NG= 0  NL= 3
   1KRM  83 1 1.0352E-04  10.0          10.0          10.0
   2KRM  85 1 4.2978E-05  10.0          10.0          10.0
   3KR   85 1 2.0470E-09  29.8849E-06   10.0          10.0
   4KR   87 1 1.5141E-04  10.0          10.0          10.0
   5KR   88 1 6.8765E-05  10.0          10.0          10.0
   6KR   89 1 3.6328E-03  10.0          10.0          10.0
   7XEM 131 1 6.7414E-07 131.3039E-08  181.3039E-08   10.0
   8XEM 133 1 3.5656E-06 152.0365E-07  202.0365E-07   10.0
   9XE  133 1 1.5165E-06  83.5656E-06  159.0531E-06  209.0531E-06
  10XEM 135 1 7.3818E-04 174.8062E-06  224.8062E-06   10.0
  11XE  135 1 2.1043E-05 107.3818E-04  172.4322E-05  222.4322E-05
  12XE  138 1 8.1528E-04  10.0          10.0          10.0
  13I   131 2 9.9536E-07  10.0          10.0          10.0
  14I   132 4 8.4448E-05  10.0          10.0          10.0
  15I   133 5 9.2568E-06  10.0          10.0          10.0
  16I   134 6 2.1963E-04  10.0          10.0          10.0
  17I   135 7 2.9129E-05  10.0          10.0          10.0
  18I*  131 2 9.9536E-07  10.0          10.0          10.0
  19I*  132 4 8.4448E-05  10.0          10.0          10.0
  20I*  133 5 9.2568E-06  10.0          10.0          10.0
  21I*  134 6 2.1963E-04  10.0          10.0          10.0
  22I*  135 7 2.9129E-05  10.0          10.0          10.0
  23H     3 3 1.7785E-09  10.0000E+00   10.0000E+00   10.0000E+00
//GO.SYSIN3 DD *
1  'REACTOR COOLANT ANS/ANSI-18.1-1984 UCI/GM, WBNAPS3-003 R3'
 1 0.0 2 1.71E-1 3 2.66E-1 4 1.61E-1 5 3.00E-1 6 0.0
 7 6.54E-1 8 7.17E-2 9 2.53E0  10 1.39E-1 11 9.04E-1 12 1.29E-1
 13 4.77E-2 14 2.25E-1 15 1.49E-1 16 3.64E-1 17 2.78E-1
 18 0.0  19 0.0  20 0.0  21 0.0  22 0.0  23 9.84E1
0
2  'SECONDARY COOL  ANS/ANSI-18.1-1984 UCI/GM, WBNAPS3-003 R3'
 1 0.0 2 3.63E-8 3 5.51E-8 4 3.22E-8 5 6.31E-8 6 0.0
 7 1.34E-7 8 1.54E-8 9 5.25E-7 10 2.90E-8 11 1.91E-7 12 2.68E-8
 13 1.41E-6 14 3.37E-6 15 4.03E-6 16 2.93E-6 17 6.19E-6
 18 0.0  19 0.0  20 0.0  21 0.0  22 0.0  23 9.84E-2
0
T
STEAM GENERATER TUBE RUPTURE ACCIDENT
NJ= 4
1 'REACTOR COOLANT'
2 'STEAM GEN FAULTED'
3 'STM GEN UNFAULTED'
4 'ENVIRONMENT'
-1
INITIAL ACTIVITY
V 1 2.622E8 GM
V 2 5.31E7 GM
V 3 1.593E8 GM
V 4 1.0
S 1 1 3 2.622E2
S 2 2 0 1.665E6
S 2 3 0 4.996E6
S 2 2 3 5.31E1
S 2 3 3 1.593E2
S 1 1 1 7.620E3
S 1 1 2 5.534E2 1 1 4 5.534E2 1 1 5 5.534E2 1 1 6 5.534E2 1 1 7 5.534E2
C 1 1 2 3.345E4 1 1 4 1.166E5 1 1 5 4.163E4 1 1 6 2.512E5 1 1 7 6.147E4
```

```
F 1 2 0 7.0217E7
F 1 3 0 7.098E4
A 4
176 SEC
TIME TO 176 SEC
196.6 SEC
TIME TO 196.6 SEC
F 1 4 0 1.0486E8
F 2 4 0 2.516E5
F 2 4 1 2.516E7 2 4 3 2.516E7
F 3 4 0 1.254E6
F 3 4 1 1.254E8 3 4 3 1.254E8
N 4 0
P 1 0 4
2208.5 SEC
TIME TO 2208.5 SEC
F 1 2 0 5.423E7
F 1 4 0 5.871E6
4670 SEC
TIME TO 4670 SEC
F 1 4 0 0.0
2 HR
TIME TO 2 HOUR
F 1 2 0 0.0
N 4 0
P 1 0 4
8 HR
TIME TO 8 HOUR
F 2 4 0 2.6837E4
F 2 4 1 2.6837E6  2 4 3 2.6837E6
F 3 4 0 6.993E5
F 3 4 1 6.993E7  3 4 3 6.993E7
N 4 0
P 1 0 4
T
T
/*
```

Appendix C: Example of COROD Model (ARCON96 X/Q)

```
//TSR8C9A JOB 264360,'9MBERG.BIN111',MSGLEVEL=1,MSGCLASS=T
//*MAIN ORG=KNXLCL01,CLASS=SB
//JCL JCLLIB ORDER=(APB.NEN.EX262358.PROCLIB)
//STEP1 EXEC CORODV6,COND=(4,LT)
//COROD1.FT05F001 DD *
NIT= 23   NR= 1   ITP= 6   FACT= 1.0
COROD-WBN MHA FINAL ABSCE                                              S
KRM 83  KRM 85  KR 85  KR 87  KR 88  KR 89
XEM 131  XEM 133  XE 133  XEM 135  XE 135  XE 138
I 131  I 132  I 133  I 134  I 135
I* 131  I* 132  I* 133  I* 134  I* 135  H 3
   4  'ENVIRONMENT                      ' $ TN=  0.5461E-01
       1 0.0           2 2.963E+00    3 4.646E+00    4 2.734E+00    5 5.174E+00
       6 0.0           7 1.142E+01    8 1.252E+00    9 4.418E+01   10 2.710E+00
      11 1.583E+01    12 1.936E+00   13 4.717E+00   14 2.190E+01   15 1.471E+01
      16 3.455E+01    17 2.734E+01   18 0.0         19 0.0         20 0.0
      21 0.0          22 0.0         23 5.921E+01
   4  'ENVIRONMENT                      ' $ TN=  0.2000E+01
       1 0.0           2 1.360E+02    3 2.500E+02    4 8.656E+01    5 2.166E+02
       6 0.0           7 6.129E+02    8 6.672E+01    9 2.369E+03   10 2.633E+02
      11 9.076E+02    12 1.385E+01   13 2.748E+01   14 1.140E+02   15 8.468E+01
      16 1.534E+02    17 1.531E+02   18 0.0         19 0.0         20 0.0
      21 0.0          22 0.0         23 3.194E+03
   4  'ENVIRONMENT                      ' $ TN=  0.8000E+01
       1 0.0           2 2.125E+01    3 6.768E+01    4 4.318E+00    5 2.504E+01
       6 0.0           7 1.645E+02    8 1.763E+01    9 6.367E+02   10 9.654E+01
      11 3.241E+02    12 5.927E-03   13 1.694E+00   14 1.917E+00   15 4.524E+00
      16 5.152E-01    17 5.877E+00   18 0.0         19 0.0         20 0.0
       21 0.0          22 0.0         23 8.644E+02
   -6  'ENVIRONMENT         CURIES       ' $ TN=  0.2400E+02
       1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
       6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
      11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
      16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
      21 0.000E+00   22 0.000E+00   23 0.000E+00
   -6  'ENVIRONMENT         CURIES       ' $ TN=  0.9600E+02
       1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
       6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
      11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
      16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
      21 0.000E+00   22 0.000E+00   23 0.000E+00
   -6  'ENVIRONMENT         CURIES       ' $ TN=  0.7200E+03
       1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
       6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
      11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
      16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
      21 0.000E+00   22 0.000E+00   23 0.000E+00
4.03E-03  4.03E-03  3.35E-03  2.27E-04  1.81E-04  1.45E-04
20.6  7179.4  21600.0  57600.0  259200.0  2246400.0
3200.0 51.0
711.0  51.0
711.0  51.0
711.0  51.0
711.0  51.0
711.0  51.0
0.0  0.0  0.0  0.0  0.0  0.0  3200.0
0.95  0.70  0.95  0.70  0.99  0.0  2889.0
0.95  0.70  0.95  0.70  0.99  0.0  2889.0
0.95  0.70  0.95  0.70  0.99  0.0  2889.0
0.95  0.70  0.95  0.70  0.99  0.0  2889.0
0.95  0.70  0.95  0.70  0.99  0.0  2889.0
100.0  60.0  40.0  1440.0  5760.0 257198.0
1.2492 0.63  0.8352
322.0 45.0 17.75 46.0 9.0 4.0 161.0 22.5 4.0 0.0
ROOFFLUX DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE THROUGH ROOF
1000.0 1000.0 1000.0  20.0  20.0 20.0  500.0  500.0  -16.0  2.25
ADJACENT DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE FROM AUX BUILDING
270.0 150.0 148.0 27.0 15.0 14.0 135.0 75.0 -25.5  3.0
ADJACENT DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE FROM TURBINE BLDG
322.0  112.0  341.0  32.0 11.0 34.0  161.0  56.0  -25.5  3.0
ADJACENT DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE FROM SPREADING ROOM
```

```
322.0  45.0  26.0 32.0 9.0 5.0  22.5  161.0  -4.67  0.67
ADJACENT DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE FROM CR BLDG END
18.0 45.0 460.0 10.0 10.0 100.0 4.0 22.5 -25.5 3.0
ADJACENT DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE FROM CR BLDG END
18.0 45.0 460.0 10.0 10.0 100.0 4.0 22.5 -25.5 3.0
/*
//
```

Appendix D: Example of FENCDOSE Model

```
//TSR8F9A JOB 264360,'9MBERG.BIN111',MSGLEVEL=1,MSGCLASS=T
//*MAIN ORG=KNXLCL01,CLASS=SB
//JCL JCLLIB ORDER=(APB.NEN.EX262358.PROCLIB)
//STEP1 EXEC FNCDOSV4,COND=(4,LT)
//FNCDOS1.FT05F001 DD *
1
KRM-83  KRM-85  KR-85
KR-87   KR-88   KR-89
XEM-131 XEM-133 XE-133 XEM-135 XE-135 XE-138
I-131   I-132   I-133  I-134   I-135
I*-131  I*-132  I*-133 I*-134  I*-135  H-3
T
.141E-3  .668E-4  .459E-4  .204E-4  .635E-5  6.07E-4
STEAM GENERATER TUBE RUPTURE ACCIDENT
TIME TO 196.6 SEC
    4  'ENVIRONMENT                     ' $ TN=  0.5461E-01
         1 0.0          2 2.963E+00    3 4.646E+00    4 2.734E+00    5 5.174E+00
         6 0.0          7 1.142E+01    8 1.252E+00    9 4.418E+01   10 2.710E+00
        11 1.583E+01   12 1.936E+00   13 4.717E+00   14 2.190E+01   15 1.471E+01
        16 3.455E+01   17 2.734E+01   18 0.0         19 0.0         20 0.0
        21 0.0         22 0.0         23 5.921E+01
STEAM GENERATER TUBE RUPTURE ACCIDENT
TIME TO 2 HOUR
    4  'ENVIRONMENT                     ' $ TN=  0.2000E+01
         1 0.0          2 1.360E+02    3 2.500E+02    4 8.656E+01    5 2.166E+02
         6 0.0          7 6.129E+02    8 6.672E+01    9 2.369E+03   10 2.633E+02
        11 9.076E+02   12 1.385E+01   13 2.748E+01   14 1.140E+02   15 8.468E+01
        16 1.534E+02   17 1.531E+02   18 0.0         19 0.0         20 0.0
        21 0.0         22 0.0         23 3.194E+03
STEAM GENERATER TUBE RUPTURE ACCIDENT
TIME TO 8 HOUR
    4  'ENVIRONMENT                     ' $ TN=  0.8000E+01
         1 0.0          2 2.125E+01    3 6.768E+01    4 4.318E+00    5 2.504E+01
         6 0.0          7 1.645E+02    8 1.763E+01    9 6.367E+02   10 9.654E+01
        11 3.241E+02   12 5.927E-03   13 1.694E+00   14 1.917E+00   15 4.524E+00
        16 5.152E-01   17 5.877E+00   18 0.0         19 0.0         20 0.0
        21 0.0         22 0.0         23 8.644E+02
WBN SGTR
TIME TO 1 DAY
   -6  'ENVIRONMENT        CURIES       ' $ TN=  0.2400E+02
         1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
         6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
        11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
        16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
        21 0.000E+00   22 0.000E+00   23 0.000E+00
WBN SGTR
TIME TO 4 DAYS
   -6  'ENVIRONMENT        CURIES       ' $ TN=  0.9600E+02
         1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
         6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
        11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
        16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
        21 0.000E+00   22 0.000E+00   23 0.000E+00
WBN SGTR
TIME TO 30 DAYS
   -6  'ENVIRONMENT        CURIES       ' $ TN=  0.7200E+03
         1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
         6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
        11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
        16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
        21 0.000E+00   22 0.000E+00   23 0.000E+00
```

Appendix E: Determination of Letdown Flow Uncertainty

The purpose of this appendix is to determine bounding errors for the measurements performed on the orifice restrictor flows using the Letdown Heat Exchanger Flow loop (1-F-62-82) during Preop Test Instruction PTI-062-03 R0.

Following these tests, a loop check was performed for the computer point F0134A by injecting a signal into the transmitter and reading the display on the computer. To determine the total loop error, the unmeasurable errors must be combined with the errors present at the time of the loop check.

WBN NESSD 1-F-62-1 will be used as a guide for determining the unmeasurable errors for loop 1-F-62-82 since it contains the same model flow element and a similar model transmitter. According to EMPAC, the flow element is a Vickery Simms Model MK-52 and the transmitter is a Foxboro E-13DM.

Millers Flow Measurement Engineering Handbook, Third Edition, Chapter 6, Table 6.1 states that Square Edged orifice flowmeters have an accuracy of ±1-2%URV (upper range value) of the flow rate. A value of ±2% will be used for the orifice.

The loop check performed by WO 94-14264-10 (following pages) gives as found data. The largest error at 50 GPM was 1.36 GPM (50 - 48.64) or 0.68% CS (1.36/200 = 0.68%). The largest error at 100 GPM was 0.48 GPM (100 - 99.52) or 0.24% CS (0.48/200 = 0.24%). The largest error at 150 GPM was 0.06 GPM (150 - 149.94) or 0.03% CS (0.06/200 = 0.03%).

Since the plant had not been started at the time of these tests, radiation was not present and need not be considered. Errors for temperature and power supply effect will need to be included. Since there is no data on actual temperature conditions, an enveloping value must be used. Environmental drawing 47E235-46 R5 gives the max abnormal temperature range as 50 - 110 °F for coordinates UA6 / El 737 where the transmitter is located per EMPAC. The transmitter is a model E-13DM per EMPAC. The product specification sheets (following pages) give the ambient temperature effect as ±1% per 50 °F for any span between 200 to 850" water. The transmitter will normally be calibrated at room temperature which will be between 60 and 80 °F. A temperature shift of + or - 50 °F will encompass the temperature changes seen by the transmitter. Therefore for a temperature range of ±50 °F, the temperature effect will be ±1% CS d/p. The power supply effect is given as 0.1% CS for a 10% change in voltage. Thus Power supply effect is 0.1% CS d/p.

All errors for the computer should be reflected in the loop check.

Utilizing Equation 3-24.8 of W WCAP-12096, Rev. 8 "Westinghouse Setpoint Methodology for Protection Systems, Watts Bar Units 1 and 2, Eagle 21 Version," the unmeasured transmitter errors can be converted from percent error in full scale d/p to error in percent full span at a specified point, where Fm is the maximum flow rate of 200 GPM, and Fn is the nominal flow rate (i.e. 50, 100 or 150 GPM).

EPFS (Flow) = $(Ax_{XX} / 2) * (Fm / Fn)$
$Temp_{err}$(Flow)@50GPM = $(Temp_{err}$ (d/p) / 2) * (200 / 50) = ± 2% CS Flow
$Temp_{err}$(Flow)@100GPM = $(Temp_{err}$ (d/p) / 2) * (200 / 100) = ± 1% CS Flow
$Temp_{err}$(Flow)@150GPM = $(Temp_{err}$ (d/p) / 2) * (200 / 150) = ± 0.67% CS Flow

pwr $supp_{err}$(Flow)@50GPM = (pwr $supp_{err}$ (d/p) / 2) * (200 / 50) = ± 0.2% CS Flow
pwr $supp_{err}$(Flow)@100GPM = (pwr $supp_{err}$ (d/p) / 2) * (200 / 100) = ± 0.1% CS Flow
pwr $supp_{err}$(Flow)@150GPM = (pwr $supp_{err}$ (d/p) / 2) * (200 / 150) = ± 0.067% CS Flow

Thus total loop error = $(FE_{err}{}^2 + \text{Loop check}_{err}{}^2 + Temp_{err}\text{(Flow)}^2 + \text{pwr } supp_{err}\text{(Flow)}^2)^{0.5}$
Total loop error @ 50 GPM = $(2^2 + 0.68^2 + 2^2 + 0.2^2)^{0.5} = \pm 2.92\%$ CS = ±5.84 GPM
Total loop error @ 100 GPM = $(2^2 + 0.24^2 + 1^2 + 0.1^2)^{0.5} = \pm 2.25\%$ CS = ±4.5 GPM
Total loop error @ 150 GPM = $(2^2 + 0.03^2 + 0.67^2 + 0.067^2)^{0.5} = \pm 2.11\%$ CS = ±4.22 GPM

Total loop error at 120 GPM can be determined by linear interpolation between 100 and 150 GPM. The value will be conservative since the error is nonlinear and is a function of the square root of the d/p values above and the actual loop recorded values which also follow a square root curve.

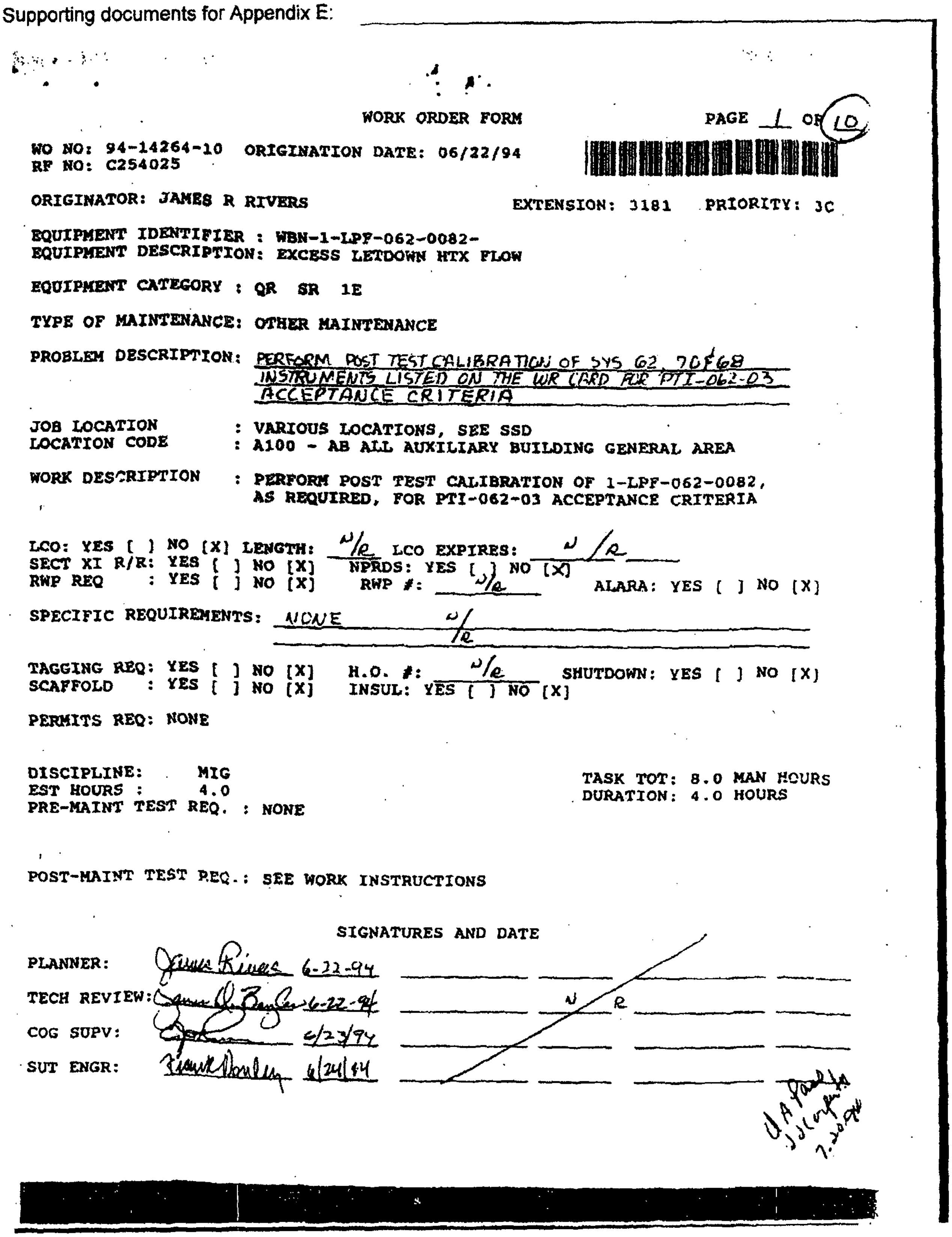
Total loop error @ 120 GPM = ±| error @ 100 GPM + 20(error @ 150 GPM - error @ 100 GPM) / (150 - 100) |
Total loop error @ 120 GPM = ±[4.5 GPM + 20(4.22 - 4.5)/50] = ±[4.5 GPM + (-0.11)] = ±4.39 GPM

The following references were used in preparation of this appendix. Revisions to these references will not impact this appendix; so the references are 'information only' in lieu of 'design input'.

1 WBN NESSD 1-F-62-1 R1 (Methodology & guidance)
2 EMPAC (Manufacturer, Model number and location)
3 Millers Flow Engineering Handbook, Third Edition, Chapter 6, Table 6.1 (Orifice accuracy)
4 WO 94-14264-10 (loop check data) - see next page
5 Drawing 47E235-46 R5 (environmental data)
6 Foxboro product specification sheets (transmitter accuracy data) - see next pages
7 WCAP-12096 R 8 (methodology for converting d/p error to flow error)

Prepared Lynn Cowan Date 6/4/01
Checked D.L.Kirby Date 6-28-01 . (original signed in R8)

Supporting documents for Appendix E:



WORK ORDER FORM

PAGE 1 OF 10

WO NO: 94-14264-10 ORIGINATION DATE: 06/22/94
RF NO: C254025

ORIGINATOR: JAMES R RIVERS EXTENSION: 3181 PRIORITY: 3C

EQUIPMENT IDENTIFIER : WBN-1-LPF-062-0082-
EQUIPMENT DESCRIPTION: EXCESS LETDOWN HTX FLOW

EQUIPMENT CATEGORY : QR SR 1E

TYPE OF MAINTENANCE: OTHER MAINTENANCE

PROBLEM DESCRIPTION: PERFORM POST TEST CALIBRATION OF SYS 62, 70 & 68 INSTRUMENTS LISTED ON THE WR CARD FOR PTI-062-03 ACCEPTANCE CRITERIA

JOB LOCATION : VARIOUS LOCATIONS, SEE SSD
LOCATION CODE : A100 - AB ALL AUXILIARY BUILDING GENERAL AREA

WORK DESCRIPTION : PERFORM POST TEST CALIBRATION OF 1-LPF-062-0082, AS REQUIRED, FOR PTI-062-03 ACCEPTANCE CRITERIA

LCO: YES [ ] NO [X] LENGTH: N/R LCO EXPIRES: N/R
SECT XI R/R: YES [ ] NO [X] NPRDS: YES [ ] NO [X]
RWP REQ : YES [ ] NO [X] RWP #: N/R ALARA: YES [ ] NO [X]

SPECIFIC REQUIREMENTS: NONE N/R

TAGGING REQ: YES [ ] NO [X] H.O. #: N/R SHUTDOWN: YES [ ] NO [X]
SCAFFOLD : YES [ ] NO [X] INSUL: YES [ ] NO [X]

PERMITS REQ: NONE

DISCIPLINE: MIG
EST HOURS : 4.0
PRE-MAINT TEST REQ. : NONE

TASK TOT: 8.0 MAN HOURS
DURATION: 4.0 HOURS

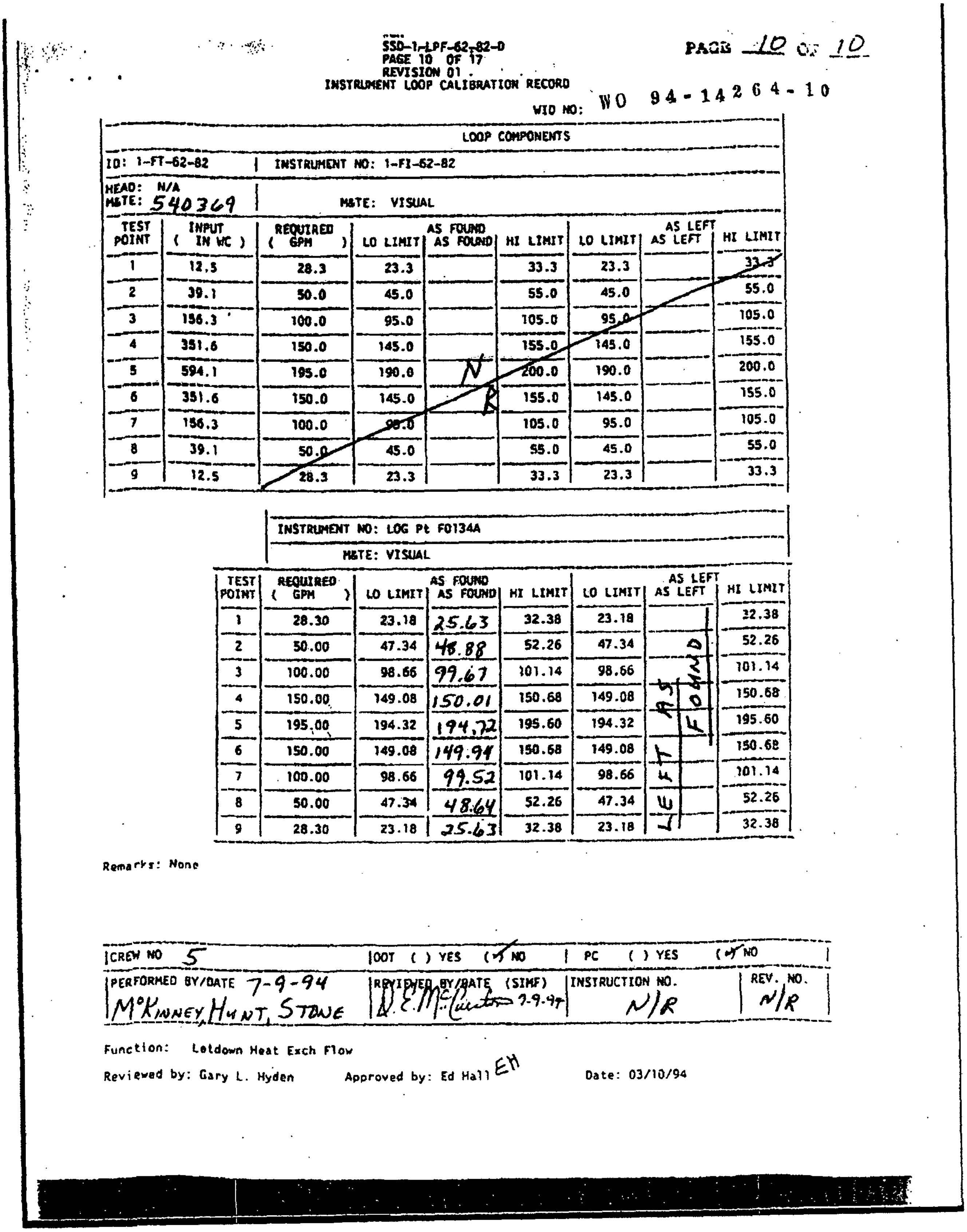
POST-MAINT TEST REQ.: SEE WORK INSTRUCTIONS

SIGNATURES AND DATE

PLANNER: James Rivers 6-22-94
TECH REVIEW: 6-22-94 N/R
COG SUPV: 6/23/94
SUT ENGR: 6/24/94

7-20-94

[redacted]



SSD-1-LPF-62-82-D
PAGE 10 OF 17
REVISION 01
INSTRUMENT LOOP CALIBRATION RECORD

PAGE 10 OF 10

WID NO: WO 94-14264-10

LOOP COMPONENTS

ID: 1-FT-62-82 | INSTRUMENT NO: 1-FI-62-82

HEAD: N/A
M&TE: 540369 | M&TE: VISUAL

TEST POINT	INPUT (IN WC)	REQUIRED (GPM)	AS FOUND LO LIMIT	AS FOUND	HI LIMIT	AS LEFT LO LIMIT	AS LEFT	HI LIMIT
1	12.5	28.3	23.3		33.3	23.3		33.3
2	39.1	50.0	45.0		55.0	45.0		55.0
3	156.3	100.0	95.0		105.0	95.0		105.0
4	351.6	150.0	145.0		155.0	145.0		155.0
5	594.1	195.0	190.0	N	200.0	190.0		200.0
6	351.6	150.0	145.0	R	155.0	145.0		155.0
7	156.3	100.0	95.0		105.0	95.0		105.0
8	39.1	50.0	45.0		55.0	45.0		55.0
9	12.5	28.3	23.3		33.3	23.3		33.3

INSTRUMENT NO: LOG Pt F0134A

M&TE: VISUAL

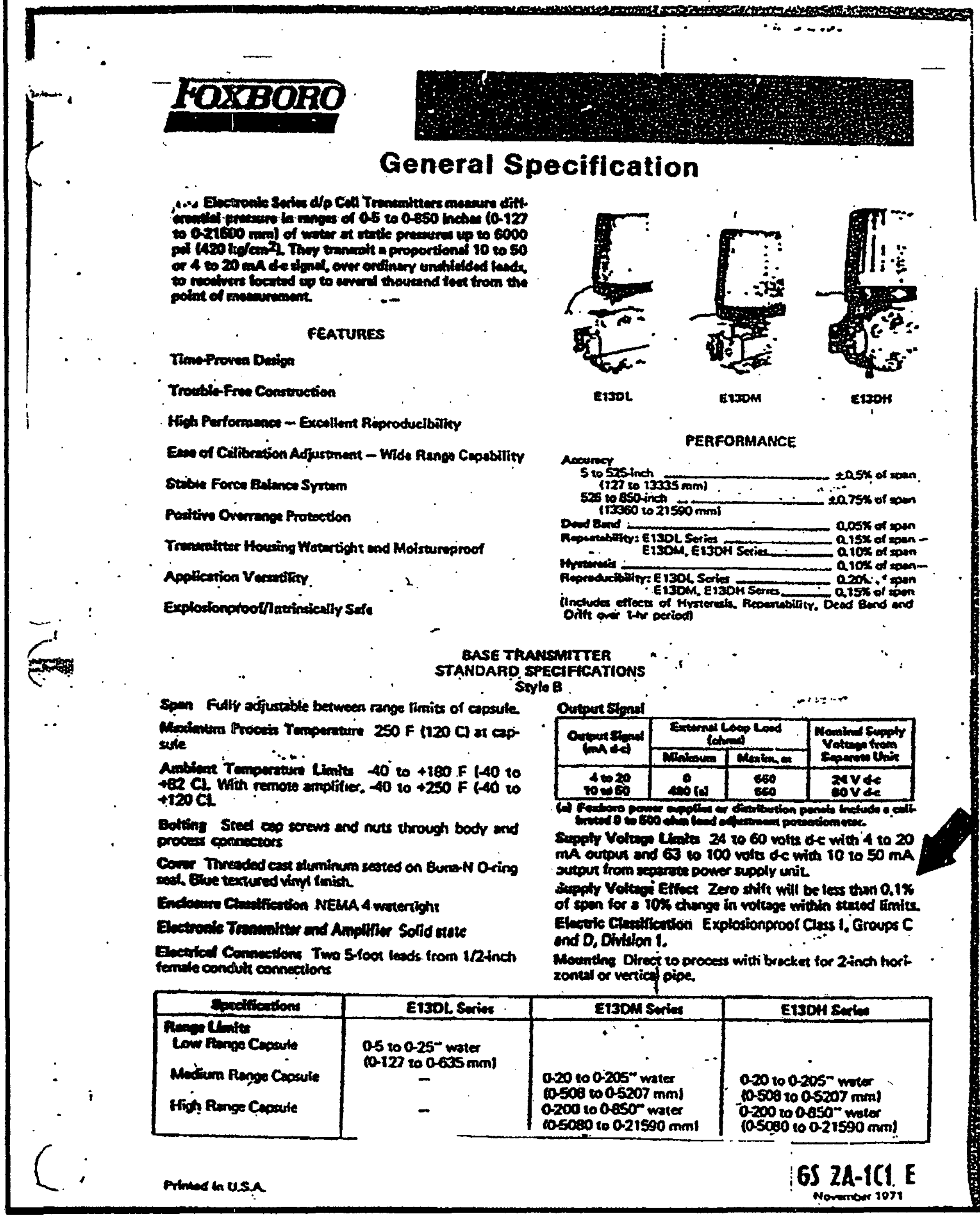
TEST POINT	REQUIRED (GPM)	AS FOUND LO LIMIT	AS FOUND	HI LIMIT	AS LEFT LO LIMIT	AS LEFT	HI LIMIT
1	28.30	23.18	25.63	32.38	23.18	LEFT AS FOUND	32.38
2	50.00	47.34	48.88	52.26	47.34		52.26
3	100.00	98.66	99.67	101.14	98.66		101.14
4	150.00	149.08	150.01	150.68	149.08		150.68
5	195.00	194.32	194.72	195.60	194.32		195.60
6	150.00	149.08	149.94	150.68	149.08		150.68
7	100.00	98.66	99.52	101.14	98.66		101.14
8	50.00	47.34	48.64	52.26	47.34		52.26
9	28.30	23.18	25.63	32.38	23.18		32.38

Remarks: None

CREW NO 5	OOT ( ) YES [✓ NO]	PC ( ) YES [✓ NO]	
PERFORMED BY/DATE 7-9-94 McKinney, Hunt, Stone	REVIEWED BY/DATE (SIMF) D.E. McClinton 7-9-94	INSTRUCTION NO. N/R	REV. NO. N/R

Function: Letdown Heat Exch Flow

Reviewed by: Gary L. Hyden Approved by: Ed Hall EH Date: 03/10/94



FOXBORO

General Specification

... Electronic Series d/p Cell Transmitters measure differential pressure in ranges of 0-5 to 0-850 inches (0-127 to 0-21600 mm) of water at static pressures up to 6000 psi (420 kg/cm²). They transmit a proportional 10 to 50 or 4 to 20 mA d-c signal, over ordinary unshielded leads, to receivers located up to several thousand feet from the point of measurement.

E13DL E13DM E13DH

FEATURES

Time-Proven Design

Trouble-Free Construction

High Performance — Excellent Reproducibility

Ease of Calibration Adjustment — Wide Range Capability

Stable Force Balance System

Positive Overrange Protection

Transmitter Housing Watertight and Moistureproof

Application Versatility

Explosionproof/Intrinsically Safe

PERFORMANCE

Accuracy	
5 to 525-inch (127 to 13335 mm)	±0.5% of span
526 to 850-inch (13360 to 21590 mm)	±0.75% of span
Dead Band	0.05% of span
Repeatability: E13DL Series	0.15% of span
E13DM, E13DH Series	0.10% of span
Hysteresis	0.10% of span
Reproducibility: E13DL Series	0.20% of span
E13DM, E13DH Series	0.15% of span

(Includes effects of Hysteresis, Repeatability, Dead Band and Drift over 1-hr period)

BASE TRANSMITTER STANDARD SPECIFICATIONS
Style B

Span Fully adjustable between range limits of capsule.

Maximum Process Temperature 250 F (120 C) at capsule

Ambient Temperature Limits -40 to +180 F (-40 to +82 C). With remote amplifier, -40 to +250 F (-40 to +120 C).

Bolting Steel cap screws and nuts through body and process connectors

Cover Threaded cast aluminum seated on Buna-N O-ring seal. Blue textured vinyl finish.

Enclosure Classification NEMA 4 watertight

Electronic Transmitter and Amplifier Solid state

Electrical Connections Two 5-foot leads from 1/2-inch female conduit connections

Output Signal

Output Signal (mA d-c)	External Loop Load (ohms)		Nominal Supply Voltage from Separate Unit
	Minimum	Maximum	
4 to 20	0	660	24 V d-c
10 to 50	480 (a)	660	60 V d-c

(a) Foxboro power supplies or distribution panels include a calibrated 0 to 500 ohm load adjustment potentiometer.

Supply Voltage Limits 24 to 60 volts d-c with 4 to 20 mA output and 63 to 100 volts d-c with 10 to 50 mA output from separate power supply unit.

Supply Voltage Effect Zero shift will be less than 0.1% of span for a 10% change in voltage within stated limits.

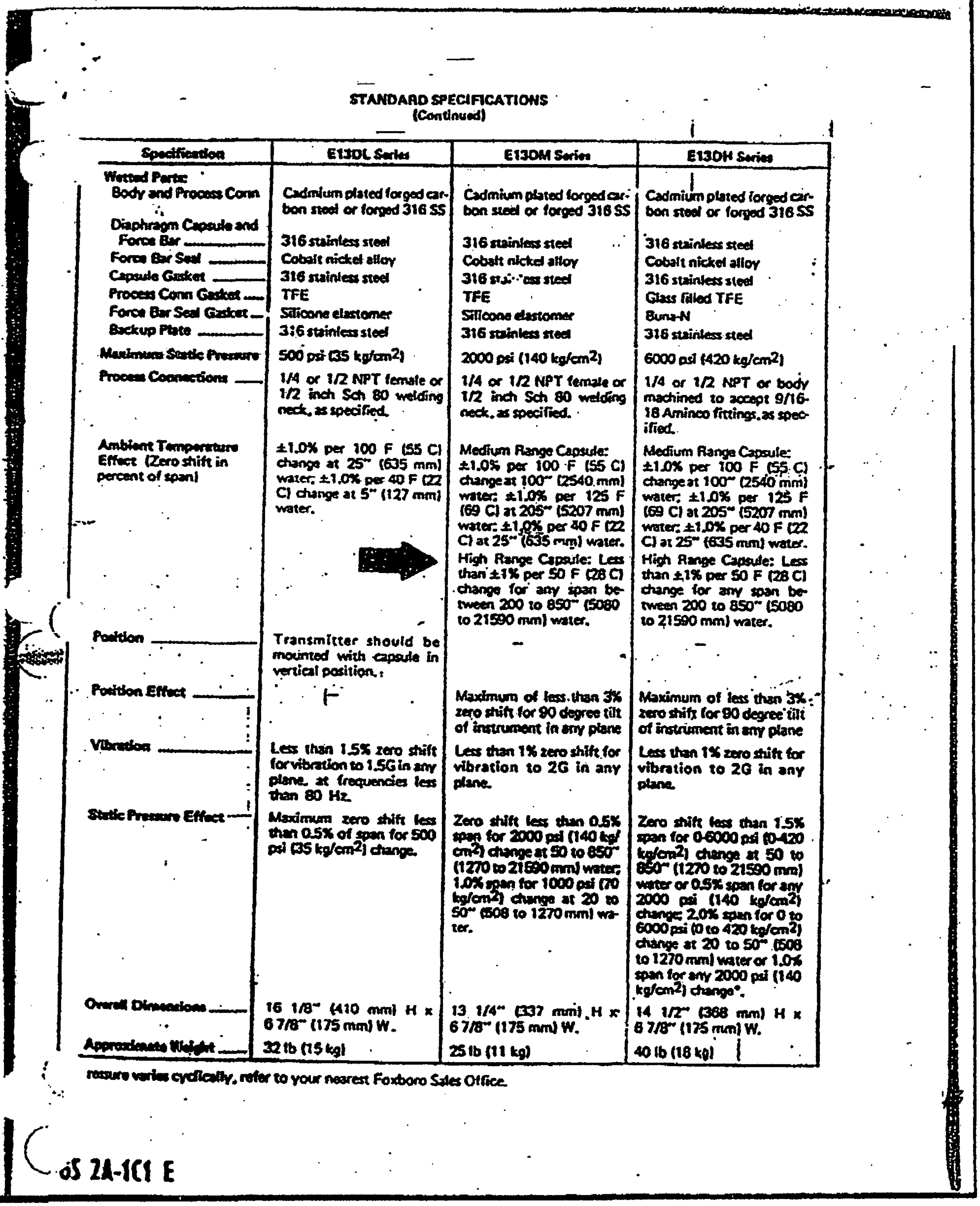
Electric Classification Explosionproof Class I, Groups C and D, Division 1.

Mounting Direct to process with bracket for 2-inch horizontal or vertical pipe.

Specifications	E13DL Series	E13DM Series	E13DH Series
Range Limits			
Low Range Capsule	0-5 to 0-25" water (0-127 to 0-635 mm)		
Medium Range Capsule	—	0-20 to 0-205" water (0-508 to 0-5207 mm)	0-20 to 0-205" water (0-508 to 0-5207 mm)
High Range Capsule	—	0-200 to 0-850" water (0-5080 to 0-21590 mm)	0-200 to 0-850" water (0-5080 to 0-21590 mm)

RB

Printed in U.S.A.



STANDARD SPECIFICATIONS
(Continued)

Specification	E13DL Series	E13DM Series	E13DH Series
Wetted Parts:			
Body and Process Conn	Cadmium plated forged carbon steel or forged 316 SS	Cadmium plated forged carbon steel or forged 316 SS	Cadmium plated forged carbon steel or forged 316 SS
Diaphragm Capsule and Force Bar	316 stainless steel	316 stainless steel	316 stainless steel
Force Bar Seal	Cobalt nickel alloy	Cobalt nickel alloy	Cobalt nickel alloy
Capsule Gasket	316 stainless steel	316 stainless steel	316 stainless steel
Process Conn Gasket	TFE	TFE	Glass filled TFE
Force Bar Seal Gasket	Silicone elastomer	Silicone elastomer	Buna-N
Backup Plate	316 stainless steel	316 stainless steel	316 stainless steel
Maximum Static Pressure	500 psi (35 kg/cm^2)	2000 psi (140 kg/cm^2)	6000 psi (420 kg/cm^2)
Process Connections	1/4 or 1/2 NPT female or 1/2 inch Sch 80 welding neck, as specified.	1/4 or 1/2 NPT female or 1/2 inch Sch 80 welding neck, as specified.	1/4 or 1/2 NPT or body machined to accept 9/16-18 Aminco fittings, as specified.
Ambient Temperature Effect (Zero shift in percent of span)	±1.0% per 100 F (55 C) change at 25" (635 mm) water; ±1.0% per 40 F (22 C) change at 5" (127 mm) water. ➡	Medium Range Capsule: ±1.0% per 100 F (55 C) change at 100" (2540 mm) water; ±1.0% per 125 F (69 C) at 205" (5207 mm) water; ±1.0% per 40 F (22 C) at 25" (635 mm) water. High Range Capsule: Less than ±1% per 50 F (28 C) change for any span between 200 to 850" (5080 to 21590 mm) water.	Medium Range Capsule: ±1.0% per 100 F (55 C) change at 100" (2540 mm) water; ±1.0% per 125 F (69 C) at 205" (5207 mm) water; ±1.0% per 40 F (22 C) at 25" (635 mm) water. High Range Capsule: Less than ±1% per 50 F (28 C) change for any span between 200 to 850" (5080 to 21590 mm) water.
Position	Transmitter should be mounted with capsule in vertical position.	—	—
Position Effect	—	Maximum of less than 3% zero shift for 90 degree tilt of instrument in any plane	Maximum of less than 3% zero shift for 90 degree tilt of instrument in any plane
Vibration	Less than 1.5% zero shift for vibration to 1.5G in any plane, at frequencies less than 80 Hz.	Less than 1% zero shift for vibration to 2G in any plane.	Less than 1% zero shift for vibration to 2G in any plane.
Static Pressure Effect	Maximum zero shift less than 0.5% of span for 500 psi (35 kg/cm^2) change.	Zero shift less than 0.5% span for 2000 psi (140 kg/cm^2) change at 50 to 850" (1270 to 21590 mm) water; 1.0% span for 1000 psi (70 kg/cm^2) change at 20 to 50" (508 to 1270 mm) water.	Zero shift less than 1.5% span for 0-6000 psi (0-420 kg/cm^2) change at 50 to 850" (1270 to 21590 mm) water or 0.5% span for any 2000 psi (140 kg/cm^2) change; 2.0% span for 0 to 6000 psi (0 to 420 kg/cm^2) change at 20 to 50" (508 to 1270 mm) water or 1.0% span for any 2000 psi (140 kg/cm^2) change*.
Overall Dimensions	16 1/8" (410 mm) H x 6 7/8" (175 mm) W.	13 1/4" (337 mm) H x 6 7/8" (175 mm) W.	14 1/2" (368 mm) H x 6 7/8" (175 mm) W.
Approximate Weight	32 lb (15 kg)	25 lb (11 kg)	40 lb (18 kg)

ressure varies cyclically, refer to your nearest Foxboro Sales Office.

Appendix F: Original Steam Generator Results

The following results are for the original steam generators. The details leading to these results are found in revision 8. The COROD runs were corrected (recirculation rate and time increments). A 2 CREVS case was also added. Only the ARCON96 21 µCi/gm and 0.265 µCi/gm I-131 equivalent Iodine spiking cases were corrected.

Tritium Production Core Doses:

Offsite Dose with Preaccident Iodine Spike

	21 µCi/gm I spike		
	2hr EAB	30day LPZ	limit
Gamma	3.587E-01	8.755E-02	25
Beta	2.121E-01	5.387E-02	300
Thyroid (ICRP-2)	2.714E+01	6.438E+00	300
Thyroid (ICRP-30)	1.324E+01	3.150E+00	300
TEDE	1.215E+00	2.906E-01	25

Offsite Dose with Accident Initiated Iodine Spike - 11 gpm leak (10+1unidentified.)

	0.265 µCi/gm, 500 I spike		
	2hr EAB	30day LPZ	limit
Gamma	5.181E-01	1.306E-01	2.5
Beta	2.514E-01	6.655E-02	30
Thyroid (ICRP-2)	1.956E+01	4.724E+00	30
Thyroid (ICRP-30)	6.375E+00	1.554E+00	30
TEDE	1.204E+00	2.945E-01	2.5

Offsite Dose with Accident Initiated Iodine Spike - 6.75 gpm leak (5.75+1unidentified.)

	0.265 µCi/gm, 500 I spike		
	2hr EAB	30day LPZ	limit
Gamma	5.162E-01	1.301E-01	2.5
Beta	2.510E-01	6.642E-02	30
Thyroid (ICRP-2)	1.934E+01	4.670E+00	30
Thyroid (ICRP-30)	6.265E+00	1.527E+00	30
TEDE	1.195E+00	2.923E-01	2.5

Offsite Dose with Accident Initiated Iodine Spike - 3.15 gpm leak (2.15+1unidentified.)

	0.265 µCi/gm, 500 I spike		
	2hr EAB	30day LPZ	limit
Gamma	5.147E-01	1.298E-01	2.5
Beta	2.505E-01	6.631E-02	30
Thyroid (ICRP-2)	1.915E+01	4.624E+00	30
Thyroid (ICRP-30)	6.172E+00	1.505E+00	30
TEDE	1.188E+00	2.905E-01	2.5

Appendix F: Original Steam Generator Results (continued)

TPC Control Room/ARCON96 X/Q original SG

preaccident I spike 21 uCi/gm

	1 CREVS	2 CREVS	limit
Gamma	9.400E-02	1.397E-01	5
Beta	1.064E+00	1.611E+00	30
Thyroid (ICRP-30)	1.706E+01	1.534E+01	30
TEDE	1.057E+00	1.265E+00	5

accident intiated 500 I spike 0.265 uCi/gm

steady state leak =11 gpm (=10+1 unident)

Control Room	1 CREVS	2 CREVS	limit
Gamma	9.818E-02	1.471E-01	5
Beta	1.192E+00	1.779E+00	30
Thyroid (ICRP-30)	2.471E+00	2.537E+00	30
TEDE	5.886E-01	8.543E-01	5

Appendix G: Unit 2 SGTR

The Unit 2 steam generators are the same as the original Unit 1 steam generators. However, the mass releases were reanalyzed by Westinghouse. The SGTR analyses performed below use the same methodologies as the main text, with the following changes:

Flow Rates:

The following is for the Unit 2 steam generators. The amount of secondary side steam released from the ruptured steam generator is 103,300 lbm from 0-2 hours and 32,800 lbm from 2-8 hours (ref.47). The amount of secondary side steam released from the intact steam generators is 492,100 lbm from 0-2 hours and 900,200 lbm from 2-8 hours. The reactor coolant release to the steam generator was a total of 191,400 lb, of which 10077.2 (=934.4+9142.8) lb flashed (ref.47). In order to account for the release during the 20.6 second interval when the control room is not isolated, the amount of reactor coolant released at 20.6 sec is needed. However, the release from the steam generators does not actually start until 113 sec post accident. Therefore, the releases at 113+ 20.6 = 133.6 sec are actually needed for release calculations. Using the releases from reference 47 and adding each time increment release, the reactor coolant release at 134.5 sec is 9687.2 lb. The amount that flashed at 134.5 sec is 1049.026 lb. The mass release rate from the ruptured steam generator is non-linear. However since the time frame for the release is short (20.6 sec), the average release rate can be used. From reference 47, the flashing of the reactor coolant stops at 2253 sec, and the break flow stops at 5032 sec.

The following flow rates/leakage rates for each component are:

Flow from Reactor Coolant #1 to Steam Generator Faulted #2 (non-flashed):
    0-133.6 sec: F = (9687.2 lb – 1049.026 lb)*(3600 sec/hr)/(133.6 sec) = 2.328E5 lb/hr = 1.0558E8 g/hr
    133.6 sec-5032 sec: F = (191,400 lb-9687.2 lb)-(10077.2 lb-1049.026 lb)/(5032-133.6sec) = 35.253 lb/sec = =5.757E7 g/hr
    5032+ sec: F=0
Flow from Reactor Coolant #1 to Environment #4 (flashed):
    113-133.6 sec: F = (1049.026 lb)*(3600 sec/hr)/(20.6 sec) = 1.833E5 lb/hr = 8.3154E7 g/hr
    133.6 sec-2253 sec: F = (10077.2 lb-1049.026 lb)/(2253-20.6 sec]) = 4.0442 lb/sec = 6.604E6 g/hr
    2253+ sec: F=0
Flow from Steam Generator Faulted #2 to Environment #4:
    113 sec-2 hr:(103,300 lb)/(2hr-[113sec/3600sec/hr])=5.247E4 lb/hr=2.380E7g/hr(noble gas and tritium)
        0.01*(103,300 lb)/ (2hr-[113sec/3600sec/hr])=5.247E2 lb/hr=2.380E5g /hr (iodine)*
    2-8 hr: (32800 lb)/(8hr-2hr) = 5.467E3 lb/hr = 2.480E6 g/hr (noble gas)
        0.01*(32800 lb)/(8hr-2hr) = 5.467E1 lb/hr = 2.480E4 g/hr (iodine)
Flow from Steam Generator Unfaulted #3 to Environment #4:
    113 sec-2 hr: (492,100 lb)/ (2hr-[113sec/3600sec/hr]) = 2.500E5 lb/hr = 1.134E8 g/hr (noble gas)
        0.01*(492,100 lb)/ (2hr-[113sec/3600sec/hr]) = 2.500E3 lb/hr = 1.134E6 g/hr(iodine)
    2-8 hr: (900,200 lb)/(8hr-2hr) = 1.500E5 lb/hr = 6.805E7 g/hr (noble gas)
        0.01*(900,200 lb)/(8hr-2hr) = 1.500E3 lb/hr = 6.805E5 g/hr (iodine)
Flow from Reactor Coolant #1 to Steam Generator Unfaulted #3:
    F = 3 steam generators * 150 gpd * 3785.48 cc/gal / 24 hr/day * 1g/cc= 7.098E4 g/hr

* Normally, to take into account uncovery of the faulted steam generator, there is no iodine partitioning in the release to the environment (iodine partition coefficient = 1). For conservatism, no iodine scrubbing of the bubbles in the flashed water is taken into account. However, the water that boils is allowed the iodine partition of 100 (see assumption 6).

Additional data:
Volume/SG = 4.735E7 gm (1.421E8 gm in 3 unfaulted SG's) (ref.51)
RCS I-131 equivalence limits: 0.265 uCi/gm I-131 (steady state) and 21 uCi/gm (48 hr LCO) (ref.49), same as Unit 1
Leakage: 10 gm known plus 1 gpm unknown = 11gpm total, and 150 gpd per SG (ref.48,50), same as Unit 1

Results

The results (rem) are as follows:

Control Room

Pre-accident iodine spike of 21 uCi/c I-131 equivalent

	Airborne	Shine	Ingress/ Egress	Total	Limit
Gamma	0.0918	0.0007	0.0000	0.0924	5
Beta	1.0380	0.0000	0.0000	1.0380	30
Thyroid (ICRP-30)	19.4700	0.0000	0.0000	19.470	30
TEDE	1.1220	0.0007	0.0000	1.1227	5

Accident initiated iodine spike of 500 at 0.265 uCi/g I-131 equivalent

	Airborne	Shine	Ingress/ Egress	Total	Limit
Gamma	0.0853	0.0007	0.0000	0.0860	5
Beta	0.9992	0.0000	0.0000	0.9992	30
Thyroid (ICRP-30)	1.9870	0.0000	0.0000	1.9870	30
TEDE	0.5428	0.0007	0.0000	0.5435	5

Offsite

Pre-accident iodine spike of 21 uCi/c I-131 equivalent

	2-hr EAB	30-Day LPZ	Limit
Gamma	3.59E-01	8.76E-02	25
Beta	2.06E-01	5.25E-02	300
Thyroid (ICRP-30)	1.38E+01	3.28E+00	300
TEDE	1.26E+00	3.00E-01	25

Accident initiated iodine spike of 500 at 0.265 uCi/g I-131 equivalent

	2-hr EAB	30-Day LPZ	Limit (10% of 10CFR100)
Gamma	3.99E-01	9.72E-02	2.5
Beta	2.10E-01	5.36E-02	30
Thyroid (ICRP-30)	4.49E+00	1.09E+00	30
TEDE	7.92E-01	1.92E-01	2.5

Discussion and Conclusion

The Unit 2 steam generators (same as the original Unit 1 steam generators) with a Steam Generator Tube Rupture will not exceed the 10CFR50 App.A GDC 19 control room dose limits or the 10CFR100 offsite dose limits.

Attachment 1: Justification for Using ANSI/ANS-18.1-1984 Expected Coolant Spectrum

The choice of iodine spectrum is fairly important, since several isotopes have short halflives. Results may be affected when accident times are on the order of the decay of the short lived isotopes. There are several possible spectra available. The spectrum chosen for this analysis is the one that most closely resembles the actual spectrum present at WBN. From the surveillance tests 1-SI-68-28 performed on 7/10/00 and 4/9/01 (see following surveillance tests attached), the following concentrations were determined:

RCS activities 7/10/00				RCS activities 4/9/01			
	µCi/gm RCS Gaseous		µCi/gram RCS Degassed		µCi/gm RCS Gaseous		µCi/gram RCS Degassed
Ar-41	1.303E-02	F-18	1.179E-01	Ar-41	2.696E-03	F-18	1.116E-01
Kr-85M	1.915E-04	Na-24	9.169E-04	Kr-85M	2.013E-04	Na-24	2.060E-03
Kr-87	4.575E-04	Mn-56	9.313E-05	Kr-87	4.809E-04	Mn-56	2.088E-04
Xe-133	9.565E-04	Co-58	5.019E-04	Kr-88	4.982E-04	Co-58	6.218E-04
Xe-135	1.429E-03	Nb-95	3.132E-05	Xe-133	1.202E-03	Co-60	2.776E-05
Xe-135M	7.364E-04	I-131	6.070E-05	Xe-135	1.676E-03	Nb-95	2.794E-05
Xe-138	1.796E-03	I-132	1.459E-03	Xe-135M	1.105E-03	I-131	3.881E-05
		I-133	8.208E-04			I-132	1.165E-03
		I-134	2.694E-03			I-133	6.105E-04
		I-135	1.608E-03			I-134	2.334E-03
		Xe-135	8.914E-05			I-135	1.158E-03
		Xe-135M	1.406E-02			Xe-135	1.380E-04
		Cs-138	2.395E-03			Xe-135M	1.972E-02
						Cs-138	2.195E-03

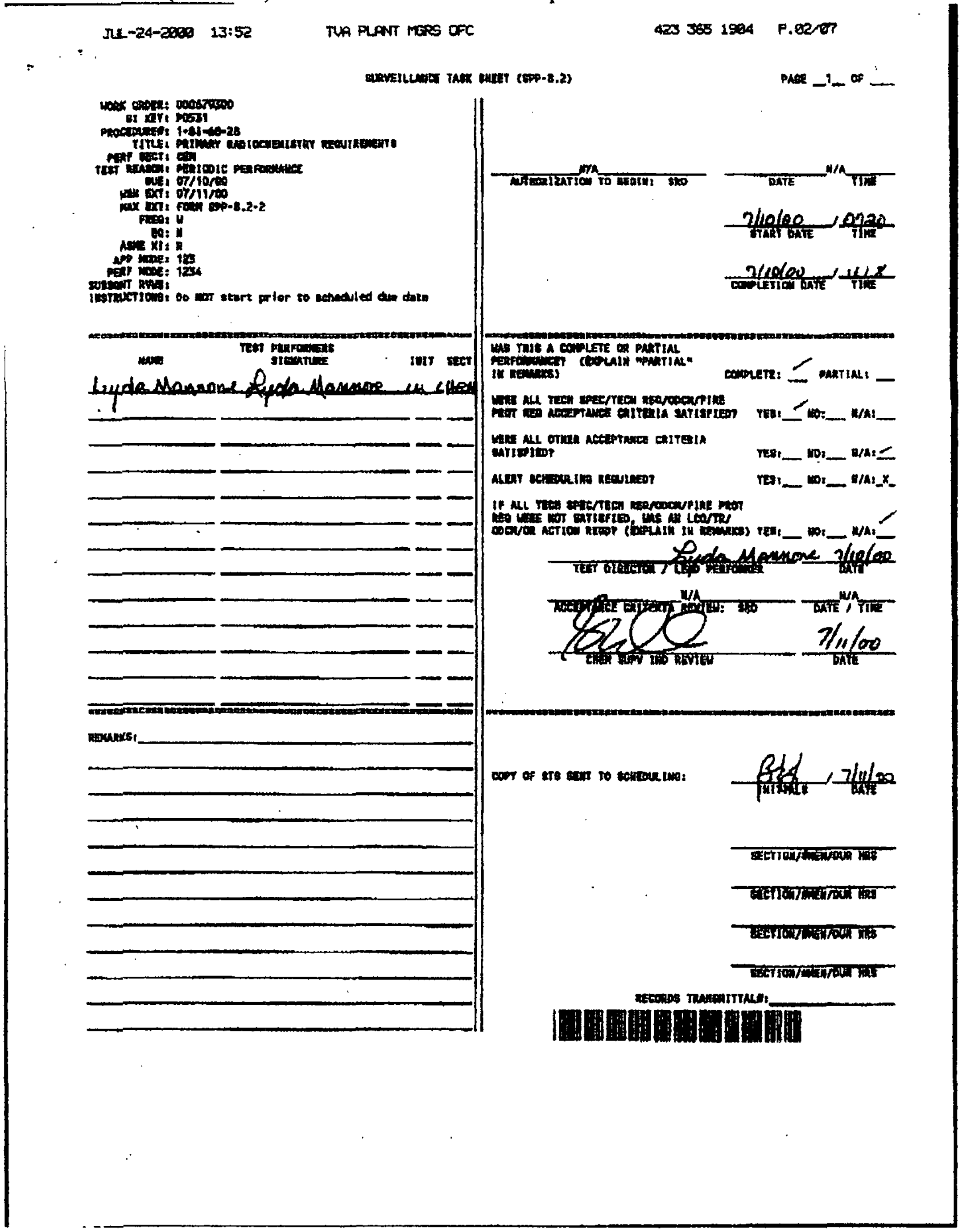
Two potential spectra are from WBNNAL3-003 (Reactor Coolant Activities in Accordance with ANSI/ANS-18.1-1984) and from the FSAR Table 11.1-2 (Historical Design Activities). The iodine concentrations and relative concentrations for each spectrum are as follows:

	7/10/00 WBN actual µCi/gm	7/10/00 WBN actual relative fraction	4/9/01 WBN actual µCi/gm	4/9/01 WBN actual relative fraction
I-131	6.070E-05	0.0091	3.881E-05	0.0073
I-132	1.459E-03	0.2196	1.165E-03	0.2195
I-133	8.208E-04	0.1236	6.105E-04	0.1151
I-134	2.694E-03	0.4056	2.334E-03	0.4399
I-135	1.608E-03	0.2421	1.158E-03	0.2182
sum:	6.643E-03		5.306E-03	

	ANS 18.1 µCi/gm	ANS 18.1 relative fraction	FSAR 11.1-2 µCi/gm	FSAR 11.1-2 relative fraction
I-131	0.0477	0.0448	2.5	0.2461
I-132	0.225	0.2115	0.9	0.0886
I-133	0.149	0.1401	4	0.3937
I-134	0.364	0.3422	0.56	0.0551
I-135	0.278	0.2614	2.2	0.2165
sum:	1.0637		10.16	

As can be seen, the FSAR historical design concentrations do not reflect the actual measured concentrations. The FSAR values are weighted too strongly in favor of I-131 (24.6% of total as opposed to < 1% of the actual total). By comparison, the ANSI/ANS-18.1-1984 fractions are very close to the actual fractions. The worst fit was for I-134 which was 40.1% actual versus ANSI/ANS-18.1-1984 34.22%. The I-131 is slightly over predicted by ANS-18.1 (0.9% on 7/10/00 and 0.7% on 4/9/01 versus 4.48%), however this difference is not as large compared to the FSAR fraction. The ANSI/ANS-18.1-1984 spectrum overall fit is much better than the FSAR spectrum, therefore it can be concluded that the use of the ANSI/ANS-18.1-1984 spectrum is acceptable.

Attachment 1 (continued): Surveillance test 1-SI-68-28 performed on 7/10/00



JUL-24-2000 13:52 TVA PLANT MGRS OFC 423 365 1904 P.02/07

SURVEILLANCE TASK SHEET (SPP-8.2)

PAGE 1 OF ___

WORK ORDER: 000579300
SI KEY: P0531
PROCEDURE#: 1-SI-68-28
TITLE: PRIMARY RADIOCHEMISTRY REQUIREMENTS
PERF SECT: CEM
TEST REASON: PERIODIC PERFORMANCE
DUE: 07/10/00
MIN EXT: 07/11/00
MAX EXT: FORM SPP-8.2-2
FREQ: W
BQ: N
ASME XI: N
APP MODE: 123
PERF MODE: 1234
SUBSQNT RVWS:
INSTRUCTIONS: Do NOT start prior to scheduled due date

N/A AUTHORIZATION TO BEGIN: SRO
N/A DATE / TIME

7/10/00 / 0920 START DATE / TIME

7/10/00 / 1118 COMPLETION DATE / TIME

TEST PERFORMERS

NAME	SIGNATURE	UNIT	SECT
Lyda Mannone	Lyda Mannone	[illegible]	CHEM

WAS THIS A COMPLETE OR PARTIAL PERFORMANCE? (EXPLAIN "PARTIAL" IN REMARKS) COMPLETE: ✓ PARTIAL: ___

WERE ALL TECH SPEC/TECH REQ/ODCM/FIRE PROT REQ ACCEPTANCE CRITERIA SATISFIED? YES: ✓ NO: ___ N/A: ___

WERE ALL OTHER ACCEPTANCE CRITERIA SATISFIED? YES: ___ NO: ___ N/A: ✓

ALERT SCHEDULING REQUIRED? YES: ___ NO: ___ N/A: X

IF ALL TECH SPEC/TECH REQ/ODCM/FIRE PROT REQ WERE NOT SATISFIED, WAS AN LCO/TR/ODCM/OR ACTION REQD? (EXPLAIN IN REMARKS) YES: ___ NO: ___ N/A: ✓

Lyda Mannone TEST DIRECTOR / LEAD PERFORMER 7/10/00 DATE

N/A ACCEPTANCE CRITERIA REVIEW: SRO N/A DATE / TIME

CHEM SUPV IND REVIEW 7/11/00 DATE

REMARKS:

COPY OF STS SENT TO SCHEDULING: BLd / 7/11/00 INITIALS DATE

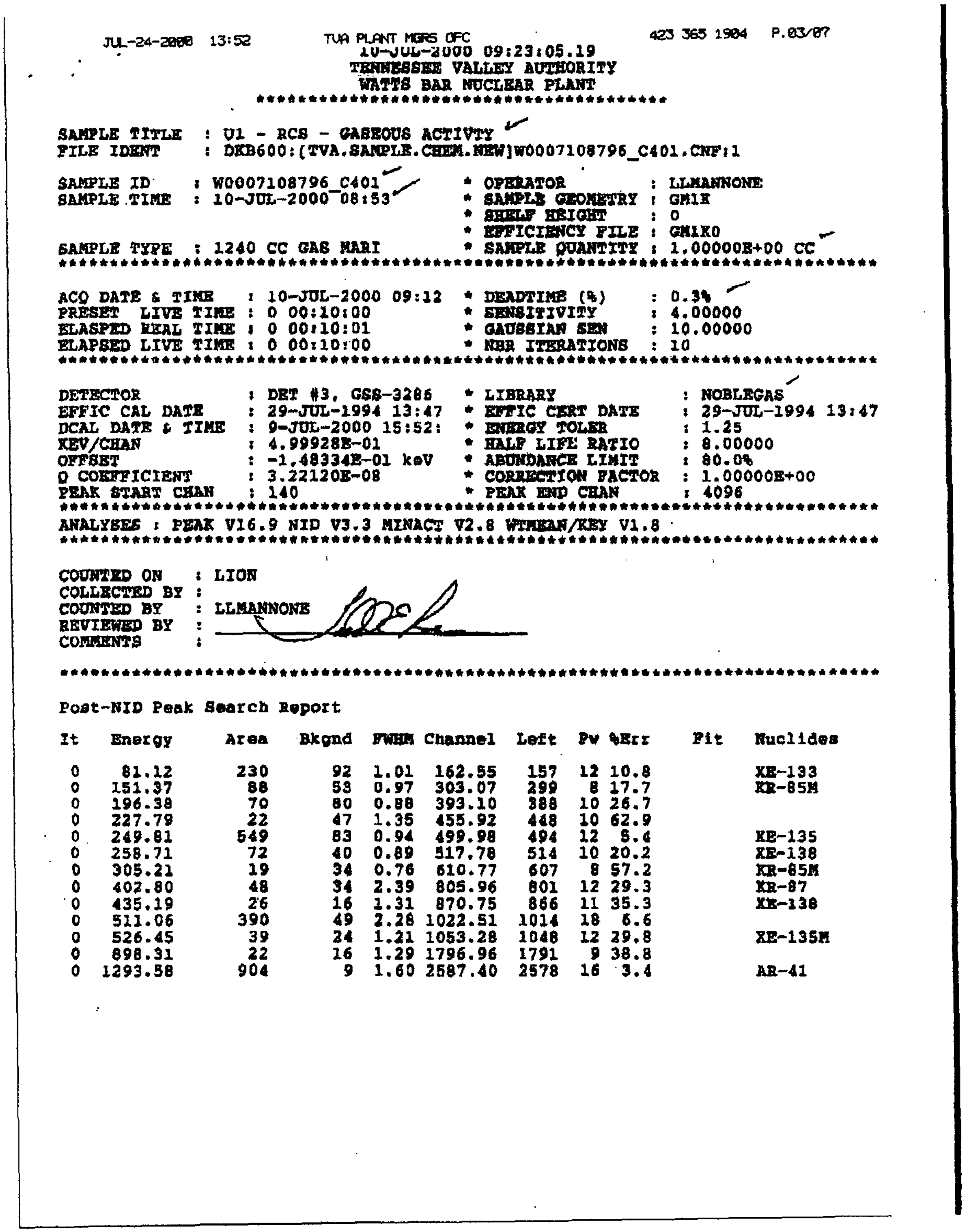
SECTION/MAN/DUR HRS

SECTION/MAN/DUR HRS

SECTION/MAN/DUR HRS

SECTION/MAN/DUR HRS

RECORDS TRANSMITTAL#:



```
JUL-24-2000  13:52          TVA PLANT MGRS OFC                    423 365 1904    P.03/07
                                    10-JUL-2000 09:23:05.19
                                  TENNESSEE VALLEY AUTHORITY
                                   WATTS BAR NUCLEAR PLANT
                          ******************************************

SAMPLE TITLE  : U1 - RCS - GASEOUS ACTIVTY
FILE IDENT    : DKB600:[TVA.SAMPLE.CHEM.NEW]W0007108796_C401.CNF:1

SAMPLE ID     : W0007108796_C401         * OPERATOR          : LLMANNONE
SAMPLE TIME   : 10-JUL-2000 08:53        * SAMPLE GEOMETRY   : GM1K
                                         * SHELF HEIGHT      : 0
                                         * EFFICIENCY FILE   : GM1K0
SAMPLE TYPE   : 1240 CC GAS MARI         * SAMPLE QUANTITY   : 1.00000E+00 CC
*****************************************************************************

ACQ DATE & TIME     : 10-JUL-2000 09:12  * DEADTIME (%)      : 0.3%
PRESET  LIVE TIME   : 0 00:10:00         * SENSITIVITY       : 4.00000
ELASPED REAL TIME   : 0 00:10:01         * GAUSSIAN SEN      : 10.00000
ELAPSED LIVE TIME   : 0 00:10:00         * NBR ITERATIONS    : 10
*****************************************************************************

DETECTOR            : DET #3, GSS-3286   * LIBRARY              : NOBLEGAS
EFFIC CAL DATE      : 29-JUL-1994 13:47  * EFFIC CERT DATE      : 29-JUL-1994 13:47
DCAL DATE & TIME    : 9-JUL-2000 15:52:  * ENERGY TOLER         : 1.25
KEV/CHAN            : 4.99928E-01        * HALF LIFE RATIO      : 8.00000
OFFSET              : -1.48334E-01 keV   * ABUNDANCE LIMIT      : 80.0%
Q COEFFICIENT       : 3.22120E-08        * CORRECTION FACTOR    : 1.00000E+00
PEAK START CHAN     : 140                * PEAK END CHAN        : 4096
*****************************************************************************
ANALYSES : PEAK V16.9 NID V3.3 MINACT V2.8 WTMEAN/KEY V1.8
*****************************************************************************

COUNTED ON     : LION
COLLECTED BY   :
COUNTED BY     : LLMANNONE
REVIEWED BY    :
COMMENTS       :

*****************************************************************************

Post-NID Peak Search Report

It   Energy      Area    Bkgnd  FWHM Channel   Left  Pw %Err      Fit    Nuclides

 0     81.12      230      92  1.01  162.55    157  12 10.8              XE-133
 0    151.37       88      53  0.97  303.07    299   8 17.7              KR-85M
 0    196.38       70      80  0.88  393.10    388  10 26.7
 0    227.79       22      47  1.35  455.92    448  10 62.9
 0    249.81      549      83  0.94  499.98    494  12  5.4              XE-135
 0    258.71       72      40  0.89  517.78    514  10 20.2              XE-138
 0    305.21       19      34  0.76  610.77    607   8 57.2              KR-85M
 0    402.80       48      34  2.39  805.96    801  12 29.3              KR-87
 0    435.19       26      16  1.31  870.75    866  11 35.3              XE-138
 0    511.06      390      49  2.28 1022.51   1014  18  6.6
 0    526.45       39      24  1.21 1053.28   1048  12 29.8              XE-135M
 0    898.31       22      16  1.29 1796.96   1791   9 38.8
 0   1293.58      904       9  1.60 2587.40   2578  16  3.4              AR-41
```

```
JUL-24-2000  13:53        TVA PLANT MGRS OFC                    423 365 1904   P.04/07
  REPORT DATE : 10-JUL-2000 09:23
  REQUESTOR   : LLMANNONE

                          TENNESSEE VALLEY AUTHORITY
                           WATTS BAR NUCLEAR PLANT

                             POST NID QA ANALYSIS

  TITLE : U1 - RCS - GASEOUS ACTIVTY

  SAMPLE No.  : W0007108796_C401       OPERATOR NAME    : LLMANNONE
  SAMPLE TYPE : 1240 CC GAS MARI       SAMPLE GEOMETRY  : GM1K
  COUNT TIME  : 10-JUL-2000 09:12:51   SAMPLE QUANTITY  : 1.00000E+00
  SAMPLE TIME : 10-JUL-2000 08:53:00   DETECTOR         : DET #3, GSS-3286
  LIBRARY     : NOBLEGAS

                PEAK     ENERGY      DECAY CORR
   ISOTOPE     ENERGY  DIFF (KEV)    uCi/CC           COMMENTS
   --------   -------  ----------   ----------  ----------------------
    AR-41     1293.64    -0.06      1.303E-02        QA Results OK
    KR-85M     151.18     0.19      1.915E-04        QA Results OK
    KR-87      402.58     0.22      4.575E-04        QA Results OK
    XE-133      81.00     0.12      9.565E-04        QA Results OK
    XE-135     249.79     0.02      1.429E-03        QA Results OK
    XE-135M    526.56    -0.11      7.364E-04        QA Results OK
    XE-138     258.31     0.40      1.796E-03        QA Results OK
                         ------     ---------
    AVG ENERGY DIFF =     0.11      1.859E-02 = TOTAL GAMMA ACTIVITY
                                    0.000E+00 = Total DGL Activity
                                    1.859E-02 = Total Gas Activity

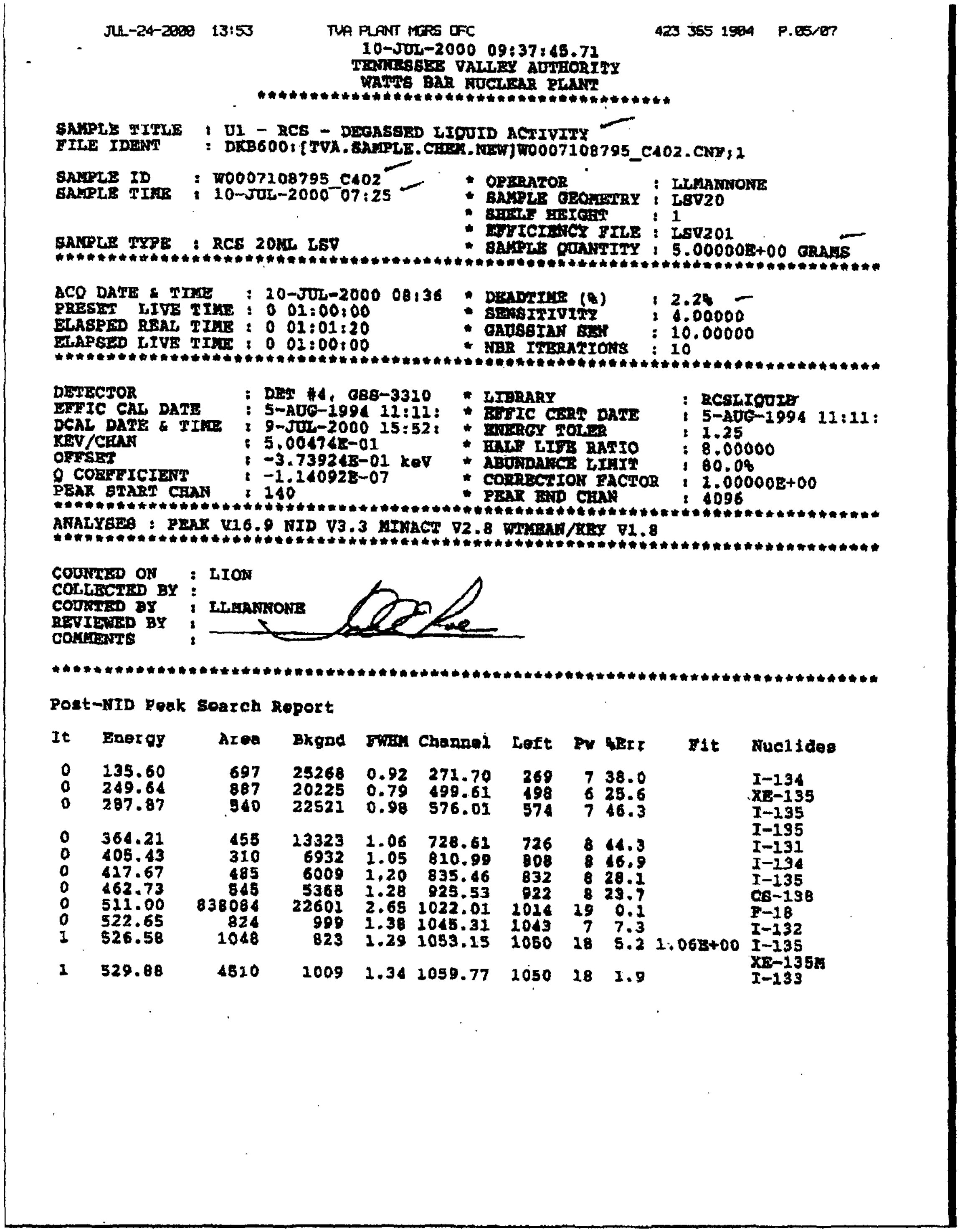


                          UNIDENTIFIED/REJECTED PEARS

                                         GAMMA/SEC                  POTENTIAL
 ENERGY   NET AREA   FWHM   GAMMA/SEC  /CC        % ERROR  FLAG     ID      ACTIVITY
 -------  --------  -----  ---------  ---------  -------  ----  --------  ---------
 196.38        70.   0.88  4.728E+00  4.728E+00     26.7     R    KR-88   5.438E-04
 227.79        22.   1.35  1.675E+00  1.675E+00     62.9     U    TE-132  5.163E-05
                                                             U    CS-138  5.110E-03
                                                             U    NP-239  4.252E-04
 511.06       390.   2.28  7.016E+01  7.016E+01     6.60     U    ANNIL   0.000E+00
 898.31        22.   1.29  7.079E+00  7.079E+00     38.8     U    RB-88   1.512E-03
                                                             U    Y-88    2.049E-04
```

NO Peaks of INTEREST

7/10/00



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JUL-24-2000  13:53        TVA PLANT MGRS OFC                    423 365 1904   P.05/07
                          10-JUL-2000 09:37:46.71
                        TENNESSEE VALLEY AUTHORITY
                          WATTS BAR NUCLEAR PLANT
                 ****************************************

SAMPLE TITLE   : U1 - RCS - DEGASSED LIQUID ACTIVITY
FILE IDENT     : DKB600:[TVA.SAMPLE.CHEM.NEW]W0007108795_C402.CNF;1

SAMPLE ID      : W0007108795_C402             * OPERATOR           : LLMANNONE
SAMPLE TIME    : 10-JUL-2000 07:25            * SAMPLE GEOMETRY    : LSV20
                                              * SHELF HEIGHT       : 1
                                              * EFFICIENCY FILE    : LSV201
SAMPLE TYPE    : RCS 20ML LSV                 * SAMPLE QUANTITY    : 5.00000E+00 GRAMS
*************************************************************************************

ACQ DATE & TIME    : 10-JUL-2000 08:36  * DEADTIME (%)       : 2.2%
PRESET  LIVE TIME  : 0 01:00:00         * SENSITIVITY        : 4.00000
ELASPED REAL TIME  : 0 01:01:20         * GAUSSIAN SEN       : 10.00000
ELAPSED LIVE TIME  : 0 01:00:00         * NBR ITERATIONS     : 10
*************************************************************************************

DETECTOR           : DET #4, GSS-3310    * LIBRARY              : RCSLIQUID
EFFIC CAL DATE     : 5-AUG-1994 11:11:   * EFFIC CERT DATE      : 5-AUG-1994 11:11:
DCAL DATE & TIME   : 9-JUL-2000 15:52:   * ENERGY TOLER         : 1.25
KEV/CHAN           : 5.00474E-01         * HALF LIFE RATIO      : 8.00000
OFFSET             : -3.73924E-01 keV    * ABUNDANCE LIMIT      : 80.0%
Q COEFFICIENT      : -1.14092E-07        * CORRECTION FACTOR    : 1.00000E+00
PEAK START CHAN    : 140                 * PEAK END CHAN        : 4096
*************************************************************************************
ANALYSES : PEAK V16.9 NID V3.3 MINACT V2.8 WTMEAN/KEY V1.8
*************************************************************************************

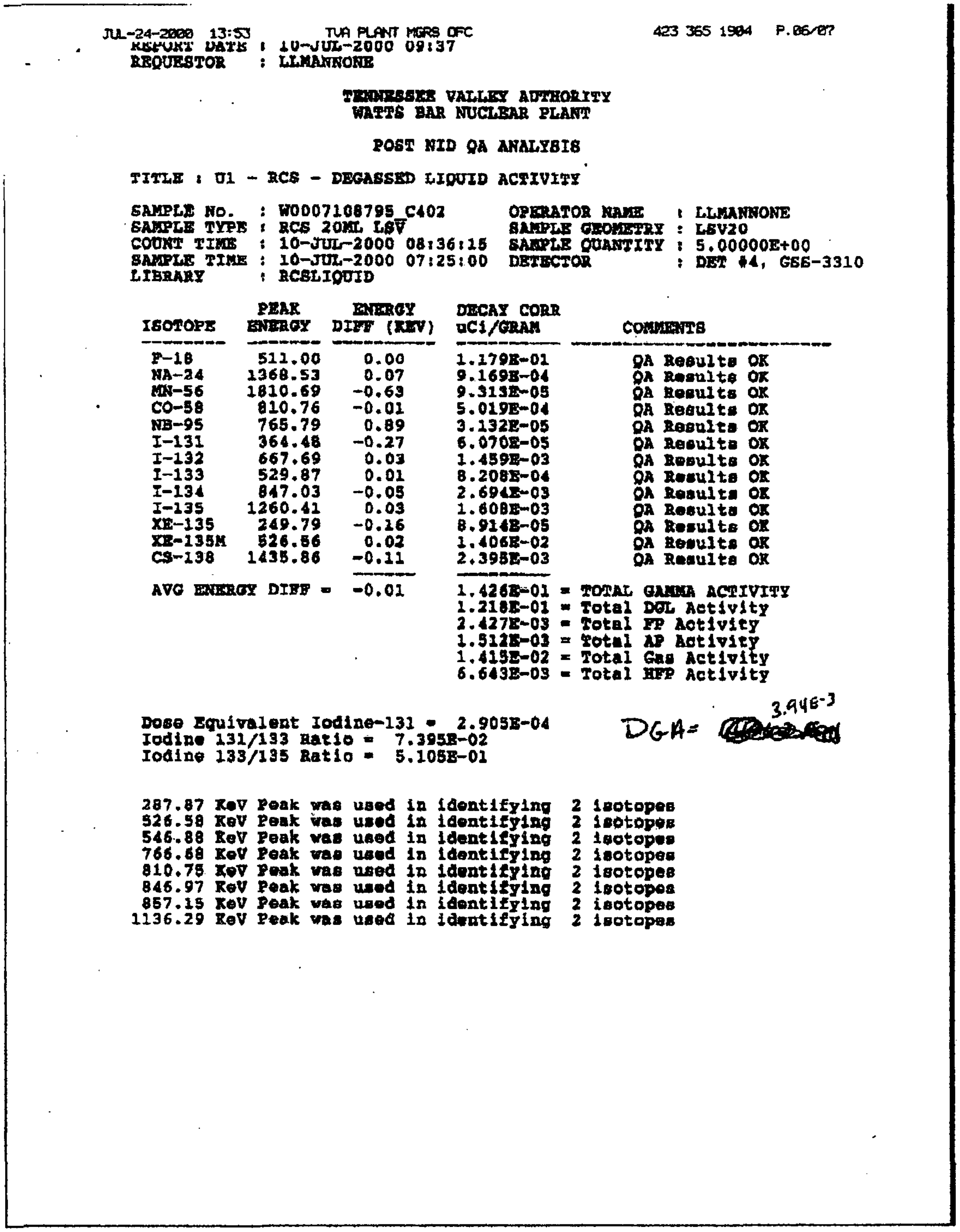
COUNTED ON    : LION
COLLECTED BY  :
COUNTED BY    : LLMANNONE
REVIEWED BY   :
COMMENTS      :

*************************************************************************************

Post-NID Peak Search Report

It   Energy       Area    Bkgnd  FWHM Channel   Left   Pw %Err       Fit    Nuclides

 0   135.60        697    25268  0.92  271.70    269    7 38.0              I-134
 0   249.64        887    20225  0.79  499.61    498    6 25.6              XE-135
 0   287.87        540    22521  0.98  576.01    574    7 46.3              I-135
                                                                            I-135
 0   364.21        455    13323  1.06  728.61    726    8 44.3              I-131
 0   405.43        310     6932  1.05  810.99    808    8 46.9              I-134
 0   417.67        485     6009  1.20  835.46    832    8 28.1              I-135
 0   462.73        545     5368  1.28  925.53    922    8 23.7              CS-138
 0   511.00     838084    22601  2.65 1022.01   1014   19  0.1              F-18
 0   522.65        824      999  1.38 1045.31   1043    7  7.3              I-132
 1   526.58       1048      823  1.29 1053.15   1050   18  5.2 1.06E+00    I-135
                                                                            XE-135M
 1   529.88       4510     1009  1.34 1059.77   1050   18  1.9              I-133
```



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JUL-24-2000  13:53          TVA PLANT MGRS OFC                    423 365 1904   P.06/07
  REPORT DATE : 10-JUL-2000 09:37
  REQUESTOR   : LLMANNONE

                         TENNESSEE VALLEY AUTHORITY
                          WATTS BAR NUCLEAR PLANT

                            POST NID QA ANALYSIS

  TITLE : U1 - RCS - DEGASSED LIQUID ACTIVITY

  SAMPLE No.  : W0007108795_C402      OPERATOR NAME   : LLMANNONE
  SAMPLE TYPE : RCS 20ML LSV          SAMPLE GEOMETRY : LSV20
  COUNT TIME  : 10-JUL-2000 08:36:15  SAMPLE QUANTITY : 5.00000E+00
  SAMPLE TIME : 10-JUL-2000 07:25:00  DETECTOR        : DET #4, GSE-3310
  LIBRARY     : RCSLIQUID

                PEAK     ENERGY      DECAY CORR
   ISOTOPE     ENERGY  DIFF (KEV)   uCi/GRAM          COMMENTS
   --------    ------  ----------   ----------   ------------------------
    F-18       511.00     0.00      1.179E-01         QA Results OK
    NA-24     1368.53     0.07      9.169E-04         QA Results OK
    MN-56     1810.69    -0.63      9.313E-05         QA Results OK
    CO-58      810.76    -0.01      5.019E-04         QA Results OK
    NB-95      765.79     0.89      3.132E-05         QA Results OK
    I-131      364.48    -0.27      6.070E-05         QA Results OK
    I-132      667.69     0.03      1.459E-03         QA Results OK
    I-133      529.87     0.01      8.208E-04         QA Results OK
    I-134      847.03    -0.05      2.694E-03         QA Results OK
    I-135     1260.41     0.03      1.608E-03         QA Results OK
    XE-135     249.79    -0.16      8.914E-05         QA Results OK
    XE-135M    526.56     0.02      1.406E-02         QA Results OK
    CS-138    1435.86    -0.11      2.398E-03         QA Results OK
                         -------    ----------
    AVG ENERGY DIFF =    -0.01      1.426E-01 = TOTAL GAMMA ACTIVITY
                                    1.218E-01 = Total DGL Activity
                                    2.427E-03 = Total FP Activity
                                    1.512E-03 = Total AP Activity
                                    1.415E-02 = Total Gas Activity
                                    6.643E-03 = Total HFP Activity

   Dose Equivalent Iodine-131 =  2.905E-04
   Iodine 131/133 Ratio =  7.395E-02
   Iodine 133/135 Ratio =  5.105E-01

   287.87 KeV Peak was used in identifying  2 isotopes
   526.58 KeV Peak was used in identifying  2 isotopes
   546.88 KeV Peak was used in identifying  2 isotopes
   766.68 KeV Peak was used in identifying  2 isotopes
   810.75 KeV Peak was used in identifying  2 isotopes
   846.97 KeV Peak was used in identifying  2 isotopes
   857.15 KeV Peak was used in identifying  2 isotopes
  1136.29 KeV Peak was used in identifying  2 isotopes
```

DGA= [illegible] $3.94E^{-3}$

JUL-24-2000 13:53 TVA PLANT MGRS OFC 423 365 1904 P.07/07

REPORT DATE : 10-JUL-2000 09:37
REQUESTOR : LLMANNONE

TENNESSEE VALLEY AUTHORITY
WATTS BAR NUCLEAR PLANT

POST NID QA ANALYSIS

UNIDENTIFIED/REJECTED PEAKS

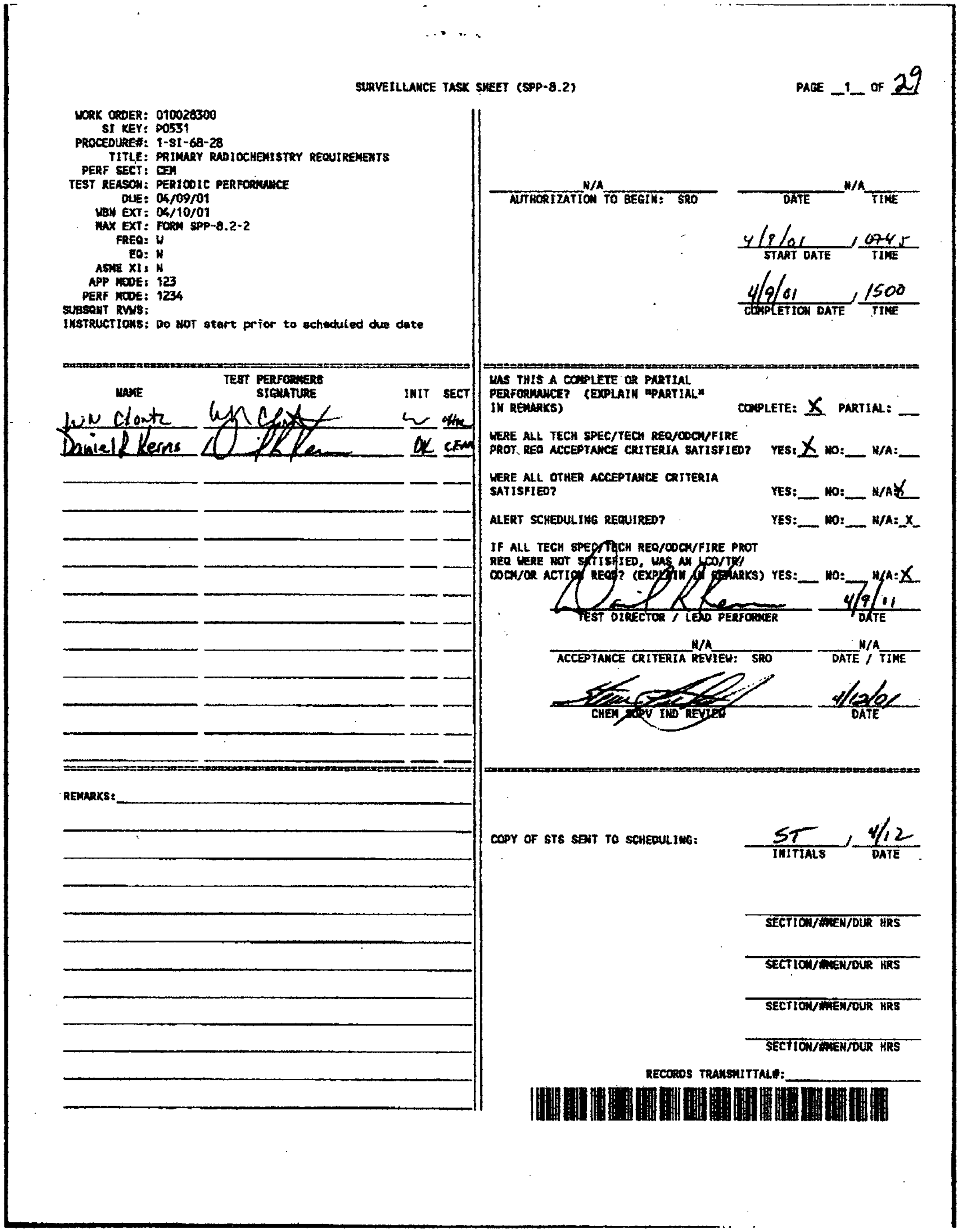
ENERGY	NET AREA	FWHM	GAMMA/SEC	GAMMA/SEC /GRAM	% ERROR	FLAG	POTENTIAL ID	ACTIVITY
681.90	334.	2.71	1.143E+01	2.285E+00	25.7	U	I-135	
684.87	217.	2.04	7.446E+00	1.489E+00	31.1	R	W-187 Found	1.448E-04
1288.56	38.	1.81	2.239E+00	4.478E-01	36.5 } Continuum	U		
1291.07	30.	1.03	1.812E+00	3.624E-01	41.6	R	FE-59	2.244E-05
1566.76	75.	2.12	5.204E+00	1.041E+00	25.3	U	I-135	
1835.61	31.	1.08	2.411E+00	4.822E-01	36.4	R	RB-88 Found	9.196E-05
						U	Y-88	1.312E-05

Total Unidentified/Rejected Peaks = 6
% Unidentified/Rejected Peaks = 10.17

Flags: U - Unknown Line
R - Rejected During Analysis
P - Positively Identified (line not in analysis library)

No Peaks of interest
R
7/10/00

TOTAL P.07



SURVEILLANCE TASK SHEET (SPP-8.2)

PAGE 1 OF 29

WORK ORDER: 010028300
SI KEY: P0531
PROCEDURE#: 1-SI-68-28
TITLE: PRIMARY RADIOCHEMISTRY REQUIREMENTS
PERF SECT: CEM
TEST REASON: PERIODIC PERFORMANCE
DUE: 04/09/01
WBN EXT: 04/10/01
MAX EXT: FORM SPP-8.2-2
FREQ: W
EQ: N
ASME XI: N
APP MODE: 123
PERF MODE: 1234
SUBSQNT RVWS:
INSTRUCTIONS: Do NOT start prior to scheduled due date

N/A
AUTHORIZATION TO BEGIN: SRO

N/A
DATE TIME

4/9/01, 0745
START DATE TIME

4/9/01, 1500
COMPLETION DATE TIME

TEST PERFORMERS

NAME	SIGNATURE	INIT	SECT
W N Clontz			[illegible]
Daniel L Kerns		DK	CEM

REMARKS:

WAS THIS A COMPLETE OR PARTIAL PERFORMANCE? (EXPLAIN "PARTIAL" IN REMARKS) COMPLETE: X PARTIAL: ___

WERE ALL TECH SPEC/TECH REQ/ODCM/FIRE PROT. REQ ACCEPTANCE CRITERIA SATISFIED? YES: X NO: ___ N/A: ___

WERE ALL OTHER ACCEPTANCE CRITERIA SATISFIED? YES: ___ NO: ___ N/A: X

ALERT SCHEDULING REQUIRED? YES: ___ NO: ___ N/A: X

IF ALL TECH SPEC/TECH REQ/ODCM/FIRE PROT REQ WERE NOT SATISFIED, WAS AN LCO/TR/ODCM/OR ACTION REQD? (EXPLAIN IN REMARKS) YES: ___ NO: ___ N/A: X

TEST DIRECTOR / LEAD PERFORMER — 4/9/01
DATE

N/A
ACCEPTANCE CRITERIA REVIEW: SRO

N/A
DATE / TIME

CHEM SUPV IND REVIEW — 4/12/01
DATE

COPY OF STS SENT TO SCHEDULING: ST, 4/12
INITIALS DATE

SECTION/#MEN/DUR HRS

SECTION/#MEN/DUR HRS

SECTION/#MEN/DUR HRS

SECTION/#MEN/DUR HRS

RECORDS TRANSMITTAL#:

```
                    ******************************************
                          9-APR-2001 14:25:02.67
                       TENNESSEE VALLEY AUTHORITY
                         WATTS BAR NUCLEAR PLANT
                    ******************************************

SAMPLE TITLE  : U1 - RCS - GASEOUS ACTIVTY
FILE IDENT    : DKB600:[TVA.SAMPLE.CHEM.NEW]W0104095767_C401.CNF;1

SAMPLE ID    : W0104095767_C401         * OPERATOR          : DRKERNS
SAMPLE TIME  : 9-APR-2001 13:25:        * SAMPLE GEOMETRY : GM1K
                                        * SHELF HEIGHT      : 0
                                        * EFFICIENCY FILE : GM1K0
SAMPLE TYPE  : 1240 CC GAS MARI         * SAMPLE QUANTITY : 2.51000E+00 CC
****************************************************************************

ACQ DATE & TIME    : 9-APR-2001 14:14:  * DEADTIME (%)      : 0.1%
PRESET  LIVE TIME : 0 00:10:00          * SENSITIVITY       : 4.00000
ELASPED REAL TIME : 0 00:10:00          * GAUSSIAN SEN      : 10.00000
ELAPSED LIVE TIME : 0 00:10:00          * NBR ITERATIONS    : 10
****************************************************************************

DETECTOR           : DET #4, GSS-3310   * LIBRARY             : NOBLEGAS
EFFIC CAL DATE     : 2-AUG-1994 11:26:  * EFFIC CERT DATE     : 2-AUG-1994 11:26:
DCAL DATE & TIME   : 9-APR-2001 02:40:  * ENERGY TOLER        : 1.25
KEV/CHAN           : 5.00516E-01        * HALF LIFE RATIO     : 8.00000
OFFSET             : 1.44837E-01 keV    * ABUNDANCE LIMIT     : 80.0%
Q COEFFICIENT      : -1.10914E-07       * CORRECTION FACTOR   : 1.00000E+00
PEAK START CHAN    : 140                * PEAK END CHAN       : 4096
****************************************************************************
ANALYSES : PEAK V16.9 NID V3.3 MINACT V2.8 WTMEAN/KEY V1.8
****************************************************************************

COUNTED ON    : LION
COLLECTED BY  :
COUNTED BY    : DRKERNS
REVIEWED BY   :
COMMENTS      :

****************************************************************************

Post-NID Peak Search Report

It   Energy      Area    Bkgnd   FWHM  Channel   Left   Pw  %Err     Fit     Nuclides

 0    80.94       902      374   1.03   161.44    157   10   5.2             XE-133
 0   151.17       294      315   1.07   301.75    297   10  12.8             KR-85M
 0   166.01        57      226   1.10   331.42    328    8  47.7             KR-88
 0   196.08       202      345   1.03   391.51    387   10  18.5             KR-88
 0   249.77      2313      340   1.12   498.78    494   12   2.6             XE-135
 0   258.57        59      201   1.04   516.37    513    8  43.2
 0   402.62       160       50   1.21   804.27    800    8  11.0             KR-87
 0   510.99      7378      174   2.34  1020.88   1013   19   1.2
 0   526.86        66       31   1.08  1052.60   1048   11  20.7             XE-135M
 0   609.00        34       35   0.87  1216.79   1209   16  43.6             XE-135
 0   677.82        14       17   1.85  1354.36   1348    9  61.5
 0   834.68        38       12   1.75  1667.96   1662   12  24.5             KR-88
 0   897.59        24       13   2.20  1793.76   1789    9  34.3
```

```
REPORT NAME : QA_CHECK (V10.4)                                PAGE :     1
REPORT DATE :  9-APR-2001 14:25
REQUESTOR   : DRKERNS

                        TENNESSEE VALLEY AUTHORITY
                         WATTS BAR NUCLEAR PLANT

                           POST NID QA ANALYSIS

TITLE : U1 - RCS - GASEOUS ACTIVTY

SAMPLE No.   : W0104095767_C401       OPERATOR NAME     : DRKERNS
SAMPLE TYPE  : 1240 CC GAS MARI       SAMPLE GEOMETRY   : GM1K
COUNT TIME   : 9-APR-2001 14:14:53.   SAMPLE QUANTITY   : 2.51000E+00
SAMPLE TIME  : 9-APR-2001 13:25:00.   DETECTOR          : DET #4, GSS-3310
LIBRARY      : NOBLEGAS

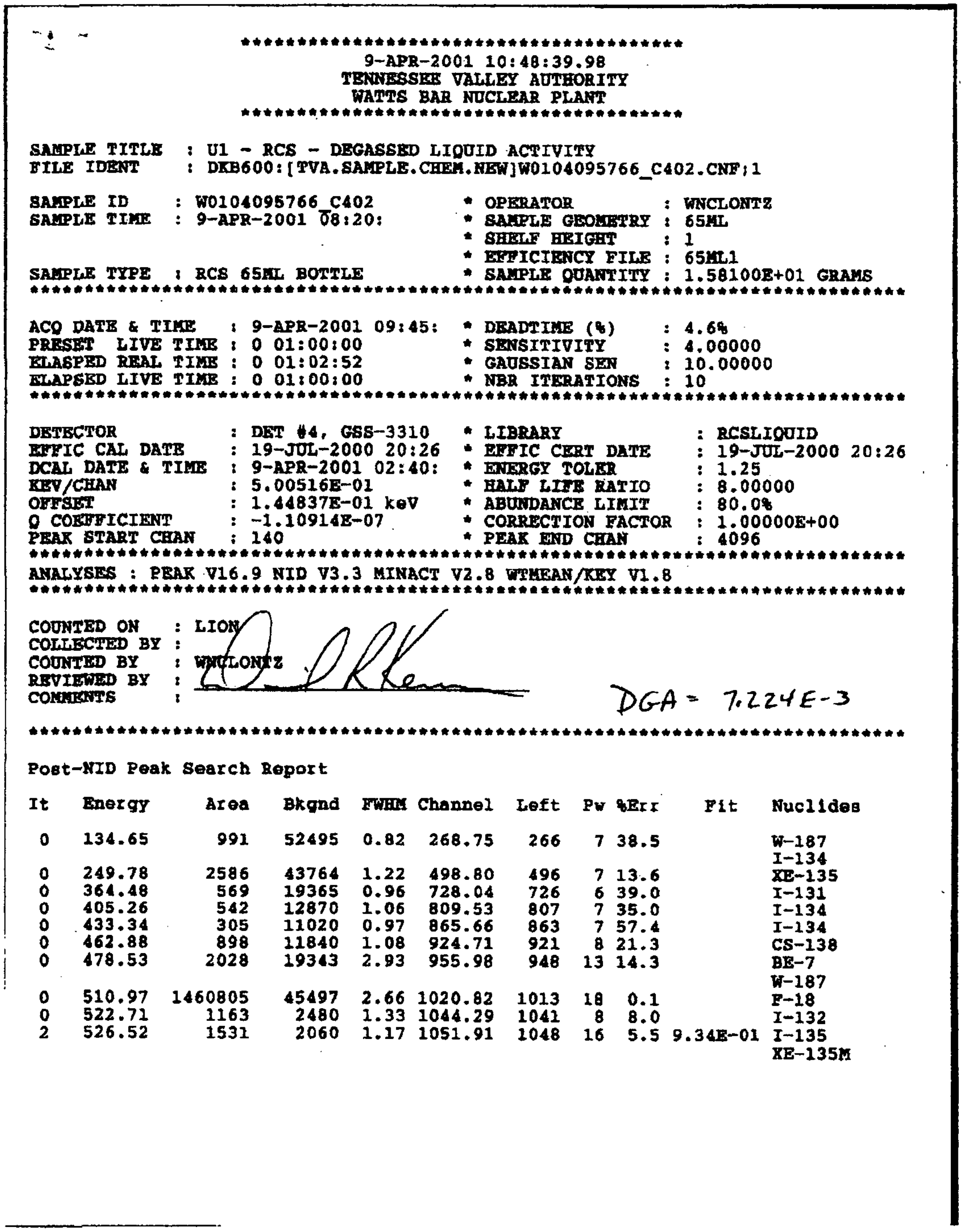
              PEAK     ENERGY      DECAY CORR
 ISOTOPE     ENERGY  DIFF (KEV)   uCi/CC            COMMENTS
 --------    ------  ----------   ----------  -------------------------
  AR-41     1293.64    -0.10      2.696E-03         QA Results OK
  KR-85M     151.18    -0.01      2.013E-04         QA Results OK
  KR-87      402.58     0.04      4.809E-04         QA Results OK
  KR-88      196.32    -0.24      4.982E-04         QA Results OK
  XE-133      81.00    -0.05      1.202E-03         QA Results OK
  XE-135     249.79    -0.03      1.676E-03         QA Results OK
  XE-135M    526.56     0.30      1.105E-03         QA Results OK
                       -----      ----------
  AVG ENERGY DIFF =    -0.01      7.859E-03 = TOTAL GAMMA ACTIVITY
                                  0.000E+00 = Total DGL Activity
                                  7.859E-03 = Total Gas Activity



                      UNIDENTIFIED/REJECTED PEAKS

                                         GAMMA/SEC                  POTENTIAL
 ENERGY   NET AREA  FWHM   GAMMA/SEC    /CC      % ERROR  FLAG     ID       ACTIVITY
 -------  --------  ----  ---------  ---------  -------  ----  --------   ---------
 258.57        59.  1.04  3.448E+00  1.374E+00    43.2     R    XE-138    1.724E-03
 510.99      7378.  2.34  7.643E+02  3.045E+02    1.25     U    F-18      6.016E-03
                                                           U    ANNIL     0.000E+00
 677.82        14.  1.85  1.829E+00  7.289E-01    61.5     U    AG-110M   1.845E-04
                                                           U    I-134     4.949E-04
 897.59        24.  2.20  4.089E+00  1.629E+00    84.3     U    RB-88     3.932E-04
                                                           U    Y-88      4.716E-05
1835.84        17.  2.13  5.418E+00  2.159E+00    24.3     U    RB-88     3.408E-04
                                                           U    Y-88      5.872E-05
```

DK 4/9/01



```
                    ****************************************
                          9-APR-2001 10:48:39.98
                        TENNESSEE VALLEY AUTHORITY
                         WATTS BAR NUCLEAR PLANT
                    ****************************************

SAMPLE TITLE   : U1 - RCS - DEGASSED LIQUID ACTIVITY
FILE IDENT     : DKB600:[TVA.SAMPLE.CHEM.NEW]W0104095766_C402.CNF;1

SAMPLE ID     : W0104095766_C402         * OPERATOR          : WNCLONTZ
SAMPLE TIME   : 9-APR-2001 08:20:        * SAMPLE GEOMETRY : 65ML
                                         * SHELF HEIGHT      : 1
                                         * EFFICIENCY FILE : 65ML1
SAMPLE TYPE   : RCS 65ML BOTTLE          * SAMPLE QUANTITY : 1.58100E+01 GRAMS
******************************************************************************

ACQ DATE & TIME    : 9-APR-2001 09:45:  * DEADTIME (%)      : 4.6%
PRESET  LIVE TIME : 0 01:00:00          * SENSITIVITY       : 4.00000
ELASPED REAL TIME : 0 01:02:52          * GAUSSIAN SEN      : 10.00000
ELAPSED LIVE TIME : 0 01:00:00          * NBR ITERATIONS    : 10
******************************************************************************

DETECTOR            : DET #4, GSS-3310   * LIBRARY             : RCSLIQUID
EFFIC CAL DATE      : 19-JUL-2000 20:26  * EFFIC CERT DATE     : 19-JUL-2000 20:26
DCAL DATE & TIME    : 9-APR-2001 02:40:  * ENERGY TOLER        : 1.25
KEV/CHAN            : 5.00516E-01        * HALF LIFE RATIO     : 8.00000
OFFSET              : 1.44837E-01 keV    * ABUNDANCE LIMIT     : 80.0%
Q COEFFICIENT       : -1.10914E-07       * CORRECTION FACTOR   : 1.00000E+00
PEAK START CHAN     : 140                * PEAK END CHAN       : 4096
******************************************************************************
ANALYSES : PEAK V16.9 NID V3.3 MINACT V2.8 WTMEAN/KEY V1.8
******************************************************************************

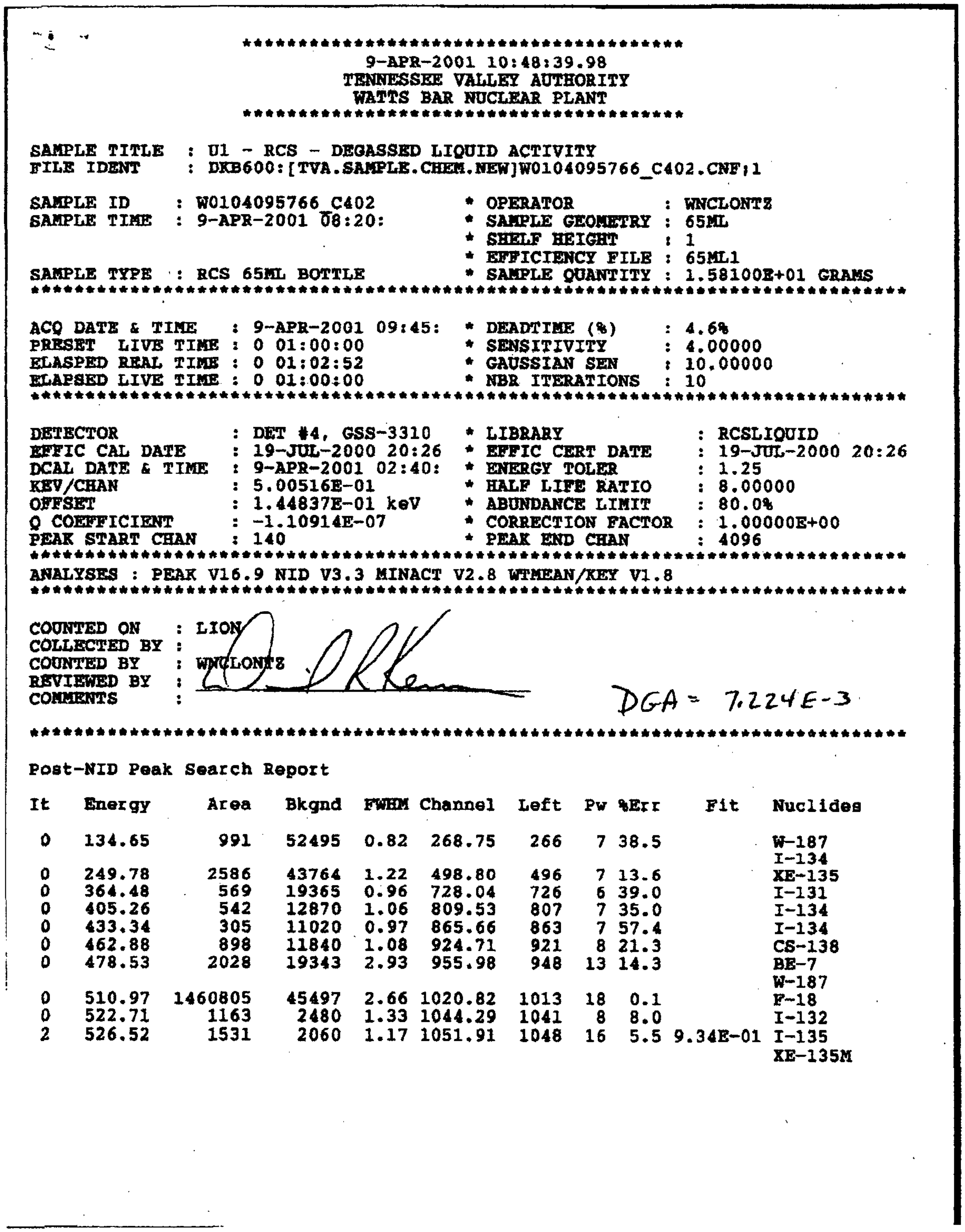
COUNTED ON     : LION
COLLECTED BY :
COUNTED BY     : WNCLONTZ
REVIEWED BY    :
COMMENTS       :                                    DGA = 7.224E-3

******************************************************************************

Post-NID Peak Search Report

It   Energy       Area     Bkgnd  FWHM Channel   Left  Pw %Err      Fit    Nuclides

 0   134.65        991     52495  0.82  268.75    266   7 38.5              W-187
                                                                            I-134
 0   249.78       2586     43764  1.22  498.80    496   7 13.6              XE-135
 0   364.48        569     19365  0.96  728.04    726   6 39.0              I-131
 0   405.26        542     12870  1.06  809.53    807   7 35.0              I-134
 0   433.34        305     11020  0.97  865.66    863   7 57.4              I-134
 0   462.88        898     11840  1.08  924.71    921   8 21.3              CS-138
 0   478.53       2028     19343  2.93  955.98    948  13 14.3              BE-7
                                                                            W-187
 0   510.97    1460805     45497  2.66 1020.82   1013  18  0.1              F-18
 0   522.71       1163      2480  1.33 1044.29   1041   8  8.0              I-132
 2   526.52       1531      2060  1.17 1051.91   1048  16  5.5 9.34E-01 I-135
                                                                            XE-135M
```



```
                  ****************************************
                        9-APR-2001 10:48:39.98
                      TENNESSEE VALLEY AUTHORITY
                       WATTS BAR NUCLEAR PLANT
                  ****************************************

SAMPLE TITLE  : U1 - RCS - DEGASSED LIQUID ACTIVITY
FILE IDENT    : DKB600:[TVA.SAMPLE.CHEM.NEW]W0104095766_C402.CNF;1

SAMPLE ID     : W0104095766_C402         * OPERATOR        : WNCLONTZ
SAMPLE TIME   : 9-APR-2001 08:20:        * SAMPLE GEOMETRY : 65ML
                                         * SHELF HEIGHT    : 1
                                         * EFFICIENCY FILE : 65ML1
SAMPLE TYPE   : RCS 65ML BOTTLE          * SAMPLE QUANTITY : 1.58100E+01 GRAMS
*******************************************************************************

ACQ DATE & TIME    : 9-APR-2001 09:45:   * DEADTIME (%)    : 4.6%
PRESET  LIVE TIME  : 0 01:00:00          * SENSITIVITY     : 4.00000
ELASPED REAL TIME  : 0 01:02:52          * GAUSSIAN SEN    : 10.00000
ELAPSED LIVE TIME  : 0 01:00:00          * NBR ITERATIONS  : 10
*******************************************************************************

DETECTOR           : DET #4, GSS-3310    * LIBRARY            : RCSLIQUID
EFFIC CAL DATE     : 19-JUL-2000 20:26   * EFFIC CERT DATE    : 19-JUL-2000 20:26
DCAL DATE & TIME   : 9-APR-2001 02:40:   * ENERGY TOLER       : 1.25
KEV/CHAN           : 5.00516E-01         * HALF LIFE RATIO    : 8.00000
OFFSET             : 1.44837E-01 keV     * ABUNDANCE LIMIT    : 80.0%
Q COEFFICIENT      : -1.10914E-07        * CORRECTION FACTOR  : 1.00000E+00
PEAK START CHAN    : 140                 * PEAK END CHAN      : 4096
*******************************************************************************
ANALYSES : PEAK V16.9 NID V3.3 MINACT V2.8 WTMEAN/KEY V1.8
*******************************************************************************

COUNTED ON    : LION
COLLECTED BY  :
COUNTED BY    : WNCLONTZ
REVIEWED BY   :
COMMENTS      :

*******************************************************************************

Post-NID Peak Search Report

It   Energy      Area    Bkgnd  FWHM Channel   Left   Pw %Err      Fit    Nuclides

 0   134.65       991    52495  0.82  268.75    266    7 38.5              W-187
                                                                           I-134
 0   249.78      2586    43764  1.22  498.80    496    7 13.6              XE-135
 0   364.48       569    19365  0.96  728.04    726    6 39.0              I-131
 0   405.26       542    12870  1.06  809.53    807    7 35.0              I-134
 0   433.34       305    11020  0.97  865.66    863    7 57.4              I-134
 0   462.88       898    11840  1.08  924.71    921    8 21.3              CS-138
 0   478.53      2028    19343  2.93  955.98    948   13 14.3              BE-7
                                                                           W-187
 0   510.97   1460805    45497  2.66 1020.82   1013   18  0.1              F-18
 0   522.71      1163     2480  1.33 1044.29   1041    8  8.0              I-132
 2   526.52      1531     2060  1.17 1051.91   1048   16  5.5 9.34E-01 I-135
                                                                           XE-135M
```

DGA = 7.224E-3

```
REPORT NAME : QA_CHECK (V10.4)                          PAGE :     1
REPORT DATE :  9-APR-2001 10:48
REQUESTOR   : WNCLONTZ

                    TENNESSEE VALLEY AUTHORITY
                     WATTS BAR NUCLEAR PLANT

                       POST NID QA ANALYSIS

TITLE : U1 - RCS - DEGASSED LIQUID ACTIVITY

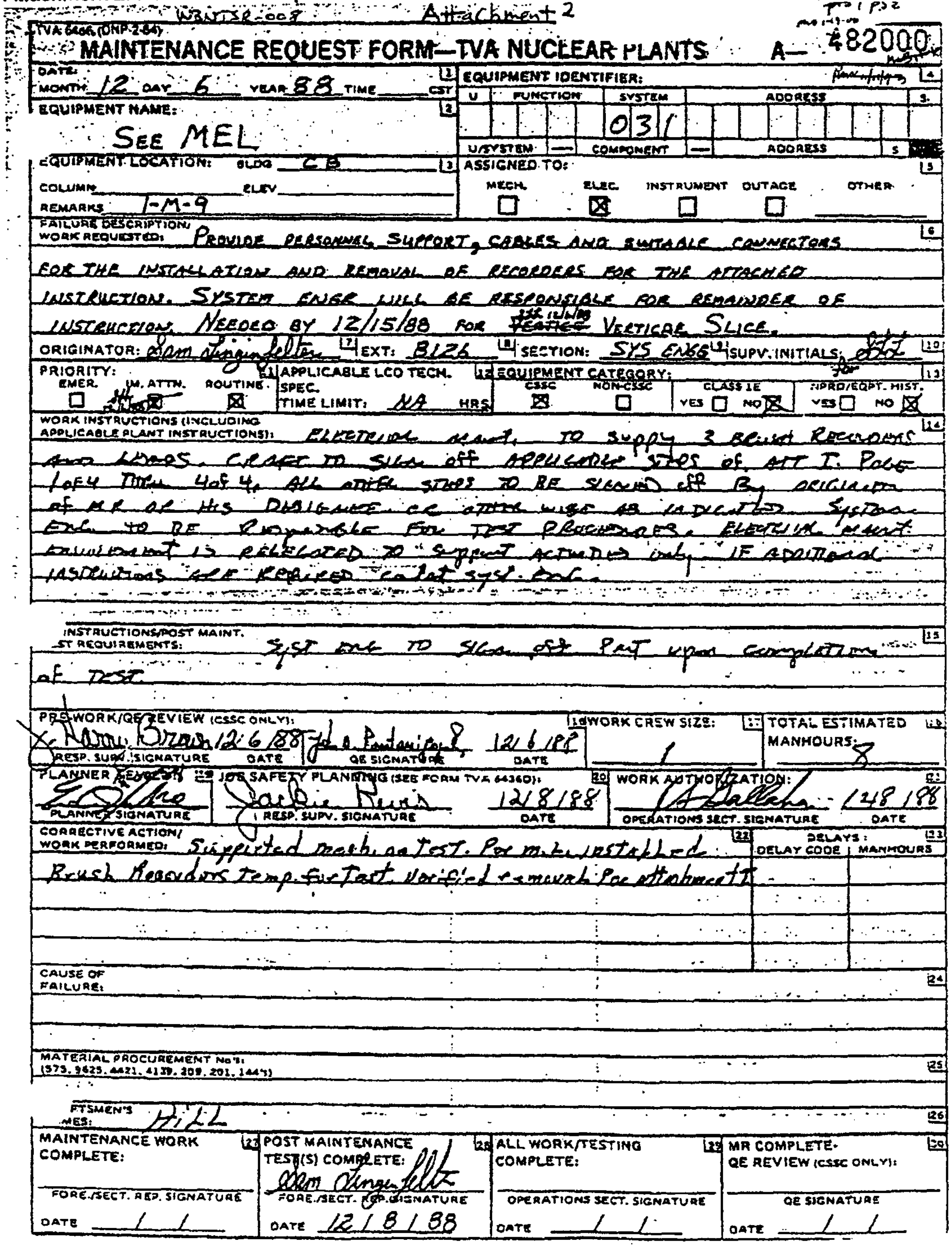
SAMPLE No.  : W0104095766_C402       OPERATOR NAME   : WNCLONTZ
SAMPLE TYPE : RCS 65ML BOTTLE        SAMPLE GEOMETRY : 65ML
COUNT TIME  : 9-APR-2001 09:45:36.   SAMPLE QUANTITY : 1.58100E+01
SAMPLE TIME : 9-APR-2001 08:20:00.   DETECTOR        : DET #4, GSS-3310
LIBRARY     : RCSLIQUID

            PEAK     ENERGY     DECAY CORR
 ISOTOPE   ENERGY  DIFF (KEV)   uCi/GRAM         COMMENTS
 -------   ------  ----------   ----------  ------------------------
  F-18     511.00    -0.03      1.116E-01         QA Results OK
  NA-24   1368.53     0.05      2.060E-03         QA Results OK
  MN-56   1810.69     0.33      2.088E-04         QA Results OK
  CO-58    810.76     0.00      6.218E-04         QA Results OK
  CO-60   1173.22     0.28      2.776E-05         QA Results OK
  NB-95    765.79     0.46      2.794E-05         QA Results OK
  I-131    364.48     0.00      3.881E-05         QA Results OK
  I-132    667.69     0.00      1.165E-03         QA Results OK
  I-133    529.87     0.01      6.105E-04         QA Results OK
  I-134    847.03    -0.04      2.334E-03         QA Results OK
  I-135   1260.41    -0.03      1.158E-03         QA Results OK
  XE-135   249.79    -0.02      1.380E-04         QA Results OK
  XE-135M  526.56    -0.04      1.972E-02         QA Results OK
  CS-138  1435.86    -0.20      2.195E-03         QA Results OK
                     -----      ---------
  AVG ENERGY DIFF =   0.06      1.419E-01 = TOTAL GAMMA ACTIVITY
                                1.168E-01 = Total DGL Activity
                                2.223E-03 = Total FP Activity
                                2.918E-03 = Total AP Activity
                                1.986E-02 = Total Gas Activity
                                5.307E-03 = Total HFP Activity


 Dose Equivalent Iodine-131 =  2.098E-04
 Iodine 131/133 Ratio =  6.357E-02
 Iodine 133/135 Ratio =  5.274E-01


 134.65 KeV Peak was used in identifying  2 isotopes
 478.53 KeV Peak was used in identifying  2 isotopes
 526.52 KeV Peak was used in identifying  2 isotopes
 546.50 KeV Peak was used in identifying  2 isotopes
 766.25 KeV Peak was used in identifying  2 isotopes
 772.62 KeV Peak was used in identifying  2 isotopes
 810.76 KeV Peak was used in identifying  2 isotopes
 835.61 KeV Peak was used in identifying  2 isotopes
 846.98 KeV Peak was used in identifying  2 isotopes
```

Attachment 2: Maintenance Request Form A-482000



WBNTSR-008 Attachment 2

TVA 6406 (ONP-2-84)

MAINTENANCE REQUEST FORM—TVA NUCLEAR PLANTS A— 482000

DATE: MONTH 12 DAY 6 YEAR 88 TIME ____ CST [1]

EQUIPMENT IDENTIFIER: [4]

U	FUNCTION	SYSTEM	ADDRESS	S
		031		

EQUIPMENT NAME: SEE MEL [2]

EQUIPMENT LOCATION: BLDG CB [3]

COLUMN ____ ELEV ____

REMARKS 1-M-9

ASSIGNED TO: [5] MECH. ☐ ELEC. ☒ INSTRUMENT ☐ OUTAGE ☐ OTHER ____

FAILURE DESCRIPTION/WORK REQUESTED: PROVIDE PERSONNEL SUPPORT, CABLES AND SUITABLE CONNECTORS FOR THE INSTALLATION AND REMOVAL OF RECORDERS FOR THE ATTACHED INSTRUCTION. SYSTEM ENGR WILL BE RESPONSIBLE FOR REMAINDER OF INSTRUCTION. NEEDED BY 12/15/88 FOR ~~[illegible]~~ VERTICAL SLICE. [6]

ORIGINATOR: Sam Lingenfelter [7] EXT: 8126 [8] SECTION: SYS ENGG [9] SUPV. INITIALS: [10]

PRIORITY: [11] EMER. ☐ IM. ATTN. ☐ ROUTINE ☒

APPLICABLE LCO TECH. SPEC. TIME LIMIT: NA HRS [12]

EQUIPMENT CATEGORY: [13] CSSC ☒ NON-CSSC ☐ CLASS 1E YES ☐ NO ☒ NPRD/EQPT. HIST. YES ☐ NO ☒

WORK INSTRUCTIONS (INCLUDING APPLICABLE PLANT INSTRUCTIONS): ELECTRICAL MAINT. TO SUPPLY 3 BRUSH RECORDERS AND LEADS. CRAFT TO SIGN OFF APPLICABLE STEPS OF ATT I. PAGE 1 OF 4 THRU 4 OF 4. ALL OTHER STEPS TO BE SIGNED OFF BY ORIGINATOR OF MR OR HIS DESIGNEE OR OTHERWISE AS INDICATED. SYSTEM ENG TO BE RESPONSIBLE FOR TEST PROCEDURES. ELECTRICAL MAINT. INVOLVEMENT IS RELEGATED TO "SUPPORT ACTIVITIES" ONLY. IF ADDITIONAL INSTRUCTIONS ARE REQUIRED CONTACT SYST. ENG. [14]

INSTRUCTIONS/POST MAINT. TEST REQUIREMENTS: Syst Eng to sign off Part upon completion of Test. [15]

PRE-WORK/QE REVIEW (CSSC ONLY): [16]

	12/6/88		12/6/88
RESP. SUPV. SIGNATURE	DATE	QE SIGNATURE	DATE

WORK CREW SIZE: 1 [17]

TOTAL ESTIMATED MANHOURS: 8 [18]

PLANNER REVIEW [19]	JOB SAFETY PLANNING (SEE FORM TVA 6436D): [20]		WORK AUTHORIZATION: [21]	
	Jackie Davis	12/8/88		12/8/88
PLANNER SIGNATURE	RESP. SUPV. SIGNATURE	DATE	OPERATIONS SECT. SIGNATURE	DATE

CORRECTIVE ACTION/WORK PERFORMED: Supported mech. on Test. Per M.I. installed Brush Recorders temp. for Test. Verified removal per attachment II - [22]

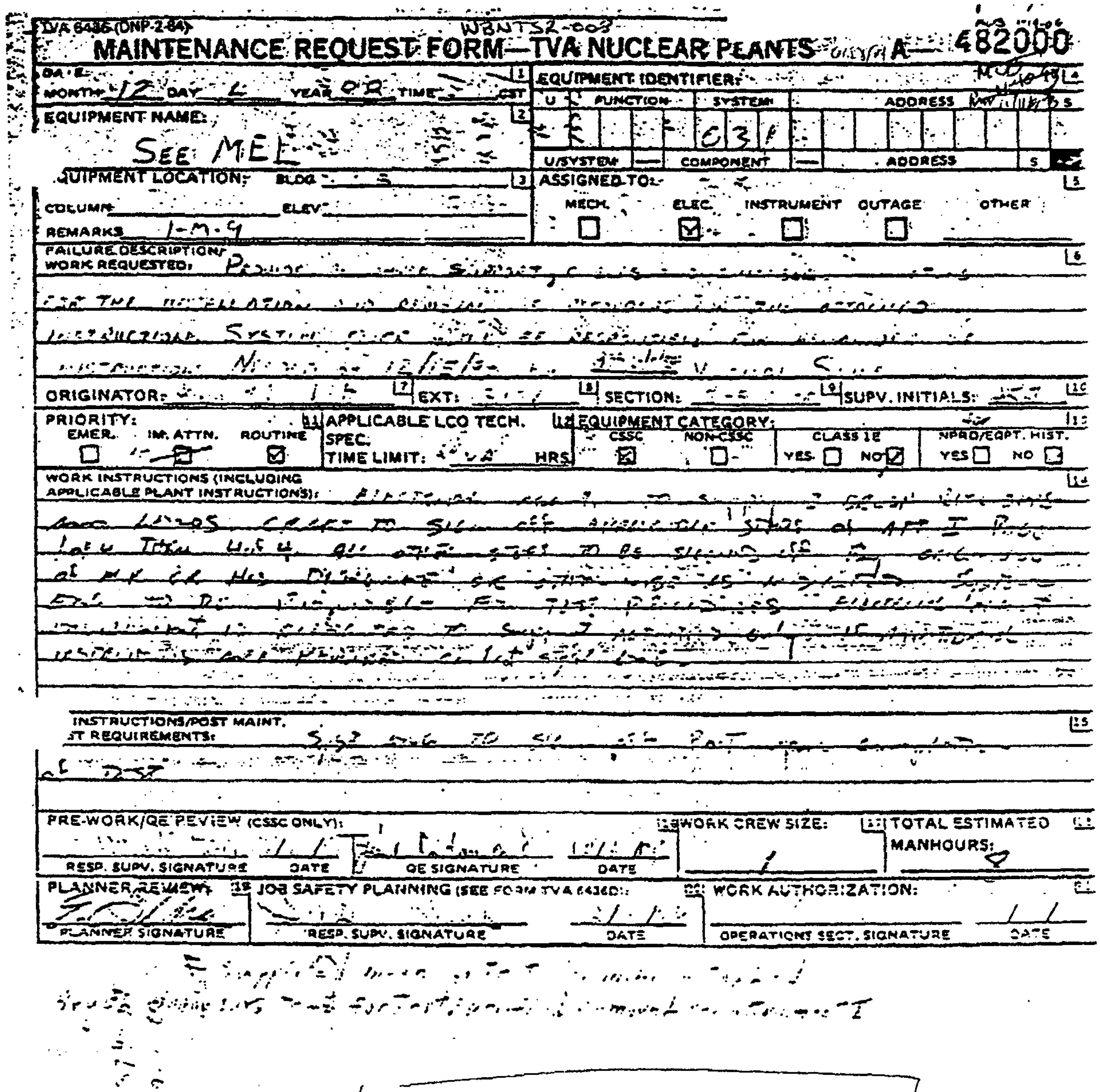
DELAYS: DELAY CODE | MANHOURS [23]

CAUSE OF FAILURE: [24]

MATERIAL PROCUREMENT No's: (575, 5425, 6421, 4139, 309, 201, 1447) [25]

CRAFTSMEN'S NAMES: HILL [26]

MAINTENANCE WORK COMPLETE: [27]	POST MAINTENANCE TEST(S) COMPLETE: [28]	ALL WORK/TESTING COMPLETE: [29]	MR COMPLETE- QE REVIEW (CSSC ONLY): [30]
	Sam Lingenfelter		
FORE./SECT. REP. SIGNATURE	FORE./SECT. REP. SIGNATURE	OPERATIONS SECT. SIGNATURE	QE SIGNATURE
DATE / /	DATE 12/8/88	DATE / /	DATE / /



TVA 6436 (DNP-2-84) WBNTS2-008

MAINTENANCE REQUEST FORM—TVA NUCLEAR PLANTS A 482000

DATE: MONTH 12 DAY 4 YEAR 82 TIME [illegible] CST

EQUIPMENT NAME: SEE MEL

EQUIPMENT IDENTIFIER: U FUNCTION SYSTEM 031 ADDRESS S

U/SYSTEM — COMPONENT — ADDRESS S

EQUIPMENT LOCATION: BLDG [illegible]

COLUMN ELEV

REMARKS 1-M-9

ASSIGNED TO: MECH. ☐ ELEC. ☑ INSTRUMENT ☐ OUTAGE ☐ OTHER

FAILURE DESCRIPTION/WORK REQUESTED: [illegible]

ORIGINATOR: [illegible] EXT: [illegible] SECTION: [illegible] SUPV. INITIALS: [illegible]

PRIORITY: EMER. ☐ IM. ATTN. ☐ ROUTINE ☑

APPLICABLE LCO TECH. SPEC. TIME LIMIT: NA HRS.

EQUIPMENT CATEGORY: CSSC ☒ NON-CSSC ☐ CLASS 1E YES ☐ NO ☑ NPRD/EQPT. HIST. YES ☐ NO ☐

WORK INSTRUCTIONS (INCLUDING APPLICABLE PLANT INSTRUCTIONS): [illegible]

INSTRUCTIONS/POST MAINT. TEST REQUIREMENTS: [illegible]

PRE-WORK/QE REVIEW (CSSC ONLY): RESP. SUPV. SIGNATURE DATE QE SIGNATURE DATE

WORK CREW SIZE: 1

TOTAL ESTIMATED MANHOURS: 4

PLANNER REVIEW: PLANNER SIGNATURE

JOB SAFETY PLANNING (SEE FORM TVA 6436D): RESP. SUPV. SIGNATURE DATE

WORK AUTHORIZATION: OPERATIONS SECT. SIGNATURE DATE

BEST Available Copy
MCB 3/9/89

WBN
AI-9.2
Appendix E
Page 1 of 1
Revision 19

MULTIPLE EQUIPMENT LIST

NOTE:

This form is also used to maintain traceability for QA Levels I & II equipment when components are moved from one location to another.

MR# A 482000

Page 1 of 1

EQUIPMENT IDENTIFIER				EQUIPMENT NAME	EQUIPMENT LOCATION
UNIT	FUNCTION	SYSTEM	ADDRESS		
0	FCV	31	3-A	MCRHZ Iso. Damper	Control Bldg
0	FCV	31	4-B	" "	" "
0	FCO	31	9-B	" "	" "
0	FCO	31	10-A	" "	" "
0	FCO	31	16-B	" "	" "
0	FCO	31	17-A	" "	" "
0	FCO	31	25	" "	" "
0	FCO	31	26	" "	" "
0	FCV	31	36-B	" "	" "
0	FCV	31	37-A	" "	" "
0	FCV	31	204	" "	" "

p.55
MLD 1-14-10

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MR 482000
PAGE 1 OF 9

1) CONNECT 3 BRUSH RECORDERS ON 1-M-9 AS SPECIFIED IN ATTACHMENT 1. VERIFY CONNECTIONS COMPLETED / 12/8/88

2) ENSURE THE FOLLOWING SYSTEM LINE-UP.

CONTROL BLDG PRESS FAN A-A OR B-B	ON	/12/8/88
MCR AHU A-A OR B-B	ON	/12/8/88
SPREADING RM SUPPLY FAN	ON	/12/8/88
SPREADING RM EXH FAN A-A	ON	/12/8/88
SPREADING RM EXH FAN B-B	ON	/12/8/88
SMOKE REMOVAL FAN (FROM HS-31-204)	ON	/12/8/88
FCV-31-3	OPEN	/12/8/88
FCV-31-4	OPEN	/12/8/88
FCO-31-9	OPEN	/12/8/88
FCO-31-10	OPEN	/12/8/88
FCO-31-16	OPEN	/12/8/88
FCO-31-17	OPEN	/12/8/88
FCO-31-25	OPEN	/12/8/88
FCO-31-26	OPEN	/12/8/88
FCV-31-36	OPEN	/12/8/88
FCV-31-37	OPEN	/12/8/88
FCV-31-204	OPEN	/12/8/88

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*p.56
MB 1-19-06

MR 482000
PAGE 2 OF 9

3) ESTABLISH COMMUNICATION WITH PERSON STATIONED AT FCV-31-204 / 12/8/88

4) START STRIP RECORDERS 1 AND 3. / 12/8/88

5) INITIATE A-TRAIN CRI BY 1-HS-31-177A / 12/8/88

6) VERIFY THE FOLLOWING DAMPERS CLOSE.

FCV-31-3 / 12/8/88
FCO-31-10 / 12/8/88
FCO-31-17 / 12/8/88
FCO-31-25 / 12/8/88
FCO-31-26 / 12/8/88
FCV-31-37 / 12/8/88
FCV-31-204 / 12/8/88

7) STOP RECORDERS 1 AND 3 / 12/8/88

8) RECORD FCV-31-204 CLOSURE TIME AND M&TE DATA.

STOPWATCH ID # 902597
CAL DUE DATE 7-14-89
CLOSURE TIME 8.48 SEC
DATA TAKEN BY Robert S Bartlett / 12/8/88

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PAGE 3 OF 9

9) RESET 1-HS-31-177A
/12/8/88

10) REINSTATE THE FOLLOWING SYSTEM LINEUP

CONTROL BLDG PRESS. FAN A-A OR B-B ON /12/8/88
SPREADING RM EXH FAN A-A ON /12/8/88
SPREADING RM EXH FAN B-B ON /12/8/88
SPREADING RM SUPPLY FAN ON /12/8/88
SMOKE REMOVAL FAN (FROM HS-31-204) ON /12/8/88
FCV-31-3 OPEN /12/8/88
FCO-31-25 OPEN /12/8/88
FCO-31-26 OPEN /12/8/88
FCO-31-10 OPEN /12/8/88
FCO-31-17 OPEN /12/8/88
FCV-31-37 OPEN /12/8/88
FCV-31-204 OPEN /12/8/88

11) ESTABLISH COMMUNICATION WITH PERSON STATIONED AT FCV-31-204
/12/8/88

12) START RECORDERS 2 AND 3
/12/8/88

MVB 11-9-06
MR- 482000
PAGE 4 OF 9

13) INITIATE B-TRAIN CRI BY 1-HS-31-177B
/ 12/8/88

~~p. 63 5/68~~ MVB 11/09

14) VERIFY THE FOLLOWING DAMPERS CLOSE ~~p. 36~~ ~~p. 39 MVB 1-15~~ p. 64 p. 65 MVB 3.2

FCV-31-4 / 12/8/88
FCO-31-9 / 12/8/88
FCO-31-16 / 12/8/88
FCO-31-25 / 12/8/88
FCO-31-26 / 12/8/88
FCV-31-36 / 12/8/88
FCV-31-204 / 12/8/88

15) STOP RECORDERS 2 AND 3
/ 12/8/88

16) RECORD FCV-31-204 CLOSURE TIME AND M&TE DATA
STOPWATCH ID # 902597
CAL DUE DATE 7-14-89
CLOSURE TIME 8.22 SEC.
DATA TAKEN BY Robert S Bralett 12/8/88

17) RESET 1-HS-31-177B
/ 12/8/88

MR- 482000 MCB 1-14-06
PAGE 5 of 9

18) RETURN CONTROL OF SYSTEM TO OPERATIONS TO BE ALIGNED AT THEIR DISCRETION.
/ 12-8-88
OPERATIONS

19) RECORD THE CLOSURE TIME FOR THE FOLLOWING DAMPERS AS MEASURED BY THE STRIP CHARTS. (EXCEPT FCV-31-204 WHICH WAS MEASURED BY STOPWATCH)

A-TRAIN CRI		B-TRAIN CRI	
FCV-31-3	12.43 SEC	FCV-31-4	13.15 SEC
FCO-31-10	9.64 SEC	FCO-31-9	10.94 SEC
FCO-31-17	16.3 SEC	FCO-31-16	7.64 SEC
FCV-31-37	13.56 SEC	FCO-31-36	12.32 SEC
FCO-31-25	8.60 SEC	FCO-31-25	8.57 SEC
FCO-31-26	6.56 SEC	FCO-31-26	6.44 SEC
FCV-31-204	8.48 SEC	FCV-31-204	8.22 SEC

DATA RECORDED BY / 12/8/88

20) ATTACH STRIP CHARTS TO THIS MR. RECORD MR NUMBER ON THE CHARTS.
/ 12/8/88

21) REMOVE TEST EQUIPMENT AS LISTED IN ATTACHMENT 1. SECOND PERSON VERIFICATION IS REQUIRED.
VERIFY ATTACHMENT 1 COMPLETED / 12/8/88

ATTACHMENT 1
Page 1 of 4

1 p.00
MCB 1-19-06

MR# 482000
Page 6 of 9

PERFORMERS:

SIGNATURE	INTITIAL
Robert S Brackett	RSB
James S Hill	
Sam Lingenfelter	

ATTACHMEN, 1
Age 2 of 4

RECORDER 1 ID# 434858
Calibration Due Date 7-7-89
Verified By R.S. Brockett

MR # 482000
PAGE 7 OF 9

CHANNEL	COMPONENT	RISER	STRIP	WIRE	TERM.	PERFORMED BY/Date	Removed By/Date	2nd Rch/Date REMOVAL
ONE	1-HS-31-177A	A2	A2-3 Cable 1 12/8/88 RSB	VRD1	7	12/7/88	12-8-88	RSB 12/8/88
				VKDL	6	12/7/88	12-8-88	RSB 12/8/88
TWO	0-FCV-31-3	3	3-4L Cable 2 RSB 12/8/88	VKGY	3 Dum	12/7/88	12-8-88	RSB 12/8/8
				VKG22	11	12/7/88	12-8-88	RSB 12/8/8
THREE	0-FCO-31-10	3	3-4M Cable 3 RSB 12/8/88	VKG24	1	12/7/88	12-8-88	RSB 12/8/8
				VKGY	7 Dom	12/7/88	12-8-88	RSB 12/8/8
FOUR	0-FCO-31-17	3	3-4M Cable 4 RSB 12/8/88	VKG26	4	12/7/88	12-8-88	RSB 12/8/8
				VKGY	7 Dom	12/7/88	12-8-88	RSB 12/8/88
FIVE	0-FCV-31-37	3	3-4M Cable 5 RSB 12/8/88	VKG16	12	12/7/88	12-8-88	RSB 12/8/8
				VKGY	7 Dom	12/7/88	12-8-88	RSB 12/8/88

NOTE: IF ANY CHANNEL BECOMES INOPERABLE, THEN THE SPARE(S) MAY BE USED. ENSURE THIS IS NOTED BY SINGLE LINE, INITIAL AND DATE THROUGH THE INOPERABLE CHANNEL, AND SPECIFYING WHICH CHANNEL IS USED.

ATTACHMENT 1
Page 3 of 4

RECORDER 2 ID# 434857
Calibration Due Date 8-31-89
Verified By R.S. Bragstoff

MR # 482000
PAGE 8 OF 9

CHANNEL	COMPONENT	RISER	STRIP	WIRE	TERM	PERFORMED BY/Date		Removed BY/Date		2nd Party/Date Removal	
ONE	1-HS-31-177B	B1	B1-29	VKEL	6	JAH	12/5/88	JAH	12/8/88	RSB	12/8/
		Cable 2 RSB 12/8/88		VKE1	7	JAH	12/5/88	JAH	12/8/88	RSB	12/8/
TWO	0-FCV-31-4	3	3-3N	VKH24	2	JAH	12/5/88	JAH	12/8/88	RSB	12/8/
		Cable 2 RSB 12/8/88	3-3M	VKHY com	3	JAH	12/5/88	JAH	12/8/88	RSB	12/8/
THREE	0-FCO-31-9	3	3-3N	VKH52	5	JAH	12/5/88	JAH	12/8/88	RSB	12/8/
		Cable 3 RSB 12/8/88	3-3M	VKHY com	9	JAH	12/5/88	JAH	12/8/88	RSB	12/8/
FOUR	0-FCO-31-16	3	3-3N	VKH54	7	JAH	12/5/88	JAH	12/8/88	RSB	12/8/
		Cable 4 RSB 12/8/88	3-3M	VKHY com	9	JAH	12/5/88	JAH	12/8/88	RSB	12/8/
FIVE	0-FCV-31-36	3	3-2M	VKH56	5	JAH	12/5/88	JAH	12/8/88	RSB	12/8/
		Cable 5 RSB 12/8/88		VKHY com	6	JAH	12/5/88	JAH	12/8/88	RSB	12/8/

NOTE: IF ANY CHANNEL BECOMES INOPERABLE, THEN THE SPARE(S) MAY BE USED. ENSURE THIS IS NOTED BY SINGLE LINE, INITIAL AND DATE THROUGH THE INOPERABLE CHANNEL, AND SPECIFYING WHICH CHANNEL IS USED.

ATTACHMENT 1
Page 4 of 4

RECORDER 3 ID # 379817
Calibration Due Date 9-1-89
Verified By R.S. Brackett

MR # 482000
PAGE 9 of 9

CHANNEL	COMPONENT	RISER	STRIP	WIRE	TERM	PERFORMED BY / Date	Removed By / Date	2nd Party / Date REMOVAL
ONE	1-HS-31-177A	A2	A2-3	VKD1	7	JAH / 12/5/88	JAH / 12-8-88	RSB / 12/8/88
			cable 3 RSB 8/8/88	VKDL	6	JAH / 12/5/88	JAH / 12-8-88	RSB / 12/8/88
TWO	1-HS-31-177B	B1	B1-29	VKEL	6	JAH / 12/5/88	JAH / 12-8-88	RSB / 12/8/88
			cable 4 RSB 8/8/88	VKE1	7	JAH / 12/5/88	JAH / 12-8-88	RSB / 12/8/88
THREE	0-FCO-31-25	3	3-2L	VKH4B	2	JAH / 12/5/88	JAH / 12-8-88	RSB / 12/8/88
				VKHY Com	3	JAH / 12/5/88	JAH / 12-8-88	RSB / 12/8/88
FOUR	0-FCO-31-26	3	3-2L	VKH5D	6	JAH / 12/5/88	JAH / 12-8-88	RSB / 12/8/88
				VKHY Com	9	JAH / 12/5/88	JAH / 12-8-88	RSB / 12/8/88

NOTE: IF ANY CHANNEL BECOMES INOPERABLE, THEN THE SPARE (S) MAY BE USED. ENSURE THIS IS NOTED BY SINGLE LINE, INITIAL AND DATE THROUGH THE INOPERABLE CHANNEL, AND SPECIFYING WHICH CHANNEL IS USED.

Attachment 4

FENCDOSE Run

TSR8F11Aout.txt

Time Dependent Releases
21 uCi/g I-131 equivalent preaccident Iodine
spiking case

```
1
          FFFFFFFFFF  EEEEEEEEEE  NN      NN    CCCCCC    DDDDDDDD      OOOOOO
SSSSSS    EEEEEEEEEE
          FFFFFFFFFF  EEEEEEEEEE  NNN     NN   CCCCCCCC   DDDDDDDDD    OOOOOOOO
SSSSSSSS   EEEEEEEEEE
          FF          EE          NNNN    NN  CC      CC  DD      DD  OO      OO  SS
     SS  EE
          FF          EE          NN NN   NN  CC          DD      DD  OO      OO  SS
         EE
          FFFFFFFF    EEEEEEEE    NN  NN  NN  CC          DD      DD  OO      OO
SSSSSSSSS  EEEEEEEE
          FFFFFFFF    EEEEEEEE    NN   NN NN  CC          DD      DD  OO      OO
SSSSSSSSS  EEEEEEEE
          FF          EE          NN    NNNN  CC          DD      DD  OO      OO
     SS  EE
          FF          EE          NN     NNN  CC      CC  DD      DD  OO      OO  SS
     SS  EE
          FF          EEEEEEEEEE  NN      NN   CCCCCCCC   DDDDDDDDD    OOOOOOOO
SSSSSSSS   EEEEEEEEEE
          FF          EEEEEEEEEE  NN      NN    CCCCCC    DDDDDDDD      OOOOOO
SSSSSS    EEEEEEEEEE

          RRRRRRRR    EEEEEEEEEE  VV      VV              5555555555

          RRRRRRRRR   EEEEEEEEEE  VV      VV              5555555555

          RR      RR  EE           VV    VV               55

          RR      RR  EE           VV    VV               55

          RRRRRRRRR   EEEEEEEE      VV  VV                 5555555

          RRRRRRRR    EEEEEEEE      VV  VV                  5555555

          RR   RR     EE             VVVV                         55

          RR    RR    EE             VVVV                 55      55

          RR     RR   EEEEEEEEEE      VV                   55555555

          RR      RR  EEEEEEEEEE      VV                    555555


          WW      WW    IIIIII    NN      NN    999999    5555555555  NN      NN
QQQQQQ      AAAAAA
          WW      WW    IIIIII    NNN     NN   99999999   5555555555  NNN     NN
QQQQQQQQ   AAAAAAAA
          WW      WW      II      NNNN    NN  99      99  55          NNNN    NN  QQ
     QQ  AA      AA
          WW      WW      II      NN NN   NN  99      99  55          NN NN   NN  QQ
     QQ  AA      AA
          WW      WW      II      NN  NN  NN   999999999   5555555    NN  NN  NN  QQ
     QQ  AA      AA
          WW  WW  WW      II      NN   NN NN    99999999    5555555   NN   NN NN  QQ
  Q  QQ  AAAAAAAAAA
          WW WWWW WW      II      NN    NNNN          99          55  NN    NNNN  QQ
   Q QQ  AAAAAAAAAA
          WWWW  WWWW      II      NN     NNN  99      99  55      55  NN     NNN  QQ
    QQQ  AA      AA
          WWW    WWW    IIIIII    NN      NN   99999999    55555555   NN      NN
QQQQQQQQ   AA      AA
```

```
          WW      WW    IIIIII    NN      NN    999999      555555    NN      NN
QQQQQQ Q  AA      AA


            00000         11              //      11          11              //
 11        00000
           0000000       111             //      111         111             //
111       0000000
          00     00     1111            //      1111        1111            //
1111      00     00
          00     00       11           //         11          11           //
 11      00     00
          00     00       11          //          11          11          //
 11      00     00
          00     00       11         //           11          11         //
 11      00     00
          00     00       11        //            11          11        //
 11      00     00
          00     00       11       //             11          11       //
 11      00     00
           0000000      111111    //            111111      111111    //
111111     0000000
            00000       111111    /             111111      111111    /
111111      00000


              11        888888                  222222      222222
00000       00000
             111       88888888                22222222    22222222
0000000     0000000
            1111      88      88      ::      22      22  22      22      ::      00
    00   00      00
              11      88      88      ::              22          22      ::      00
    00   00      00
              11       88888888                 2222222     2222222               00
    00   00      00
              11       88888888                2222222     2222222                00
    00   00      00
              11      88      88      ::      22          22              ::      00
    00   00      00
              11      88      88      ::      22          22              ::      00
    00   00      00
            111111     88888888               2222222222  2222222222
0000000     0000000
            111111      888888                2222222222  2222222222
00000       00000

1


1
 REPRODUCTION OF INPUT DATA DECK


 +         +         +         +         +         +         +         +

 1
 KRM-83  KRM-85  KR-85
 KR-87   KR-88   KR-89
 XEM-131 XEM-133 XE-133 XEM-135 XE-135 XE-138
 I-131   I-132   I-133  I-134   I-135
```

```
I*-131  I*-132  I*-133 I*-134  I*-135  H-3
T
.141E-3  .668E-4  .459E-4  .204E-4  .635E-5  6.07E-4
STEAM GENERATER TUBE RUPTURE ACCIDENT
TIME TO 133.6 SEC
    4  'ENVIRONMENT                        ' $ TN=  0.3711E-01
         1 0.000E+00    2 2.364E+00    3 3.697E+00    4 2.196E+00    5 4.135E+00
         6 0.000E+00    7 9.090E+00    8 9.963E-01    9 3.516E+01   10 2.085E+00
        11 1.259E+01   12 1.622E+00   13 3.742E+00   14 1.747E+01   15 1.168E+01
        16 2.779E+01   17 2.173E+01   18 0.000E+00   19 0.000E+00   20 0.000E+00
        21 0.000E+00   22 0.000E+00   23 4.712E+01
STEAM GENERATER TUBE RUPTURE ACCIDENT
TIME TO 2 HOUR
    4  'ENVIRONMENT                        ' $ TN=  0.2000E+01
         1 0.000E+00    2 1.462E+02    3 2.689E+02    4 9.306E+01    5 2.328E+02
         6 0.000E+00    7 6.593E+02    8 7.176E+01    9 2.548E+03   10 2.783E+02
        11 9.751E+02   12 1.538E+01   13 3.186E+01   14 1.328E+02   15 9.824E+01
        16 1.796E+02   17 1.778E+02   18 0.000E+00   19 0.000E+00   20 0.000E+00
        21 0.000E+00   22 0.000E+00   23 3.434E+03
STEAM GENERATER TUBE RUPTURE ACCIDENT
TIME TO 8 HOUR
    4  'ENVIRONMENT                        ' $ TN=  0.8000E+01
         1 0.000E+00    2 2.348E+01    3 7.488E+01    4 4.758E+00    5 2.765E+01
         6 0.000E+00    7 1.820E+02    8 1.948E+01    9 7.039E+02   10 1.003E+02
        11 3.507E+02   12 6.510E-03   13 1.752E+00   14 1.990E+00   15 4.681E+00
        16 5.361E-01   17 6.088E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
        21 0.000E+00   22 0.000E+00   23 9.564E+02
WBN SGTR
TIME TO 1 DAY
   -6  'ENVIRONMENT          CURIES        ' $ TN=  0.2400E+02
         1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
         6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
        11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
        16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
        21 0.000E+00   22 0.000E+00   23 0.000E+00
WBN SGTR
TIME TO 4 DAYS
   -6  'ENVIRONMENT          CURIES        ' $ TN=  0.9600E+02
         1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
         6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
        11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
        16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
        21 0.000E+00   22 0.000E+00   23 0.000E+00
WBN SGTR
TIME TO 30 DAYS
   -6  'ENVIRONMENT          CURIES        ' $ TN=  0.7200E+03
         1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
         6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
        11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
        16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
        21 0.000E+00   22 0.000E+00   23 0.000E+00

+         +         +         +         +         +         +         +


1                                                         PROGRAM FENCDOSE
0                                                        REVISION NUMBER:5
0                                                   REVISION DATE: 31 JUL 2009
0                                                        TODAY IS: 01/11/10
0                                                   STARTING TIME IS: 18:22:00
```

```
1ISOTOPE        GAMMA ENERGY    BETA ENERGY
                   (MEV/DIS)      (MEV/DIS)
 KRM-83             0.0025         0.0371
 KRM-85             0.1586         0.2529
 KR-85              0.0022         0.2506
 KR-87              0.7928         1.3237
 KR-88              1.9629         0.3750
 KR-89              2.0837         1.2310
 XEM-131            0.0201         0.1428
 XEM-133            0.0416         0.1898
 XE-133             0.0454         0.1354
 XEM-135            0.4318         0.0950
 XE-135             0.2470         0.3168
 XE-138             1.1830         0.6058
 I-131              0.3810         0.1943
 I-132              2.3332         0.5143
 I-133              0.6100         0.4080
 I-134              2.5928         0.6102
 I-135              1.5802         0.3680
 I*-131             0.3810         0.1943
 I*-132             2.3332         0.5143
 I*-133             0.6100         0.4080
 I*-134             2.5928         0.6102
 I*-135             1.5802         0.3680
 H-3                0.0000         0.0057


0CHI/Q
   1.410E-04   6.680E-05   4.590E-05   2.040E-05   6.350E-06
   6.070E-04


1
0STEAM GENERATER TUBE RUPTURE ACCIDENT
 TIME TO 133.6 SEC
 COMPONENT  4 ENVIRONMENT                         , TIME =  0.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.2364E+01
 KR-85          0.3697E+01
 KR-87          0.2196E+01
 KR-88          0.4135E+01
 KR-89          0.0000E+00
 XEM-131        0.9090E+01
 XEM-133        0.9963E+00
 XE-133         0.3516E+02
 XEM-135        0.2085E+01
 XE-135         0.1259E+02
 XE-138         0.1622E+01
 I-131          0.3742E+01
 I-132          0.1747E+02
 I-133          0.1168E+02
 I-134          0.2779E+02
 I-135          0.2173E+02
 I*-131         0.0000E+00
 I*-132         0.0000E+00
 I*-133         0.0000E+00
 I*-134         0.0000E+00
 I*-135         0.0000E+00
 H-3            0.4712E+02
0STEAM GENERATER TUBE RUPTURE ACCIDENT
 TIME TO 2 HOUR
```

```
 COMPONENT   4 ENVIRONMENT                              , TIME =   2.
 1ISOTOPE

 KRM-83          0.0000E+00
 KRM-85          0.1462E+03
 KR-85           0.2689E+03
 KR-87           0.9306E+02
 KR-88           0.2328E+03
 KR-89           0.0000E+00
 XEM-131         0.6593E+03
 XEM-133         0.7176E+02
 XE-133          0.2548E+04
 XEM-135         0.2783E+03
 XE-135          0.9751E+03
 XE-138          0.1538E+02
 I-131           0.3186E+02
 I-132           0.1328E+03
 I-133           0.9824E+02
 I-134           0.1796E+03
 I-135           0.1778E+03
 I*-131          0.0000E+00
 I*-132          0.0000E+00
 I*-133          0.0000E+00
 I*-134          0.0000E+00
 I*-135          0.0000E+00
 H-3             0.3434E+04
0STEAM GENERATER TUBE RUPTURE ACCIDENT
 TIME TO 8 HOUR
 COMPONENT   4 ENVIRONMENT                              , TIME =   8.
 1ISOTOPE

 KRM-83          0.0000E+00
 KRM-85          0.2348E+02
 KR-85           0.7488E+02
 KR-87           0.4758E+01
 KR-88           0.2765E+02
 KR-89           0.0000E+00
 XEM-131         0.1820E+03
 XEM-133         0.1948E+02
 XE-133          0.7039E+03
 XEM-135         0.1003E+03
 XE-135          0.3507E+03
 XE-138          0.6510E-02
 I-131           0.1752E+01
 I-132           0.1990E+01
 I-133           0.4681E+01
 I-134           0.5361E+00
 I-135           0.6088E+01
 I*-131          0.0000E+00
 I*-132          0.0000E+00
 I*-133          0.0000E+00
 I*-134          0.0000E+00
 I*-135          0.0000E+00
 H-3             0.9564E+03
0WBN SGTR
 TIME TO 1 DAY
 COMPONENT   6 ENVIRONMENT             CURIES           , TIME = 24.
 1ISOTOPE

 KRM-83          0.0000E+00
 KRM-85          0.0000E+00
 KR-85           0.0000E+00
 KR-87           0.0000E+00
```

```
 KR-88           0.0000E+00
 KR-89           0.0000E+00
 XEM-131         0.0000E+00
 XEM-133         0.0000E+00
 XE-133          0.0000E+00
 XEM-135         0.0000E+00
 XE-135          0.0000E+00
 XE-138          0.0000E+00
 I-131           0.0000E+00
 I-132           0.0000E+00
 I-133           0.0000E+00
 I-134           0.0000E+00
 I-135           0.0000E+00
 I*-131          0.0000E+00
 I*-132          0.0000E+00
 I*-133          0.0000E+00
 I*-134          0.0000E+00
 I*-135          0.0000E+00
 H-3             0.0000E+00
0WBN SGTR
 TIME TO 4 DAYS
 COMPONENT  6 ENVIRONMENT         CURIES        , TIME = 96.
 1ISOTOPE

 KRM-83          0.0000E+00
 KRM-85          0.0000E+00
 KR-85           0.0000E+00
 KR-87           0.0000E+00
 KR-88           0.0000E+00
 KR-89           0.0000E+00
 XEM-131         0.0000E+00
 XEM-133         0.0000E+00
 XE-133          0.0000E+00
 XEM-135         0.0000E+00
 XE-135          0.0000E+00
 XE-138          0.0000E+00
 I-131           0.0000E+00
 I-132           0.0000E+00
 I-133           0.0000E+00
 I-134           0.0000E+00
 I-135           0.0000E+00
 I*-131          0.0000E+00
 I*-132          0.0000E+00
 I*-133          0.0000E+00
 I*-134          0.0000E+00
 I*-135          0.0000E+00
 H-3             0.0000E+00
0WBN SGTR
 TIME TO 30 DAYS
 COMPONENT  6 ENVIRONMENT         CURIES        , TIME =720.
 1ISOTOPE

 KRM-83          0.0000E+00
 KRM-85          0.0000E+00
 KR-85           0.0000E+00
 KR-87           0.0000E+00
 KR-88           0.0000E+00
 KR-89           0.0000E+00
 XEM-131         0.0000E+00
 XEM-133         0.0000E+00
 XE-133          0.0000E+00
 XEM-135         0.0000E+00
 XE-135          0.0000E+00
```

```
 XE-138         0.0000E+00
 I-131          0.0000E+00
 I-132          0.0000E+00
 I-133          0.0000E+00
 I-134          0.0000E+00
 I-135          0.0000E+00
 I*-131         0.0000E+00
 I*-132         0.0000E+00
 I*-133         0.0000E+00
 I*-134         0.0000E+00
 I*-135         0.0000E+00
 H-3            0.0000E+00


1INPUT CONCENTRATION
 KRM-83       0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 KRM-85       1.4856E+02    2.3480E+01    0.0000E+00    0.0000E+00    0.0000E+00
 KR-85        2.7260E+02    7.4880E+01    0.0000E+00    0.0000E+00    0.0000E+00
 KR-87        9.5256E+01    4.7580E+00    0.0000E+00    0.0000E+00    0.0000E+00
 KR-88        2.3693E+02    2.7650E+01    0.0000E+00    0.0000E+00    0.0000E+00
 KR-89        0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 XEM-131      6.6839E+02    1.8200E+02    0.0000E+00    0.0000E+00    0.0000E+00
 XEM-133      7.2756E+01    1.9480E+01    0.0000E+00    0.0000E+00    0.0000E+00
 XE-133       2.5832E+03    7.0390E+02    0.0000E+00    0.0000E+00    0.0000E+00
 XEM-135      2.8038E+02    1.0030E+02    0.0000E+00    0.0000E+00    0.0000E+00
 XE-135       9.8769E+02    3.5070E+02    0.0000E+00    0.0000E+00    0.0000E+00
 XE-138       1.7002E+01    6.5100E-03    0.0000E+00    0.0000E+00    0.0000E+00
 I-131        3.5602E+01    1.7520E+00    0.0000E+00    0.0000E+00    0.0000E+00
 I-132        1.5027E+02    1.9900E+00    0.0000E+00    0.0000E+00    0.0000E+00
 I-133        1.0992E+02    4.6810E+00    0.0000E+00    0.0000E+00    0.0000E+00
 I-134        2.0739E+02    5.3610E-01    0.0000E+00    0.0000E+00    0.0000E+00
 I-135        1.9953E+02    6.0880E+00    0.0000E+00    0.0000E+00    0.0000E+00
 I*-131       0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 I*-132       0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 I*-133       0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 I*-134       0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 I*-135       0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 H-3          3.4811E+03    9.5640E+02    0.0000E+00    0.0000E+00    0.0000E+00

1WBN SGTR

0GAMMA DOSE FOR EACH ISOTOPE AND TIME PERIOD (REM)

   ID    ISOTOPE       0-2 HRS      2-8 HRS     8-24 HRS     1-4 DAYS     4-30 DAYS
2-HR EAB

   1     KRM-83      0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   2     KRM-85      8.307E-04    6.220E-05    0.000E+00    0.000E+00    0.000E+00
3.576E-03
   3     KR-85       2.124E-05    2.764E-06    0.000E+00    0.000E+00    0.000E+00
9.143E-05
   4     KR-87       2.662E-03    6.300E-05    0.000E+00    0.000E+00    0.000E+00
1.146E-02
   5     KR-88       1.639E-02    9.064E-04    0.000E+00    0.000E+00    0.000E+00
7.058E-02
   6     KR-89       0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   7     XEM-131     4.726E-04    6.096E-05    0.000E+00    0.000E+00    0.000E+00
2.034E-03
   8     XEM-133     1.066E-04    1.352E-05    0.000E+00    0.000E+00    0.000E+00
```

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4.588E-04
   9    XE-133        4.133E-03   5.335E-04   0.000E+00   0.000E+00   0.000E+00
1.779E-02
  10    XEM-135       4.267E-03   7.232E-04   0.000E+00   0.000E+00   0.000E+00
1.837E-02
  11    XE-135        8.598E-03   1.446E-03   0.000E+00   0.000E+00   0.000E+00
3.701E-02
  12    XE-138        7.090E-04   1.286E-07   0.000E+00   0.000E+00   0.000E+00
3.052E-03
  13    I-131         4.781E-04   1.115E-05   0.000E+00   0.000E+00   0.000E+00
2.058E-03
  14    I-132         1.236E-02   7.754E-05   0.000E+00   0.000E+00   0.000E+00
5.321E-02
  15    I-133         2.363E-03   4.768E-05   0.000E+00   0.000E+00   0.000E+00
1.017E-02
  16    I-134         1.895E-02   2.321E-05   0.000E+00   0.000E+00   0.000E+00
8.160E-02
  17    I-135         1.111E-02   1.607E-04   0.000E+00   0.000E+00   0.000E+00
4.785E-02
  18    I*-131        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  19    I*-132        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  20    I*-133        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  21    I*-134        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  22    I*-135        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  23    H-3           0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
                      ---------   ---------   ---------   ---------   ---------
---------
 TOTAL                8.346E-02   4.132E-03   0.000E+00   0.000E+00   0.000E+00
3.593E-01
0BETA DOSE FOR EACH ISOTOPE AND TIME PERIOD (REM)

   ID   ISOTOPE        0-2 HRS     2-8 HRS    8-24 HRS    1-4 DAYS    4-30 DAYS
2-HR EAB

    1   KRM-83        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
    2   KRM-85        1.218E-03   9.123E-05   0.000E+00   0.000E+00   0.000E+00
5.245E-03
    3   KR-85         2.215E-03   2.883E-04   0.000E+00   0.000E+00   0.000E+00
9.537E-03
    4   KR-87         4.089E-03   9.676E-05   0.000E+00   0.000E+00   0.000E+00
1.760E-02
    5   KR-88         2.881E-03   1.593E-04   0.000E+00   0.000E+00   0.000E+00
1.240E-02
    6   KR-89         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
    7   XEM-131       3.095E-03   3.993E-04   0.000E+00   0.000E+00   0.000E+00
1.333E-02
    8   XEM-133       4.478E-04   5.681E-05   0.000E+00   0.000E+00   0.000E+00
1.928E-03
    9   XE-133        1.134E-02   1.464E-03   0.000E+00   0.000E+00   0.000E+00
4.883E-02
   10   XEM-135       8.638E-04   1.464E-04   0.000E+00   0.000E+00   0.000E+00
3.719E-03
   11   XE-135        1.015E-02   1.707E-03   0.000E+00   0.000E+00   0.000E+00
4.368E-02
   12   XE-138        3.340E-04   6.059E-08   0.000E+00   0.000E+00   0.000E+00
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1.438E-03
  13    I-131         2.243E-04   5.230E-06   0.000E+00   0.000E+00   0.000E+00
9.657E-04
  14    I-132         2.506E-03   1.572E-05   0.000E+00   0.000E+00   0.000E+00
1.079E-02
  15    I-133         1.454E-03   2.934E-05   0.000E+00   0.000E+00   0.000E+00
6.261E-03
  16    I-134         4.104E-03   5.026E-06   0.000E+00   0.000E+00   0.000E+00
1.767E-02
  17    I-135         2.381E-03   3.442E-05   0.000E+00   0.000E+00   0.000E+00
1.025E-02
  18    I*-131        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  19    I*-132        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  20    I*-133        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  21    I*-134        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  22    I*-135        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  23    H-3           6.412E-04   8.346E-05   0.000E+00   0.000E+00   0.000E+00
2.760E-03
                      ---------   ---------   ---------   ---------   ---------

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 TOTAL                4.795E-02   4.583E-03   0.000E+00   0.000E+00   0.000E+00
2.064E-01
0INHALATION DOSE FOR EACH IODINE AND TIME PERIOD (REM) (ICRP 2 DATA

   ID   ISOTOPE        0-2 HRS     2-8 HRS    8-24 HRS    1-4 DAYS    4-30 DAYS
2-HR EAB

   1    I-131         2.578E+00   6.010E-02   0.000E+00   0.000E+00   0.000E+00
1.110E+01
   2    I-132         3.933E-01   2.468E-03   0.000E+00   0.000E+00   0.000E+00
1.693E+00
   3    I-133         2.151E+00   4.340E-02   0.000E+00   0.000E+00   0.000E+00
9.261E+00
   4    I-134         2.537E-01   3.107E-04   0.000E+00   0.000E+00   0.000E+00
1.092E+00
   5    I-135         1.211E+00   1.750E-02   0.000E+00   0.000E+00   0.000E+00
5.211E+00
   6    I*-131        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   7    I*-132        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   8    I*-133        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   9    I*-134        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  10    I*-135        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
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 TOTAL                6.587E+00   1.238E-01   0.000E+00   0.000E+00   0.000E+00
2.836E+01
0INHALATION DOSE FOR EACH IODINE AND TIME PERIOD (REM) (ICRP 30 DATA)

   ID   ISOTOPE        0-2 HRS     2-8 HRS    8-24 HRS    1-4 DAYS    4-30 DAYS
2-HR EAB

   1    I-131         1.881E+00   4.386E-02   0.000E+00   0.000E+00   0.000E+00
8.099E+00
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   2    I-132          4.735E-02   2.971E-04   0.000E+00   0.000E+00   0.000E+00
2.038E-01
   3    I-133          9.681E-01   1.953E-02   0.000E+00   0.000E+00   0.000E+00
4.167E+00
   4    I-134          1.086E-02   1.330E-05   0.000E+00   0.000E+00   0.000E+00
4.674E-02
   5    I-135          3.056E-01   4.417E-03   0.000E+00   0.000E+00   0.000E+00
1.315E+00
   6    I*-131         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   7    I*-132         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   8    I*-133         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   9    I*-134         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  10    I*-135         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
                       ---------   ---------   ---------   ---------   ---------
---------
 TOTAL                 3.213E+00   6.812E-02   0.000E+00   0.000E+00   0.000E+00
1.383E+01
0AT 2 HOUR EXCLUSION AREA BOUNDARY (EAB)


 TOTAL GAMMA DOSE =  3.593E-01 REM
 TOTAL BETA DOSE =  2.064E-01 REM
 TOTAL INHALATION DOSE (ICRP-2) =  2.836E+01 REM
 TOTAL INHALATION DOSE (ICRP-30) =  1.383E+01 REM

0AT 30 DAY LPZ BOUNDARY


 TOTAL GAMMA DOSE =  8.760E-02 REM
 TOTAL BETA DOSE =  5.253E-02 REM
 TOTAL INHALATION DOSE (ICRP-2) =  6.711E+00 REM
 TOTAL INHALATION DOSE (ICRP-30) =  3.281E+00 REM

 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.


1WBN SGTR


0TEDE FOR EACH ISOTOPE AND TIME PERIOD (REM)

   ID   ISOTOPE        0-2 HRS     2-8 HRS     8-24 HRS    1-4 DAYS    4-30 DAYS
2-HR EAB

   1    KRM-83         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   2    KRM-85         5.411E-04   4.052E-05   0.000E+00   0.000E+00   0.000E+00
2.330E-03
   3    KR-85          1.388E-05   1.806E-06   0.000E+00   0.000E+00   0.000E+00
5.975E-05
   4    KR-87          1.903E-03   4.503E-05   0.000E+00   0.000E+00   0.000E+00
8.191E-03
   5    KR-88          1.206E-02   6.670E-04   0.000E+00   0.000E+00   0.000E+00
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5.193E-02
  6    KR-89        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  7    XEM-131      1.283E-04   1.655E-05   0.000E+00   0.000E+00   0.000E+00
5.522E-04
  8    XEM-133      4.844E-05   6.145E-06   0.000E+00   0.000E+00   0.000E+00
2.085E-04
  9    XE-133       2.023E-03   2.612E-04   0.000E+00   0.000E+00   0.000E+00
8.711E-03
 10    XEM-135      2.745E-03   4.653E-04   0.000E+00   0.000E+00   0.000E+00
1.182E-02
 11    XE-135       5.416E-03   9.110E-04   0.000E+00   0.000E+00   0.000E+00
2.331E-02
 12    XE-138       4.795E-04   8.697E-08   0.000E+00   0.000E+00   0.000E+00
2.064E-03
 13    I-131        7.390E-02   1.723E-03   0.000E+00   0.000E+00   0.000E+00
3.182E-01
 14    I-132        2.884E-02   1.809E-04   0.000E+00   0.000E+00   0.000E+00
1.242E-01
 15    I-133        6.458E-02   1.303E-03   0.000E+00   0.000E+00   0.000E+00
2.780E-01
 16    I-134        2.518E-02   3.084E-05   0.000E+00   0.000E+00   0.000E+00
1.084E-01
 17    I-135        6.330E-02   9.150E-04   0.000E+00   0.000E+00   0.000E+00
2.725E-01
 18    I*-131       0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
 19    I*-132       0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
 20    I*-133       0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
 21    I*-134       0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
 22    I*-135       0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
 23    H-3          1.050E-02   1.366E-03   0.000E+00   0.000E+00   0.000E+00
4.520E-02
                    ---------   ---------   ---------   ---------   ---------
---------
 TOTAL              2.917E-01   7.934E-03   0.000E+00   0.000E+00   0.000E+00
1.256E+00
 TOTAL TEDE =  2.996E-01
0THIS RUN IS DATED 01/11/10. THE TOTAL ELAPSED TIME IS  0.0 MINUTES.  0.0 SECONDS.
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Attachment 5

FENCDOSE Run

TSR8FBout.txt

Time Dependent Releases
0.265 uCi/g I-131 equivalent accident initiate
Iodine spike case

```
1
          FFFFFFFFFF  EEEEEEEEEE  NN      NN    CCCCCC    DDDDDDDD      OOOOOO
SSSSSS    EEEEEEEEEE
          FFFFFFFFFF  EEEEEEEEEE  NNN     NN   CCCCCCCC   DDDDDDDDD    OOOOOOOO
SSSSSSSS   EEEEEEEEEE
          FF          EE          NNNN    NN  CC      CC  DD      DD  OO      OO  SS
     SS  EE
          FF          EE          NN NN   NN  CC          DD      DD  OO      OO  SS
         EE
          FFFFFFFF    EEEEEEEE    NN  NN  NN  CC          DD      DD  OO      OO
SSSSSSSSS   EEEEEEEE
          FFFFFFFF    EEEEEEEE    NN   NN NN  CC          DD      DD  OO      OO
SSSSSSSSS  EEEEEEEE
          FF          EE          NN    NNNN  CC          DD      DD  OO      OO
     SS  EE
          FF          EE          NN     NNN  CC      CC  DD      DD  OO      OO  SS
     SS  EE
          FF          EEEEEEEEEE  NN      NN   CCCCCCCC   DDDDDDDDD    OOOOOOOO
SSSSSSSS   EEEEEEEEEE
          FF          EEEEEEEEEE  NN      NN    CCCCCC    DDDDDDDD      OOOOOO
SSSSSS    EEEEEEEEEE

          RRRRRRRR    EEEEEEEEEE  VV      VV              5555555555

          RRRRRRRRR   EEEEEEEEEE  VV      VV              5555555555

          RR      RR  EE           VV    VV               55

          RR      RR  EE           VV    VV               55

          RRRRRRRRR   EEEEEEEE      VV  VV                 5555555

          RRRRRRRR    EEEEEEEE      VV  VV                  5555555

          RR   RR     EE             VVVV                         55

          RR    RR    EE             VVVV                 55      55

          RR     RR   EEEEEEEEEE      VV                   55555555

          RR      RR  EEEEEEEEEE      VV                    555555


          WW      WW    IIIIII    NN      NN    999999    5555555555   NN      NN
QQQQQQ      AAAAAA
          WW      WW    IIIIII    NNN     NN   99999999   5555555555   NNN     NN
QQQQQQQQ    AAAAAAAA
          WW      WW      II      NNNN    NN  99      99  55           NNNN    NN  QQ
     QQ  AA      AA
          WW      WW      II      NN NN   NN  99      99  55           NN NN   NN  QQ
     QQ  AA      AA
          WW      WW      II      NN  NN  NN   99999999    5555555     NN  NN  NN  QQ
     QQ  AA      AA
          WW  WW  WW      II      NN   NN NN    99999999    5555555    NN   NN NN  QQ
  Q  QQ  AAAAAAAAAA
          WW WWWW WW      II      NN    NNNN          99          55   NN    NNNN  QQ
   Q QQ  AAAAAAAAAA
          WWWW  WWWW      II      NN     NNN  99      99  55      55   NN     NNN  QQ
    QQQ  AA      AA
          WWW     WWW     IIIIII  NN      NN   99999999    55555555    NN      NN
QQQQQQQQ   AA      AA
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          WW      WW    IIIIII    NN      NN    999999      555555    NN      NN
QQQQQQ Q  AA      AA


            00000         11              //      11          11              //
 11        00000
           0000000       111             //      111         111             //
111       0000000
          00     00     1111            //      1111        1111            //
1111      00     00
          00     00       11           //         11          11           //
 11      00     00
          00     00       11          //          11          11          //
 11      00     00
          00     00       11         //           11          11         //
 11      00     00
          00     00       11        //            11          11        //
 11      00     00
          00     00       11       //             11          11       //
 11      00     00
           0000000      111111    //            111111      111111    //
111111     0000000
            00000       111111    /             111111      111111    /
111111      00000


              11        888888                  222222      222222
222222      333333
             111       88888888                22222222    22222222
22222222    33333333
            1111      88      88      ::      22      22  22      22      ::      22
     22  33      33
              11      88      88      ::              22          22      ::
     22          33
              11       88888888                 2222222     2222222
2222222       33333
              11       88888888                2222222     2222222
2222222        33333
              11      88      88      ::      22          22              ::      22
                 33
              11      88      88      ::      22          22              ::      22
         33      33
            111111     88888888               2222222222  2222222222
2222222222   33333333
            111111      888888                2222222222  2222222222
2222222222    333333

1


1
 REPRODUCTION OF INPUT DATA DECK


 +         +         +         +         +         +         +         +

 1
 KRM-83  KRM-85  KR-85
 KR-87   KR-88   KR-89
 XEM-131 XEM-133 XE-133 XEM-135 XE-135 XE-138
 I-131   I-132   I-133  I-134   I-135
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I*-131  I*-132  I*-133 I*-134  I*-135  H-3
T
.141E-3  .668E-4  .459E-4  .204E-4  .635E-5  6.07E-4
STEAM GENERATER TUBE RUPTURE ACCIDENT
TIME TO 133.6 SEC
    4  'ENVIRONMENT                       ' $ TN=  0.3711E-01
          1 0.000E+00    2 2.364E+00    3 3.697E+00    4 2.196E+00    5 4.135E+00
          6 0.000E+00    7 9.090E+00    8 9.962E-01    9 3.516E+01   10 1.778E+00
         11 1.254E+01   12 1.622E+00   13 1.460E-01   14 1.831E+00   15 5.307E-01
         16 5.915E+00   17 1.328E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
         21 0.000E+00   22 0.000E+00   23 4.712E+01
STEAM GENERATER TUBE RUPTURE ACCIDENT
TIME TO 2 HOUR
    4  'ENVIRONMENT                       ' $ TN=  0.2000E+01
          1 0.000E+00    2 1.462E+02    3 2.689E+02    4 9.306E+01    5 2.328E+02
          6 0.000E+00    7 6.593E+02    8 7.160E+01    9 2.545E+03   10 2.224E+02
         11 9.328E+02   12 1.538E+01   13 9.456E+00   14 1.356E+02   15 3.597E+01
         16 4.100E+02   17 9.531E+01   18 0.000E+00   19 0.000E+00   20 0.000E+00
         21 0.000E+00   22 0.000E+00   23 3.434E+03
STEAM GENERATER TUBE RUPTURE ACCIDENT
TIME TO 8 HOUR
    4  'ENVIRONMENT                       ' $ TN=  0.8000E+01
          1 0.000E+00    2 2.348E+01    3 7.488E+01    4 4.758E+00    5 2.765E+01
          6 0.000E+00    7 1.820E+02    8 1.934E+01    9 7.013E+02   10 1.207E+02
         11 3.663E+02   12 6.510E-03   13 1.187E+00   14 5.062E+00   15 3.866E+00
         16 4.067E+00   17 7.417E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
         21 0.000E+00   22 0.000E+00   23 9.564E+02
WBN SGTR
TIME TO 1 DAY
   -6  'ENVIRONMENT        CURIES         ' $ TN=  0.2400E+02
          1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
          6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
         11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
         16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
         21 0.000E+00   22 0.000E+00   23 0.000E+00
WBN SGTR
TIME TO 4 DAYS
   -6  'ENVIRONMENT        CURIES         ' $ TN=  0.9600E+02
          1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
          6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
         11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
         16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
         21 0.000E+00   22 0.000E+00   23 0.000E+00
WBN SGTR
TIME TO 30 DAYS
   -6  'ENVIRONMENT        CURIES         ' $ TN=  0.7200E+03
          1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
          6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
         11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
         16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
         21 0.000E+00   22 0.000E+00   23 0.000E+00

 +         +         +         +         +         +         +         +


1                                                          PROGRAM FENCDOSE
0                                                         REVISION NUMBER:5
0                                                    REVISION DATE: 31 JUL 2009
0                                                         TODAY IS: 01/11/10
0                                                     STARTING TIME IS: 18:22:23
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1ISOTOPE         GAMMA ENERGY    BETA ENERGY
                  (MEV/DIS)       (MEV/DIS)
 KRM~83             0.0025          0.0371
 KRM~85             0.1586          0.2529
 KR-85              0.0022          0.2506
 KR-87              0.7928          1.3237
 KR-88              1.9629          0.3750
 KR-89              2.0837          1.2310
 XEM~131            0.0201          0.1428
 XEM~133            0.0416          0.1898
 XE-133             0.0454          0.1354
 XEM~135            0.4318          0.0950
 XE-135             0.2470          0.3168
 XE-138             1.1830          0.6058
 I-131              0.3810          0.1943
 I-132              2.3332          0.5143
 I-133              0.6100          0.4080
 I-134              2.5928          0.6102
 I-135              1.5802          0.3680
 I*-131             0.3810          0.1943
 I*-132             2.3332          0.5143
 I*-133             0.6100          0.4080
 I*-134             2.5928          0.6102
 I*-135             1.5802          0.3680
 H-3                0.0000          0.0057


0CHI/Q
   1.410E-04    6.680E-05    4.590E-05    2.040E-05    6.350E-06
   6.070E-04


1
0STEAM GENERATER TUBE RUPTURE ACCIDENT
 TIME TO 133.6 SEC
 COMPONENT  4 ENVIRONMENT                          , TIME =   0.
 1ISOTOPE

 KRM~83         0.0000E+00
 KRM~85         0.2364E+01
 KR-85          0.3697E+01
 KR-87          0.2196E+01
 KR-88          0.4135E+01
 KR-89          0.0000E+00
 XEM~131        0.9090E+01
 XEM~133        0.9962E+00
 XE-133         0.3516E+02
 XEM~135        0.1778E+01
 XE-135         0.1254E+02
 XE-138         0.1622E+01
 I-131          0.1460E+00
 I-132          0.1831E+01
 I-133          0.5307E+00
 I-134          0.5915E+01
 I-135          0.1328E+01
 I*-131         0.0000E+00
 I*-132         0.0000E+00
 I*-133         0.0000E+00
 I*-134         0.0000E+00
 I*-135         0.0000E+00
 H-3            0.4712E+02
0STEAM GENERATER TUBE RUPTURE ACCIDENT
 TIME TO 2 HOUR
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 COMPONENT   4 ENVIRONMENT                          , TIME =  2.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.1462E+03
 KR-85          0.2689E+03
 KR-87          0.9306E+02
 KR-88          0.2328E+03
 KR-89          0.0000E+00
 XEM-131        0.6593E+03
 XEM-133        0.7160E+02
 XE-133         0.2545E+04
 XEM-135        0.2224E+03
 XE-135         0.9328E+03
 XE-138         0.1538E+02
 I-131          0.9456E+01
 I-132          0.1356E+03
 I-133          0.3597E+02
 I-134          0.4100E+03
 I-135          0.9531E+02
 I*-131         0.0000E+00
 I*-132         0.0000E+00
 I*-133         0.0000E+00
 I*-134         0.0000E+00
 I*-135         0.0000E+00
 H-3            0.3434E+04
0STEAM GENERATER TUBE RUPTURE ACCIDENT
 TIME TO 8 HOUR
 COMPONENT   4 ENVIRONMENT                          , TIME =  8.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.2348E+02
 KR-85          0.7488E+02
 KR-87          0.4758E+01
 KR-88          0.2765E+02
 KR-89          0.0000E+00
 XEM-131        0.1820E+03
 XEM-133        0.1934E+02
 XE-133         0.7013E+03
 XEM-135        0.1207E+03
 XE-135         0.3663E+03
 XE-138         0.6510E-02
 I-131          0.1187E+01
 I-132          0.5062E+01
 I-133          0.3866E+01
 I-134          0.4067E+01
 I-135          0.7417E+01
 I*-131         0.0000E+00
 I*-132         0.0000E+00
 I*-133         0.0000E+00
 I*-134         0.0000E+00
 I*-135         0.0000E+00
 H-3            0.9564E+03
0WBN SGTR
 TIME TO 1 DAY
 COMPONENT   6 ENVIRONMENT         CURIES           , TIME = 24.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.0000E+00
 KR-85          0.0000E+00
 KR-87          0.0000E+00
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 KR-88          0.0000E+00
 KR-89          0.0000E+00
 XEM-131        0.0000E+00
 XEM-133        0.0000E+00
 XE-133         0.0000E+00
 XEM-135        0.0000E+00
 XE-135         0.0000E+00
 XE-138         0.0000E+00
 I-131          0.0000E+00
 I-132          0.0000E+00
 I-133          0.0000E+00
 I-134          0.0000E+00
 I-135          0.0000E+00
 I*-131         0.0000E+00
 I*-132         0.0000E+00
 I*-133         0.0000E+00
 I*-134         0.0000E+00
 I*-135         0.0000E+00
 H-3            0.0000E+00
0WBN SGTR
 TIME TO 4 DAYS
 COMPONENT  6 ENVIRONMENT        CURIES        , TIME = 96.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.0000E+00
 KR-85          0.0000E+00
 KR-87          0.0000E+00
 KR-88          0.0000E+00
 KR-89          0.0000E+00
 XEM-131        0.0000E+00
 XEM-133        0.0000E+00
 XE-133         0.0000E+00
 XEM-135        0.0000E+00
 XE-135         0.0000E+00
 XE-138         0.0000E+00
 I-131          0.0000E+00
 I-132          0.0000E+00
 I-133          0.0000E+00
 I-134          0.0000E+00
 I-135          0.0000E+00
 I*-131         0.0000E+00
 I*-132         0.0000E+00
 I*-133         0.0000E+00
 I*-134         0.0000E+00
 I*-135         0.0000E+00
 H-3            0.0000E+00
0WBN SGTR
 TIME TO 30 DAYS
 COMPONENT  6 ENVIRONMENT        CURIES        , TIME =720.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.0000E+00
 KR-85          0.0000E+00
 KR-87          0.0000E+00
 KR-88          0.0000E+00
 KR-89          0.0000E+00
 XEM-131        0.0000E+00
 XEM-133        0.0000E+00
 XE-133         0.0000E+00
 XEM-135        0.0000E+00
 XE-135         0.0000E+00
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 XE-138         0.0000E+00
 I-131          0.0000E+00
 I-132          0.0000E+00
 I-133          0.0000E+00
 I-134          0.0000E+00
 I-135          0.0000E+00
 I*-131         0.0000E+00
 I*-132         0.0000E+00
 I*-133         0.0000E+00
 I*-134         0.0000E+00
 I*-135         0.0000E+00
 H-3            0.0000E+00

1INPUT CONCENTRATION
 KRM-83       0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 KRM-85       1.4856E+02    2.3480E+01    0.0000E+00    0.0000E+00    0.0000E+00
 KR-85        2.7260E+02    7.4880E+01    0.0000E+00    0.0000E+00    0.0000E+00
 KR-87        9.5256E+01    4.7580E+00    0.0000E+00    0.0000E+00    0.0000E+00
 KR-88        2.3693E+02    2.7650E+01    0.0000E+00    0.0000E+00    0.0000E+00
 KR-89        0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 XEM-131      6.6839E+02    1.8200E+02    0.0000E+00    0.0000E+00    0.0000E+00
 XEM-133      7.2596E+01    1.9340E+01    0.0000E+00    0.0000E+00    0.0000E+00
 XE-133       2.5802E+03    7.0130E+02    0.0000E+00    0.0000E+00    0.0000E+00
 XEM-135      2.2418E+02    1.2070E+02    0.0000E+00    0.0000E+00    0.0000E+00
 XE-135       9.4534E+02    3.6630E+02    0.0000E+00    0.0000E+00    0.0000E+00
 XE-138       1.7002E+01    6.5100E-03    0.0000E+00    0.0000E+00    0.0000E+00
 I-131        9.6020E+00    1.1870E+00    0.0000E+00    0.0000E+00    0.0000E+00
 I-132        1.3743E+02    5.0620E+00    0.0000E+00    0.0000E+00    0.0000E+00
 I-133        3.6501E+01    3.8660E+00    0.0000E+00    0.0000E+00    0.0000E+00
 I-134        4.1592E+02    4.0670E+00    0.0000E+00    0.0000E+00    0.0000E+00
 I-135        9.6638E+01    7.4170E+00    0.0000E+00    0.0000E+00    0.0000E+00
 I*-131       0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 I*-132       0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 I*-133       0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 I*-134       0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 I*-135       0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 H-3          3.4811E+03    9.5640E+02    0.0000E+00    0.0000E+00    0.0000E+00

1WBN SGTR

0GAMMA DOSE FOR EACH ISOTOPE AND TIME PERIOD (REM)

   ID   ISOTOPE        0-2 HRS      2-8 HRS     8-24 HRS     1-4 DAYS     4-30 DAYS
2-HR EAB

   1    KRM-83       0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   2    KRM-85       8.307E-04    6.220E-05    0.000E+00    0.000E+00    0.000E+00
3.576E-03
   3    KR-85        2.124E-05    2.764E-06    0.000E+00    0.000E+00    0.000E+00
9.143E-05
   4    KR-87        2.662E-03    6.300E-05    0.000E+00    0.000E+00    0.000E+00
1.146E-02
   5    KR-88        1.639E-02    9.064E-04    0.000E+00    0.000E+00    0.000E+00
7.058E-02
   6    KR-89        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   7    XEM-131      4.726E-04    6.096E-05    0.000E+00    0.000E+00    0.000E+00
2.034E-03
   8    XEM-133      1.064E-04    1.342E-05    0.000E+00    0.000E+00    0.000E+00
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4.578E-04
   9    XE-133         4.128E-03    5.315E-04    0.000E+00    0.000E+00    0.000E+00
1.777E-02
  10    XEM-135        3.412E-03    8.703E-04    0.000E+00    0.000E+00    0.000E+00
1.469E-02
  11    XE-135         8.230E-03    1.511E-03    0.000E+00    0.000E+00    0.000E+00
3.543E-02
  12    XE-138         7.090E-04    1.286E-07    0.000E+00    0.000E+00    0.000E+00
3.052E-03
  13    I-131          1.289E-04    7.552E-06    0.000E+00    0.000E+00    0.000E+00
5.551E-04
  14    I-132          1.130E-02    1.972E-04    0.000E+00    0.000E+00    0.000E+00
4.866E-02
  15    I-133          7.848E-04    3.938E-05    0.000E+00    0.000E+00    0.000E+00
3.379E-03
  16    I-134          3.801E-02    1.761E-04    0.000E+00    0.000E+00    0.000E+00
1.636E-01
  17    I-135          5.383E-03    1.957E-04    0.000E+00    0.000E+00    0.000E+00
2.317E-02
  18    I*-131         0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
  19    I*-132         0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
  20    I*-133         0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
  21    I*-134         0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
  22    I*-135         0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
  23    H-3            0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
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 TOTAL                 9.258E-02    4.637E-03    0.000E+00    0.000E+00    0.000E+00
3.985E-01
0BETA DOSE FOR EACH ISOTOPE AND TIME PERIOD (REM)

   ID   ISOTOPE         0-2 HRS      2-8 HRS     8-24 HRS     1-4 DAYS     4-30 DAYS
2-HR EAB

   1    KRM-83         0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   2    KRM-85         1.218E-03    9.123E-05    0.000E+00    0.000E+00    0.000E+00
5.245E-03
   3    KR-85          2.215E-03    2.883E-04    0.000E+00    0.000E+00    0.000E+00
9.537E-03
   4    KR-87          4.089E-03    9.676E-05    0.000E+00    0.000E+00    0.000E+00
1.760E-02
   5    KR-88          2.881E-03    1.593E-04    0.000E+00    0.000E+00    0.000E+00
1.240E-02
   6    KR-89          0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   7    XEM-131        3.095E-03    3.993E-04    0.000E+00    0.000E+00    0.000E+00
1.333E-02
   8    XEM-133        4.468E-04    5.640E-05    0.000E+00    0.000E+00    0.000E+00
1.924E-03
   9    XE-133         1.133E-02    1.459E-03    0.000E+00    0.000E+00    0.000E+00
4.877E-02
  10    XEM-135        6.907E-04    1.762E-04    0.000E+00    0.000E+00    0.000E+00
2.973E-03
  11    XE-135         9.712E-03    1.783E-03    0.000E+00    0.000E+00    0.000E+00
4.181E-02
  12    XE-138         3.340E-04    6.059E-08    0.000E+00    0.000E+00    0.000E+00
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1.438E-03
  13    I-131         6.050E-05    3.543E-06    0.000E+00    0.000E+00    0.000E+00
2.605E-04
  14    I-132         2.292E-03    4.000E-05    0.000E+00    0.000E+00    0.000E+00
9.868E-03
  15    I-133         4.830E-04    2.423E-05    0.000E+00    0.000E+00    0.000E+00
2.079E-03
  16    I-134         8.230E-03    3.813E-05    0.000E+00    0.000E+00    0.000E+00
3.543E-02
  17    I-135         1.153E-03    4.194E-05    0.000E+00    0.000E+00    0.000E+00
4.965E-03
  18    I*-131        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
  19    I*-132        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
  20    I*-133        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
  21    I*-134        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
  22    I*-135        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
  23    H-3           6.412E-04    8.346E-05    0.000E+00    0.000E+00    0.000E+00
2.760E-03
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 TOTAL                4.887E-02    4.741E-03    0.000E+00    0.000E+00    0.000E+00
2.104E-01
0INHALATION DOSE FOR EACH IODINE AND TIME PERIOD (REM) (ICRP 2 DATA

   ID   ISOTOPE        0-2 HRS      2-8 HRS     8-24 HRS     1-4 DAYS     4-30 DAYS
2-HR EAB

   1    I-131         6.953E-01    4.072E-02    0.000E+00    0.000E+00    0.000E+00
2.993E+00
   2    I-132         3.597E-01    6.277E-03    0.000E+00    0.000E+00    0.000E+00
1.549E+00
   3    I-133         7.143E-01    3.584E-02    0.000E+00    0.000E+00    0.000E+00
3.075E+00
   4    I-134         5.087E-01    2.357E-03    0.000E+00    0.000E+00    0.000E+00
2.190E+00
   5    I-135         5.863E-01    2.132E-02    0.000E+00    0.000E+00    0.000E+00
2.524E+00
   6    I*-131        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   7    I*-132        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   8    I*-133        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   9    I*-134        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
  10    I*-135        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
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 TOTAL                2.864E+00    1.065E-01    0.000E+00    0.000E+00    0.000E+00
1.233E+01
0INHALATION DOSE FOR EACH IODINE AND TIME PERIOD (REM) (ICRP 30 DATA)

   ID   ISOTOPE        0-2 HRS      2-8 HRS     8-24 HRS     1-4 DAYS     4-30 DAYS
2-HR EAB

   1    I-131         5.074E-01    2.972E-02    0.000E+00    0.000E+00    0.000E+00
2.184E+00
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   2    I-132         4.330E-02   7.556E-04   0.000E+00   0.000E+00   0.000E+00
1.864E-01
   3    I-133         3.215E-01   1.613E-02   0.000E+00   0.000E+00   0.000E+00
1.384E+00
   4    I-134         2.177E-02   1.009E-04   0.000E+00   0.000E+00   0.000E+00
9.374E-02
   5    I-135         1.480E-01   5.381E-03   0.000E+00   0.000E+00   0.000E+00
6.371E-01
   6    I*-131        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   7    I*-132        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   8    I*-133        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   9    I*-134        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  10    I*-135        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
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 TOTAL                1.042E+00   5.208E-02   0.000E+00   0.000E+00   0.000E+00
4.485E+00
0AT 2 HOUR EXCLUSION AREA BOUNDARY (EAB)


 TOTAL GAMMA DOSE =  3.985E-01 REM
 TOTAL BETA DOSE =  2.104E-01 REM
 TOTAL INHALATION DOSE (ICRP-2) =  1.233E+01 REM
 TOTAL INHALATION DOSE (ICRP-30) =  4.485E+00 REM

0AT 30 DAY LPZ BOUNDARY


 TOTAL GAMMA DOSE =  9.722E-02 REM
 TOTAL BETA DOSE =  5.361E-02 REM
 TOTAL INHALATION DOSE (ICRP-2) =  2.971E+00 REM
 TOTAL INHALATION DOSE (ICRP-30) =  1.094E+00 REM

 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.


1WBN SGTR


0TEDE FOR EACH ISOTOPE AND TIME PERIOD (REM)

   ID   ISOTOPE        0-2 HRS     2-8 HRS     8-24 HRS    1-4 DAYS    4-30 DAYS
2-HR EAB

   1    KRM-83        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   2    KRM-85        5.411E-04   4.052E-05   0.000E+00   0.000E+00   0.000E+00
2.330E-03
   3    KR-85         1.388E-05   1.806E-06   0.000E+00   0.000E+00   0.000E+00
5.975E-05
   4    KR-87         1.903E-03   4.503E-05   0.000E+00   0.000E+00   0.000E+00
8.191E-03
   5    KR-88         1.206E-02   6.670E-04   0.000E+00   0.000E+00   0.000E+00
```

```
5.193E-02
   6    KR-89         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   7    XEM-131       1.283E-04   1.655E-05   0.000E+00   0.000E+00   0.000E+00
5.522E-04
   8    XEM-133       4.834E-05   6.101E-06   0.000E+00   0.000E+00   0.000E+00
2.081E-04
   9    XE-133        2.021E-03   2.603E-04   0.000E+00   0.000E+00   0.000E+00
8.701E-03
  10    XEM-135       2.195E-03   5.599E-04   0.000E+00   0.000E+00   0.000E+00
9.450E-03
  11    XE-135        5.184E-03   9.516E-04   0.000E+00   0.000E+00   0.000E+00
2.232E-02
  12    XE-138        4.795E-04   8.697E-08   0.000E+00   0.000E+00   0.000E+00
2.064E-03
  13    I-131         1.993E-02   1.167E-03   0.000E+00   0.000E+00   0.000E+00
8.581E-02
  14    I-132         2.638E-02   4.602E-04   0.000E+00   0.000E+00   0.000E+00
1.135E-01
  15    I-133         2.144E-02   1.076E-03   0.000E+00   0.000E+00   0.000E+00
9.232E-02
  16    I-134         5.050E-02   2.339E-04   0.000E+00   0.000E+00   0.000E+00
2.174E-01
  17    I-135         3.066E-02   1.115E-03   0.000E+00   0.000E+00   0.000E+00
1.320E-01
  18    I*-131        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  19    I*-132        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  20    I*-133        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  21    I*-134        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  22    I*-135        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  23    H-3           1.050E-02   1.366E-03   0.000E+00   0.000E+00   0.000E+00
4.520E-02
                      ---------   ---------   ---------   ---------   ---------
---------
 TOTAL                1.840E-01   7.968E-03   0.000E+00   0.000E+00   0.000E+00
7.920E-01
 TOTAL TEDE =  1.920E-01
0THIS RUN IS DATED 01/11/10. THE TOTAL ELAPSED TIME IS  0.0 MINUTES.  0.0 SECONDS.
```

Attachment 6

TVA Nuclear Power Group Calculation

WBNTSR-009 R11

Control Room Operator and Offsite Doses from a Fuel Handling Accident

TVAN CALCULATION COVERSHEET/CCRIS UPDATE

Page 1

REV 0 EDMS/RIMS NO. B26 890302 008	EDMS TYPE: calculations(nuclear)	EDMS ACCESSION NO (N/A for REV. 0) T71 060706 803

Calc Title: **Control Room Operator and Offsite Doses From a Fuel Handling Accident**

CALC ID	TYPE	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	
CURRENT	CN	WBN	NTB	**WBNTSR-009**	R10	R11	REVISION APPLICABILITY
NEW	CN						Entire calc ■ Selected pages ☐

ACTION	NEW ☐ REVISION ■	DELETE ☐ RENAME ☐	SUPERSEDE ☐ DUPLICATE ☐	CCRIS UPDATE ONLY ☐ (D. V. & Approval Signatures Not Required)	No CCRIS Changes ☐ (For calc revision, CCRIS been reviewed and no CCRIS changes required)

UNITS 1/2	SYSTEMS NA	UNIDS NA
DCN.EDC.N/A EDC 51930 & 52054	APPLICABLE DESIGN DOCUMENT(S) NA	CLASSIFICATION E

QUALITY RELATED?	SAFETY RELATED? (If yes, QR = yes)	UNVERIFIED ASSUMPTION	SPECIAL REQUIREMENTS AND/OR LIMITING CONDITIONS?	DESIGN OUTPUT ATTACHMENT?	SAR/TS and/or ISFSI SAR/CoC AFFECTED
Yes ■ No ☐	Yes ■ No ☐	Yes ☐ No ■	Yes ■ No ☐	Yes ☐ No ■	Yes ■ No ☐

PREPARER ID	PREPARER PHONE NO	PREPARING ORG (BRANCH)	DESIGN VERIFICATION METHOD	NEW METHOD OF ANALYSIS
MCBERG	751-8122	NTB	Design Review	☒ Yes ☐ No

PREPARER SIGNATURE Marc C. Berg Marc C. Berg	DATE 5-3-06	CHECKER SIGNATURE Douglas P. Pollock Doug Pollock DPP 6/19/06	DATE 5/3/06
DESIGN VERIFIER SIGNATURE Douglas P. Pollock Doug Pollock	DATE 5/3/06	APPROVAL SIGNATURE Charles Allen J Robertson for CRA	DATE 6/29/06

STATEMENT OF PROBLEM/ABSTRACT

This calculation was performed to determine the dose to control room operators following a design basis fuel handling accident (FHA). In addition, the offsite doses resulting from a design basis FHA were also calculated. Base assumptions utilize either Regulatory Guide 1.25 (Safety Guide 25) or Regulatory Guide 1.183 (Alternate Source Term)

The calculation considers a FHA occurring in containment with activity passing directly to the environment (no Purge Filters) until isolation in 12.7 seconds, a FHA in containment exhausting to the environment via Purge Filters, a FHA occurring in the fuel handling area of the Auxiliary Building with activity passing through the Auxiliary Building Gas Treatment System filters, and a FHA in containment with contamination migrating, due to open penetrations, to the AB after containment isolation and going through the ABGTS. The FHA is assumed to occur at 100 hours after shutdown. All of the other assumptions used to calculate the activity released are in accordance with Safety Guide 25 and NUREG/CR-5009. All of the activity for the AB case is assumed to be released over a two hour time period per Safety Guide 25. A set of newer cases are performed using Regulatory Guide 1.183 (Alternate Source Term or AST) assumptions. The AST calculations determined the doses both with and without ABGTS filters. For AST, any containment FHA is bounded by the AB FHA with no ABGTS filters.

The computer code STP was used to calculate the activity released after a FHA. The activity released to the environment as determined by STP was input into the computer code COROD. The control room model used is identical to that described in TI-RPS-198 except that the containment shine is not included. This calculation also considers the effect of a 20.6 second unfiltered bypass flow due to the finite closure time of the control room isolation dampers (14 sec) and instrument actuation time (6.6 sec). The activity released to the environment as determined by STP was also used as input to computer code FENCDOSE to calculate the doses at the Site Boundary (SB)/Exclusion Area Boundary after 2 hours and at the Low Population Zone (LPZ) boundary after 30 days. The FENCDOSE model came from TI-RPS-197.

The control room operator doses are below the 10CFR50 Appendix A, GDC 19 limits of 5 rem gamma, 30 rem beta, 30 rem thyroid, and 10CFR50.67 limit of 5 rem TEDE. The offsite doses are less than 25% of the 10CFR100 limits of 25 rem gamma, 300 rem beta, 300 rem thyroid, and 10CFR50.67 limit of 25 rem TEDE (= 6.25 rem gamma, 75 rem beta/thyroid, and 6.25 rem TEDE).

If the design basis of the plant is Regulatory Guide 1.25, then there are several Special Requirements/Limiting Conditions in this calculation (see main text). If the design basis of the plant is Regulatory Guide 1.183, then there are no Special Requirements/Limiting Conditions.

This calculation directly impacts FSAR Table 15.5-23

MICROFICHE/EFICHE Yes ■ No ☐ FICHE NUMBER(S) TVA-F-W000575 and TVA-F-W000622 and TVA-F-W000624

☐ LOAD INTO EDMS AND DESTROY
☒ LOAD INTO EDMS AND RETURN CALCULATION TO CALCULATION LIBRARY. ADDRESS: EQB 1N-WBN
☐ LOAD INTO EDMS AND RETURN CALCULATION TO:

TVAN CALCULATION COVERSHEET/CCRIS UPDATE

Page 2

CALC ID	TYPE	PLANT	BRANCH	NUMBER	REV
	CN	WBN	NTB	WBNTSR-009	11

BLDG	ROOM	ELEV	COORD/AZIM	FIRM	Print Report Yes ☐
CATEGORIES					

KEY NOUNS (A-add, D-delete)

ACTION (A/D)	KEY NOUN	A/D	KEY NOUN
A	AST		

CROSS-REFERENCES (A-add, C-change, D-delete)

ACTION (A/C/D)	XREF CODE	XREF TYPE	XREF PLANT	XREF BRANCH	XREF NUMBER	XREF REV
A	P	RG	GEN	MEB	RG 1.140	
A	P	SS	WBN	EEB	1-RE-90-130	
A	P	RG	GEN	NTB	RG 1.183	

CCRIS ONLY UPDATES:
Following are required only when making keyword/cross reference CCRIS updates and page 1 of form NEDP-2-1 is not included:

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
PREPARER PHONE NO.	EDMS ACCESSION NO.		

TVAN CALCULATION RECORD OF REVISION

CALCULATION IDENTIFIER **WBNTSR-009**

Title **Control Room Operator and Offsite Doses From a Fuel Handling Accident**

Revision No.	DESCRIPTION OF REVISION
0	Initial Issue
1	This revision was performed because the key references changed, resulting in COROD and FENCDOSE models needing revision. Also, the case of a FHA occurring in the Auxiliary Building was added Pages added: 2.1-2.4, 4.1 Pages changed: 1-12
2	This revision was performed because the previous analysis oversimplified the dilution process. The error has been corrected analytically without running the STP code. Ref. 12, FSAR chapter 15 was deleted as it was sufficient to refer to ref. 4. Safety Guide 25. Ref. 11 MR 482000 was no longer valid and replaced by WB-DC-36.1 R4. The control room operator doses are slightly reduced. There is no impact on the conclusions of the calculation. Pages added: 1a, 2.1, 2.5 Pages deleted: 2.1 Pages changed: 1, 2, 2.2, 4, 7, 8, 9, 10 Total pages: 35 CCRIS and DCCM were checked on 01.04.93 and no changes which impact this calculation were found. This calculation does not require impact review as no other discipline uses it as design input.
3	Revision 3 was performed to take into account a single failure of the Auxiliary Building General Ventilation Exhaust Fan in the "on" position concurrent with a single isolation damper failing to close resulting in ABGTS filter bypass. All pages were rewritten for legibility and renumbered. Only areas with changed text are identified with revision bars. Pages added: all Pages deleted: all Pages changed: all
4	Revision 4 was performed because the ABGTS bypass was fixed by DCN M-29141-A. R4 reinstated the R2 models and results. Pages added: 1(new cover) Pages changed: 1.1(old cover), 2-6, 8, 9, 11, 13-15, 17 Pages deleted: none
5	Revision 5 was performed because the X/Q values changed Pages added: 1.2 Pages deleted: none Pages changed: 1-8, 10-14, 16, 17
6	Revision 6 was performed because the control room makeup flow was changed. Pages changed: 1, 1.2, 2-6, 8, 12-14, 16, 17 Pages added: none Pages deleted: none

TVAN CALCULATION RECORD OF REVISION

CALCULATION IDENTIFIER **WBNTSR-009**

Title **Control Room Operator and Offsite Doses From a Fuel Handling Accident**

Revision No.	DESCRIPTION OF REVISION
7	Revision 7 was performed to upgrade the calculation to the cycle 2 1000 EFPD, extended burnup (18 month) fuel. pages added: 1, 2.1 pages changed: 1a (old cover), 1.2, 3-17 pages deleted: none
8	Revision 8 was performed to change the FHA source terms from 1000 EFPD to 1500 EFPD as part of the corrective action of WBPER960798. pages added: none pages changed: 1, 2.1, 3-7, 9, 10, 12, 14-17 pages deleted: 1a, 1.1, 1.2
9	Revision 9 is performed to discuss the impact of D-50378-A which allow containment penetrations to be open during fuel movement. There was no impact on the final answers. Pages changed: 1, 2.1, 3, 17 Pages added: 9.1 Pages deleted: none R9: 36 total pages
10	Revision 10 is performed to incorporate NUREG/CR-5009 gap inventories, increased isolation time (WBNPER 01-000080-000), incorporate X/Q values as determined by ARCON96, and incorporate the Tritium Production Core (TPC). The latest versions of COROD (R5) and FENCDOSE (R4) were used, which determine thyroid doses based on both ICRP-2 and ICRP-30 dose conversion factors, as well as determine the TEDE. Also, independent third party review comments by Westdyne (Westinghouse) and NYSIS were incorporated where appropriate. Due to the extent of the changes, all pages were renumbered. Actual text changes are marked with revision bars. Changes in this revision will be screened for 50.59 applicability via the EDC referenced on the coversheet. Pages added: all Pages deleted all Pages changed: all R10: 47 total pages
11	Revision 11 is performed in support of PERs 61493 (control room recirculation rate modeling), 94426 (control room time increment modeling), 95217 (potential for 15 minute unfiltered releases and migration of contamination to other un-isolated areas), and 96939 (failure to evaluate FHA in the transfer canal or cask loading area) and EDC 51930 (downgrade Purge Filters) and also to add Alternate Source Term (AST) cases. EDC 51930 downgrades the Reactor Building Purge filters to non-safety related and thus credit cannot be taken for them to mitigate the FHA. The design basis for a FHA in containment is to take credit for containment isolation, which occurs in 12.7 seconds once EDC 51930 is implemented. PER 61493 documents that the wrong control room recirculation flow rate is used. The recirculation flow rate is 3600 cfm- makeup flow (711) = 2889 cfm. 2 trains of CREVS in operation for the first 2 hours is addressed in an assumption. Another case was added to analyze a FHA in containment with migration to the AB after isolation through open penetrations. The discussion about penetrations on page 11 of R10 was deleted and a Special Requirement was added to require a CVI with an ABI and vice versa. It was also required that the ABSCE be established within 4 minutes even if there are other penetrations to outside the ABSCE. AST cases were performed with and without Purge/ABGTS filters. This calculation directly impacts FSAR Table 15.5-23. EDC 51930 contains a Technical Specification change for the Reactor Building Purge filters Pages Revised/Replaced:1, 2, 4-29, renamed Attachment 4 as Attachment 1, renamed Attachment 5 as Attachment 2, renamed Attachment 6 as Attachment 3 Pages Added: 15, 23 Pages Deleted: old cover (2.1), Design Verification form, 11,13, old attachments 1-3 Total Pages = 29

TVAN CALCULATION TABLE OF CONTENTS

Calculation Identifier: WBNTSR-009	Revision: 11	

TABLE OF CONTENTS

SECTION TITLE PAGE

TVAN COMPUTER INPUT FILE
STORAGE INFORMATION SHEET

Document WBNTSR-009	Rev. 11	Plant: WBN	

Subject:
Control Room Operator and Offsite Doses From a Fuel Handling Accident

☐ Electronic storage of the input files for this calculation is not required. Comments:

■ Input files for this calculation have been stored electronically and sufficient identifying information is provided below for each input file. (Any retrieved file requires re-verification of its contents before use.)

R6: The computer input is permanently stored in FILEKEEPER file # 263662
R7: The computer input is permanently stored in FILEKEEPER file # 292579
R8: The computer input is permanently stored in FILEKEEPER file # 300126
R10: The computer input is permanently stored in FILEKEEPER file # 303621
R11: The computer input is permanently stored in FILEKEEPER file # 308333,308360

☒ Microfiche/eFiche

See next page

TVAN COMPUTER OUTPUT
MICROFICHE INFORMATION SHEET

Document **WBNTSR-009**	Rev. 11	Plant: WBN	

Subject:
Control Room Operator and Offsite Doses From a Fuel Handling Accident

Microfiche	Description
R3:TVA-F-G104672 R5:TVA-F-C000074 R6:TVA-F-C000108 R7:TVA-F-C000138 R8:TVA-F-C000219	
R10: TVA-F-W000221	R10:

Name	Code	Description
TS9S10$	STP	source term
TS9C10#$	COROD	control room operator dose
TS9F10#$	FENCODSE	Offsite dose

where
$= A = standard core, instant control room isolation
B = standard core, 20.6 sec control room isolation
C = Tritium Production Core, once burned assembly, instant control room isolation
D = Tritium Production Core, once burned assembly, 20.6 sec control room isolation
E = Tritium Production Core, twice burned assembly, instant control room isolation
F = Tritium Production Core, twice burned assembly, 20.6 sec control room isolation
G = Tritium Production Core, 3X burned assembly, instant control room isolation
H = Tritium Production Core, 3X burned assembly, 20.6 sec control room isolation
X = standard core, 20.6 sec isolation time, revision 9 (old Halitsky) X/Q values
#= A= Spent Fuel Pit/Auxiliary Building/ABGTS FHA
P = Containment/PAE FHA

Microfiche	Description
R11: TVA-F-W000575 TVA-F-W000622 TVA-F-W000624	R11:

Name	Code	Description
TS9S11$#	STP	release models
TS9C11$#	COROD	control room dose with 1 train of CREVS, 20.6 sec control room isol
TS9F11$#	FENCDOSE	offsite dose

where
$= A = standard core
B = Tritium Production Core, once burned assembly
C = Tritium Production Core, twice burned assembly
D = Tritium Production Core, thrice burned assembly
#= 1= RG 1.25 Contain FHA w/ 12.7 sec contain isolation, containment closed to AB, no Purge Filters
2= RG 1.25Spent Fuel Pit/Auxiliary Building FHA, AB open or closed to containment
3 = RG 1.25 Containment FHA with Purge Filters (no containment isolation)
4=RG 1.183 AST Auxiliary Building FHA with no ABI
5=RG 1.183 AST Auxiliary Building FHA with ABI (ABGTS)

Purpose

The purpose of this calculation is to determine the dose to the control room operators following a design basis Fuel Handling Accident (FHA). In addition, the offsite doses resulting from a FHA is also to be determined. This calculation is to address concerns raised during the vertical slice review program as to whether the Loss of Coolant Accident (LOCA) actually produces the bounding control room operator doses (ref.1).

Revision 10 is performed to increase the delay in the control room isolation to 20.6 seconds (this value is the sum of the damper closure time and the instrument reaction time, this is documented in WBN PER 01-000080-000, ref.12), to change the X/Q values to new ones determined by ARCON96 (while keeping the original Halitsky X/Q case) , to utilize NUREG/CR-5009 gap inventory releases to supplement Safety Guide 25 (Regulatory Guide 1.25), and to utilize the latest versions of FENCDOSE (R4) and COROD (R6, which now determine thyroid doses based on ICRP-2 and ICRP-30 iodine dose conversion factors, as well as the TEDE, and also allow for changes in flow rates and filter efficiencies). Finally, the Tritium Production Core (TPC) fuel assemblies (once burned, twice burned, and three times burned) are analyzed in addition to the standard core 1500 EFPD assembly. Revision 11 is performed in support of PERs 61493 (control room recirculation rate modeling), 94426 (control room time increment modeling), 95217 (potential for 15 minute unfiltered releases and migration of contamination to other un-isolated areas), and 96939 (failure to evaluate FHA in the transfer canal and cask loading area) and EDC 51930 (downgrade Purge Filters) and also to add Alternate Source Term (AST) cases. Revision 11 changes the containment FHA case to credit containment isolation in 12.7 seconds instead of crediting the purge filtration system to mitigate the consequences of an FHA in containment. The filtered release case is retained (this case will become information only once EDC 51930 is implemented). Additionally, revision 11 adds cases based on Regulatory Guide 1.183 (Alternate Source Term or AST) assumptions. One of the AST cases credits filters, the other does not credit any filters.

Special Requirements/Limiting Conditions

If the design basis for WBN is RG 1.25, then if the equipment hatch or any penetration between the Auxiliary Building and Containment is open, the containment purge system shall be operational during fuel movement and an Auxiliary Building Isolation (ABI) due to a high radiation signal shall initiate a Containment Ventilation Isolation (CVI) and a CVI due to a high radiation signal must initiate an ABI. If other penetrations are open to the outside of the ABSCE, the ABGTS system must be able to draw down within 4 minutes of the initiating event.

Also, for RG 1.25, the HVAC intake vent in the transfer canal must be blocked, and the -103 monitor must be raised so that it has a line of sight across the 757' floor. The HVAC intake vents for the cask loading area shall be blocked when handling irradiated fuel in this area. The -102 monitor is far enough away so that it will see very close to the floor at the canal/cask loading area, therefore it will not have to be raised (see assumption 17 for further discussion). This requirement is to prevent radioisotopes from entering the HVAC ductwork in the transfer canal (and ultimately released via the Auxiliary Building Vent without filtration) and therefore bypassing the isolation function of the -102 and -103 radiation monitors.

If the design basis for WBN is RG 1.183 (AST), then there are no special requirements or limiting conditions. Based on the results of this analysis, no isolation of either containment or the auxiliary building is required following a Fuel Handling Accident for AST.

Introduction

This calculation determines the offsite and control room doses due to a FHA. The computer code STP is used to determine the releases. Using the STP output, the computer code FENCDOSE determines the offsite doses, and the computer code COROD determines the control room doses. The FHA accident is analyzed for both the Auxiliary Building and the Containment. Also, 4 types of assemblies are analyzed: the 1500 EFPD end of life assembly for a standard core, a once burned TPC assembly with 24 TPBAR rods (which contain the tritium), a twice burned TPC assembly with 24 TPBAR rods, and a three times burned TPC assembly (no TPBARs).

Assumptions

1. The FHA occurs at 100 hours after shutdown, consistent with the FSAR and the Technical Specifications (ref.4 and 18).

2. All of the rods in one fuel assembly are assumed to be damaged.
Technical Justification: Safety Guide 25, ref.4, implies that the activity from the worst peak assembly is released. It is conservative to assume that all rods will break, thereby maximizing the release. Regulatory Guide 1.183 (AST), ref.36, section 3.6 requires that the case with the highest radioactivity release should be analyzed.

3. For all cases except the 12.7 containment isolation case, it is assumed that everything except tritium is released to the environment within 2 hours (ref.4). To assure this, at 2 hours all remaining isotopes (except tritium, see assumption 13) above the spent fuel pool (or in containment) are stepped into the environment (using the appropriate filter efficiency as a multiplication factor).

4. For the RG 1.25 cases, it is assumed that in the 4 minutes it takes to establish the ABSCE for an AB FHA, there will be no unfiltered releases to the environment (see assumption 17 regarding isolation). The ABSCE is normally established within 4 minutes and within this time frame all of the flow is through the ABGTS. Because there will be an ABI and CVI, any other contaminated air which does not go through the ABGTS (leakage) will have to travel to a penetration in containment or the AB to go outside of the ABSCE. Because this leakage flow will be fairly low and the distance from the contamination source is great, it can be concluded that the contaminated air will not reach the outside. Also as the ABGTS draws down the Auxiliary Building, the flow of air will be more likely to be drawn into the ABGTS due to flow characteristics of pumping the air volume down. For one of the RG 1.183 AST cases (case series 5), the above also applies. For the other AST case (case series 4), no isolation is assumed.

5. For the RG.1.25 cases (case series 1, 2, and 3), all of the gap activity in the damaged rods is released which consists of 10% of the inventory in the rods at the time of the accident (ref.4), except for the following (per NUREG/CR-5009 for 60 GWd/t, note for lesser burnups the releases are less, therefore use of these 60 GWd/t values for all burnups is conservative):

Kr-85 = 14%

Kr-87 = 10% Note: The NUREG/CR-5009 value is actually 0.7%. Since STP is limited to 9 classes, and the halflife of Kr-87 is 76 min (ref.33), after 100 hours of decay there will be exp(-100*ln(2)/(76/60)) = 1.7E-24 or 1.7E-22% left. Therefore the increase in the gap percentage does not affect the results.

Kr-88 = 10% Note: The NUREG/CR-5009 value is actually 1%. Since STP is limited to 9 classes, and the halflife of Kr-88 is 2.84 hr (ref.33), after 100 hours of decay there will be exp(-100*ln(2)/2.84) = 2.5E-11 or 2.5E-9% left. Therefore the increase in the gap percentage does not affect the results.

Kr-89 = 10%

Xe-133 = 5%

Xe-135 = 2%

I-131 = 12%

For the RG 1.183 AST cases, all of the gap activity in the damaged rods is released which consists of 8% I-131, 10% Kr-85, 5% other noble gasses and other halogens. Note that RG 1.183 also specifies 12% of Alkali metals (Cs, Rb), however since particulates have essentially an infinite partition factor, no alkali metals will be released and therefore are not included in this analysis.

6. The values assumed for individual fission product inventories are calculated assuming full power operation at the end of core life immediately preceding shutdown with a radial peaking factor of 1.65 (ref.4, 36) for the standard core assembly. For the TPC assemblies, the inventories are taken at the end of cycle,

with the factor of 1.65 applied to all isotopes except tritium. Also, the factor of 1.65 is the maximum peaking factor allowed by the COLR. The factor of 1.65 is not applied to the tritium isotope because the maximum inventory of tritium is used already at a maximum (see assumptions #13, and ref.29) at 1.2g tritium/rod with 24 rods/assembly. It would be too conservative to apply the 1.65 to a value which is already the maximum inventory which can occur.

7. From RG 1.25 (ref.4), the iodine gap inventory is composed of inorganic species (99.75%) and organic species (0.25%). From RG 1.183, the inorganic species is 99.85% and the organic species is 0.15%. An overall decontamination factor is utilized in the RG 1.183 cases(see assumption 8), therefore the makeup of the species is not utilized in AST.

8. From RG 1.25, the pool decontamination factors for the inorganic iodine is assumed to be 133, and organic iodine is assumed to be 1 (ref.4). From RG 1.183 (AST) the decontamination factors are specified to be 500 for elemental (inorganic) iodine, and 1 for organic iodine. Doing the math, this leads to an overall decontamination factor of 286 =1/(0.9985/500+0.0015/1). However, RG 1.183 also specifies an overall decontamination factor of 200. The use of the 200 factor is more conservative (also, BFN was asked by the NRC to use the overall factor instead of the species specific factors), and therefore the overall factor of 200 for AST will be used in this analysis.

9. The retention of noble gasses in the pool is negligible (ref.4).

10. For FHA in containment with isolation (case series 1), it is assumed that the Purge Air Exhaust (PAE) System isolates in 12.7 seconds (ref. 2). This includes instrument loop response time (6.7 sec) and containment purge valve closure time (6 sec). This should be noted to be a very conservative value. The instrument loop response time contains very conservative assumptions and rounding. In the event that containment needs to be purged (for instance if entry is required into containment), then it is possible to defeat the isolation. An additional case (case series 3) analyzed assumes that the PAE (including the filters) will be used to purge containment for two hours.

11. This calculation includes a case with no credit for the PAE filters for the FHA in containment once the purge filters are downgraded. However, for historical purposes, the filtered release analysis is retained in the results section (case series 3). The filter efficiencies for the PAE filter are 90% for inorganic iodines and 30% for organic iodines (ref.3). EDC 51930 downgrades the filters to non-safety related. R.G. 1.140 R3 will be the standard to which these filters conform to. The guide specifies the filter efficiency as 95%. Therefore using the original 90%/30% is conservative. One of the RG 1.183 AST cases does not credit any filters (case series 4).

12. The filter efficiency for the ABGTS is 99% for all iodines (ref.3).

13. It is assumed that all 24 TPBARs in a TPC once or twice burned assembly break. It is also assumed that all the tritium (84490 Ci) in the spent fuel pool is released following the FHA through evaporation of the pool.
Technical Justification: All TPBARs breaking is conservative. Also, it is difficult to predict the chemical form of the tritium release from a broken TPBAR in the spent fuel pit. Most likely it will be in the form of tritiated water or methane. There will not be 100% release of tritium from a TPBAR failure in a FHA because there are no high temperatures involved with the accident. Reference 26, section 2.3, gives the release from the TPBARs will not cause the water tritium concentration to exceed 60μCi/gm. If all the water (372,000 gal, ref.28) were to evaporate, then the amount of tritium release would be:

60μCi/gm * 372,000 gal * 3,785.4 cc/gal * 1 gm/cc * 1E-6 Ci/μCi = 84490 Ci

To assume all the water evaporates within 2 hours is very conservative. For the RG 1.25 containment FHA case with purge filters and Auxiliary Building case (case series 2 and 3), tritium was released over 2 hours. For the RG 1.25 containment with 12.7 sec isolation and no purge filters (case series 1) and the AST cases (case series 4 and 5), tritium was assumed to evaporate at a constant rate over 8 hours. Also, from reference 26 (see attachment 1), less than 25% of the tritium will be released at a steady rate over a period greater than 8 hours. For conservatism, 25% of the inventory will be released linearly over 8 hours for the RG 1.183 cases.

14. For the RG 1.25 case, the effective volume of upper containment is taken as 1/2 the upper containment free volume. Technical Justification: This takes into account incomplete mixing and dead end spaces and is typical for the representation of air mixing volumes.

15. It is assumed that the suction flow for the ABGTS from the spent fuel pit area is the maximum ABGTS flow (9000 cfm +10%, ref.32).
Technical Justification: The ABGTS suction is actually less than this from the spent fuel pit area, since suction is also taken from several other areas, such as the pipe chase. In discussions with John Ferguson, WBN HVAC system engineer, there have been no measurements of the suction flow during ABGTS operation from the spent fuel pit area. However the majority of the flow is from the spent fuel pit. Using the maximum flow reduces the holdup time and increases the releases at earlier times during the accident. This is therefore conservative.

16. NUREG/CR-5009 implies that Cs-134 and Cs-137 are also in the gap. This calculation assumes these isotopes do not get released to the environs.
Technical Justification: Cs-134 decays to either Xe-134 or Ba-134, both of which are stable. Cs-137 decays to Ba-137m which in turn decays to Ba-137, which is stable. Per Regulatory Guide 1.183, particulates (Cs, Ba) have an infinite decontamination factor in the spent fuel pool/reactor vessel water. Therefore, Cs-134 and Cs-137, and their daughters, may be neglected from the calculation.

17. It is assumed for the RG 1.25 design basis cases, that Auxiliary Building isolation is automatic so that there is no unfiltered release. The isolation is due to the RE-90-102 and -103 spent fuel pool monitors. PER 96939 documents that an accident in the fuel transfer canal and cask loading area will result in no automatic isolation since the monitors have no line of sight to the transfer canal and the HVAC intake ductwork is below the floor elevation. Therefore, any accident in the transfer canal or cask loading area will result in the HVAC uptake of radioactive gasses before it rises above the 757' floor elevation where it will have a line of sight to the monitors. The radioactive gasses would then be exhausted to the environs via the Auxiliary Building Vent with no filtration. The AB vent X/Q values are worse than the Shield Building Vent (the exhaust location following isolation) X/Q values. Preliminary work indicates that this situation would result in control room doses far in excess of the GDC 19 limits. Therefore, for the RG 1.25 assumptions (specifically, isolation of the Auxiliary Building), the following special requirements/limiting conditions apply: The HVAC intake vent in the transfer canal or cask loading area must be blocked, and the -103 monitor is raised so that it has a line of sight across the 757' floor. The -102 monitor is far enough away so that it will see very close to the floor at the canal, therefore it will not have to be raised. [Note: the AST case with no isolation was performed due to the possibility of the transfer canal or cask loading area accident with no ABI. In order to obtain isolation, the HVAC in the transfer canal or cask loading area must be blocked and the -103 monitor must be raised. However, since the no ABI case with AST assumptions did not exceed limits, the blockage and monitor movement will not be required if WBN becomes an AST plant for the FHA.

18. The RG 1.25 cases utilize exponential releases. That is, the releases are governed by the mixing volume and the exhaust flow rate. This results in conservative releases compared to linear releases as more gets released in the beginning of the accident when there is less control room filtration (it takes 20.6 sec to

isolate the control room) and also allows more to be released prior to isolation.

The RG 1.183 cases utilize linear releases. That is, all releases are constant over the 2 hour time period (except for tritium, which is over an 8 hour time period). This is implied in RG 1.183 by requiring all releases to be within 2 hours. Also, this methodology is utilized by Westinghouse for SQN and other utilities.

19. Only one train of CREVS is in operation. Normally, each CREVS train takes suction from separate intakes with no cross communication between trains. This leads to one contaminated train, and one uncontaminated train. The only way a 2 CREVS operation could result in higher doses would be for both trains to take suction from the same vent. For this to happen, one intake path would require a failed closed intake path **AND** a fail open of normally closed passive manual damper at the beginning of the accident. An active failure of a train plus a failure of a passive component in less than 24 hours is beyond design basis.

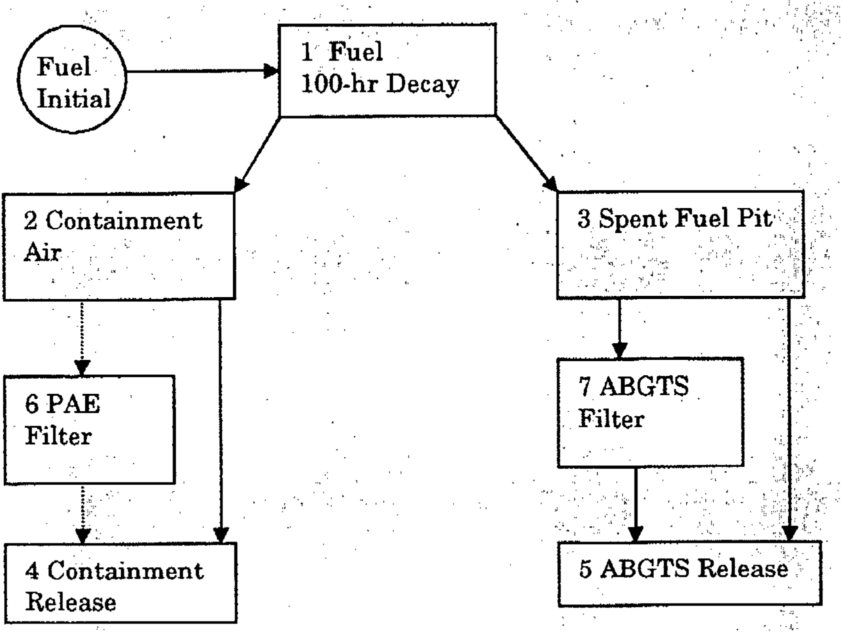
Calculations

This calculation considers several cases broken down into Regulatory Guide 1.25 and Regulatory Guide 1.183 (AST) groupings

I. Regulatory Guide 1.25 Cases:

One case is for a FHA in containment with the activity released directly to the environment until containment isolation (12.7 seconds), there are no penetrations open to the AB, and the PAE filters are not credited. Another case utilizes a containment release without isolation but with Purge Filters Credited. The third case is for a FHA at the refueling area of the Auxiliary Building with the activity release through the Auxiliary Building Gas Treatment System (ABGTS) filters. The fourth case is for a FHA in containment with penetrations open to the AB and thus the contamination migrates to the AB after the containment is isolated. This last case will be analyzed by simply adding the results of the isolated containment case and AB case. This is conservative because this would simulate two releases, one through ABGTS and one through the PAE system before isolation. In reality, the flow would be through the PAE system until isolation then contaminated air will migrate to the AB and then released to the environment via the ABGTS. Computer code STP (ref.6) is used to calculate the activity released after a FHA. Figure 1 shows the model. To insure a conservative dose, the radioisotopes are allowed only 100 hours of decay after shutdown, and are released to the containment/spent fuel pit release rate based on PAE or ABGTS flow. For the Auxiliary Building case, anything left at 2 hours is automatically released through the filters nonmechanistically so that everything is released within 2 hours, except for tritium which is assumed to take 8 hours. (This is performed by stepping the remaining isotopes into the environment at 2 hours). The step source fractions of the core inventory are based on NUREG/CR-5009 and Reg.Guide 1.25. The source terms are the 1500 EFPD maximum burnup for 18 month fuel cycle from WBNAPS3-084 (ref.14) for the standard core. These source terms are used instead of the core average 1000 EFPD source terms because the accident involves a single fuel assembly, not the entire core (as in a LOCA). For the TPC, the source terms for the once burned, twice burned, and 3 times burned assemblies are taken from WBNAPS3-098 (ref.29). The 24 TPBAR release apply only to the once and twice burned assemblies (the 3 times burned assembly will not have any TPBARs).

Figure 1
STP Model



Note: the arrow from component 2 to 4 (for crediting purge filters in Appendix D) and 3 to 5 does not imply a filter bypass. It indicates how STP models a filter with the "U" card, where F 2-6 = F*(efficiency), F2-4 = F*(1-efficiency)

Component 1: Fuel volume=1.0 (arbitrary)
Component 2: Containment Air volume = 647,000 cuft (ref.30) /2 = 3.235E5 cuft (see assumption #15)
Component 3: Spent Fuel Pit volume = 10,017 cuft = 39.5'x31.7'x8' (ref.31). Note: the dimensions come from ref.31b. The 8' dimension (air above the pool) is an arbitrary value to account for the rise of the gasses above the pool. This is reasonable and consistent with references 31a and 31c.
Component 4: Containment Release volume =1.0 (arbitrary)
Component 5: ABGTS Release volume=1.0 (arbitrary)
Component 6: PAE Filter volume =1.0 (arbitrary)
Component 7: ABGTS Filter volume =1.0 (arbitrary)

Flow from containment through PAE to release (U 2 6 4)= purge rate = 14954 cfm (ref.30, note the actual value should be 14958 cfm, but this will not change the results so is not corrected) = 8.9724E5 cfh with Purge Air Exhaust filter efficiencies: 90% inorganic iodine, 30% organic (ref.3), 0% for tritium

Flow from spent fuel pit through ABGTS to release (U 3 7 5) = ABGTS flow = 9900 cfm = 5.94E5 cfh (see assumption #16) with filter efficiencies of 99% for iodines.

Fuel activities are as given in WBNAPS3-084 (ref.14) and WBNAPS3-098 (ref.29), with the inorganic iodines equal to 99.75% of total, and organic iodines equal to 0.25% of total iodines.

Peaking Factor for the highest activity fuel assembly = 1.65 (ref.4) except for tritium isotope, which is 1.0 (see assumption #6).

ABGTS filter efficiencies: 99% (ref.3), for iodines, 0% for tritium
The gap activity in the damaged rods is released which consists of 10% of the inventory in the rods at the time of the accident, except for the following: Kr-85=14%, Xe-133=5%, Xe-135=2%, I-131=12%
Partition Factors: 133 for inorganic iodine.

The step fractions from the fuel to the containment (or spent fuel pit) are:
S = 0.1 for Kr-83m, Kr-85m, Kr-87, Kr-88, Kr-89, Xe-131m, Xe-133m, Xe-135m, Xe-138, organic iodine (except I-131)
S= 0.14 for Kr-85
S=0.05 for Xe-133
S=0.02 for Xe-135
S=0.000752 for I-132, I-133, I-134, I-134 (=0.1/133)
S=0.000902 for I-131 (=0.12/133)
S=0.12 for I-131 (organic iodine)

All of the activity for the AB FHA is assumed to be released after 2 hours, except for tritium. To simulate this all activity remaining in the Reactor Building or Auxiliary Building at the end of 2 hours is put into a new "source" which is stepped to the environment. The stepping fraction is equal to what would have gotten through the filters (i.e. 1-efficiency, or 25% for 0-2 hr and 75% for 2-8 hrs for tritium) had the isotopes been released through the filters. For the Containment case with isolation, the purge flow (F 2 4 0) is set to 0 cfm after 12.7 seconds.

The activity released to the environment as calculated by STP is used as input to computer code COROD (ref.7) to determine the control room operator doses. The control room model is identical to that described in TI-RPS-198 (ref.5) except for the shine from containment which is neglected (all activity inside the containment from FHA is released).

During the vertical slice review of the control room, a concern was raised that when the control room is isolated by a signal from the main control room intake radiation monitors, some amount of unfiltered activity could enter the control room before the isolation dampers close (ref.9). This could be the case for a fuel handling accident because there will be no safety injection signal to isolate the control room. The isolation dampers downstream from the radiation monitors are 0-FCV-31-3 and 0-FCV-31-4 (ref.10). It is required by reference 11 that the closure time of the dampers is 14 seconds, with a signal response time of 6.6 seconds (ref.13), which gives a total closure time of 20.6 seconds. Therefore all cases will analyze the first 20.6 seconds without CREVS filtration.- The ARCON96 X/Q values used (which supersede the Halitsky X/Q values) for the Shield Building Vent were: from ref.34: 1.12E-03 sec/m^3 for 0-2 hr, 9.78E-04 for 2-8 hr, (since all releases are < 8 hours, X/Q values after 8 hours are unimportant.

Prior to isolation the intake flow is 3200 cfm* (ref.10). It is assumed that the unfiltered inleakage is the same as for the isolated case (51 cfm, due to open doors, leaky valves, etc.) After isolation, the total flow rate into the control room is 711 cfm filtered plus 51 cfm unfiltered (ref.5). The circulation flow rate in the control room is the total flow – the makeup flow = 3600 – 711 = 2889 cfm (ref.5).

Cases were performed for the standard core using ARCON96 X/Q values and ICRP-30 dose conversion factors (see note on methodologies in Conclusion section).

The activity released to the environment as calculated by STP is used as input to computer code FENCDOSE (ref.8) to determine the site boundary dose. The FENCDOSE model is the same as that found in reference 19.

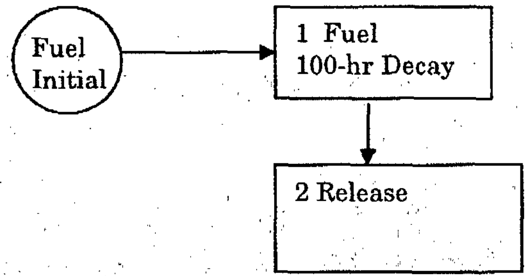
* 3200 cfm has been deleted from 1-47W866-4 R36 (ref.10), and has been measured to be approximately

2500 cfm (0-SI-31-31-A). The value comes from 1-47W866-4 R20. The 3200 cfm will be retained in this calculation revision since this value produces conservative results.

II. Regulatory Guide 1.183 (Alternate Source Term) Cases:

There are two AST FHA cases. One where there is an ABI (with ABGTS in operation) and one with no ABI with no filtration. An accident in the containment is bounded by the no ABI case because containment is exhausted through the Shield Building Vent and the no ABI case exhaust is through the Auxiliary Building Vent. The AB Vent has less favorable X/Q values than the Shield Building Vent. Computer code STP (ref.6) is used to calculate the activity released after a FHA. Figure 2 shows the model. To insure a conservative dose, the radioisotopes are allowed only 100 hours of decay after shutdown, and are released to the environment linearly, except for tritium which is assumed to take 8 hours. The step source fractions of the core inventory are based on Reg.Guide 1.183. The source terms are the 1500 EFPD maximum burnup for 18 month fuel cycle from WBNAPS3-084 (ref.14) for the standard core. These source terms are used instead of the core average 1000 EFPD source terms because the accident involves a single fuel assembly, not the entire core (as in a LOCA). For the TPC, the source terms for the once burned, twice burned, and 3 times burned assemblies are taken from WBNAPS3-098 (ref.29). The 24 TPBAR release apply only to the once and twice burned assemblies (the 3 times burned assembly will not have any TPBARs).

Figure 2
AST STP Model



The STP model consists of the assembly inventory stepped into the Fuel component with a 1.65 peaking factor and allowed to decay for 100 hours. The remaining decayed isotopes are then stepped into the Release component based on filtration efficiency (=99% for iodines for ABI case, =0% filtered for no ABI case). The tritium will only have 25%*(2hr/8hrs) for the 0-2 hour released, and 25%*(6hr/8hrs) for the 2-8 hr time period.

Component 1: Fuel volume=1.0 (arbitrary)
Component 2: Release volume = 1.0 (arbitrary)

ABGTS filter efficiencies: 99% (ref.3), for iodines, 0% for tritium

The gap activity in the damaged rods is released which consists of 5% of the inventory in the rods at the time of the accident, except for the following: Kr-85=10%, I-131=8%

Partition Factors: 200 for all iodines (see assumption 8).

The 20.6 second delay in Control Room isolation is taken into account through the appropriate Step fractions

The step fractions from the fuel to the outside "Release" component are:
0-20.6 sec:
S= 1.431E-4 (=0.05*(20.6sec/7200sec)) for all except Kr-85, iodines, and H-3
S= 2.861E-4 (=0.1*(20.6sec/7200sec)) for Kr-85
S= 7.153E-7 (=0.05*(20.6sec/7200sec/200)) with no ABI for iodines except I-131 or 7.153E-9 with an ABI (filter eff=0.01)
S= 1.144E-6 (=0.08*(20.6sec/7200sec/200)) with no ABI for I-131 or 1.144E-8 with an ABI (filter eff=0.01)
S= 1.788E-4 (=0.25*(20.6sec/7200sec*2hr/8hr)) for H-3

20.6 sec-2 hr:
S= 4.986E-2 (=0.05*(7200 sec-20.6sec)/7200sec) for all except Kr-85, iodines, and H-3
S= 9.971E-2 (=0.1*(7200 sec-20.6sec)/7200sec) for Kr-85
S= 2.493E-4 (=0.05*(7200 sec-20.6sec)/7200sec/200) with no ABI for iodines except I-131or 2.493E-6 with an ABI (filter eff=0.01)
S= 3.989E-4 (=0.08*(7200 sec-20.6sec)/7200sec/200) with no ABI for I-131or 3.989E-6 with an ABI (filter eff=0.01)
S= 6.232E-2 (=0.25*(7200 sec-20.6sec)/7200sec*2hr/8hr) for H-3

2hr-8hr
S=1.875E-1 (=0.25*(6/8)) for H-3

The activity released to the environment as calculated by STP is used as input to computer code COROD (ref.7) to determine the control room operator doses. The control room model is identical to that described in TI-RPS-198 (ref.5) except for the shine from containment which is neglected (all activity inside the containment from FHA is released). For AST, all breathing rates for all times are the same 3.47E-4 m^3/sec

The ARCON96 X/Q values used for Shield Building Vent releases (which supersede the Halitsky X/Q values) were: from ref.34: 1.12E-03 sec/m^3 for 0-2 hr, 9.78E-04 for 2-8 hr. For Auxiliary Building Vent releases (when there is no ABI), the X/Q values are:2.52E-3sec/m^3 for 0-2 hr, 1.57E-3 for 2-8 hr.

Prior to isolation the intake flow is 3200 cfm* (ref.10). It is assumed that the unfiltered inleakage is the same as for the isolated case (51 cfm, due to open doors, leaky valves, etc.) After isolation, the total flow rate into the control room is 711 cfm filtered plus 51 cfm unfiltered (ref.5). The circulation flow rate in the control room is the total flow – the makeup flow = 3600 – 711 = 2889 cfm (ref.5).

The activity released to the environment as calculated by STP is used as input to computer code FENCDOSE (ref.8) to determine the site boundary dose. The FENCDOSE model is the same as that found in reference 19.

* 3200 cfm has been deleted from 1-47W866-4 R36 (ref.10), and has been measured to be approximately 2500 cfm (0-SI-31-31-A). The value comes from 1-47W866-4 R20. The 3200 cfm will be retained in this calculation revision since this value produces conservative results.

Results

The control room doses with 1 train of CREVS and 20.6 sec control room isolation are as follows (rem):
Regulatory Guide 1.25 Control Room Doses

Spent Fuel Pit/Auxiliary Building FHA, AB open or closed to containment

	Standard Core	TPC Once Burned	TPC Twice Burned	TPC Thrice Burned	limit
Gamma	4.935E-01	5.638E-01	4.250E-01	5.546E-01	5
Beta	4.068E+00	4.743E+00	3.720E+00	4.535E+00	30
Thyroid (ICRP-30)	1.540E+00	1.634E+00	1.275E+00	1.711E+00	30
TEDE	5.824E-01	4.559E+00	4.399E+00	6.536E-01	5

Containment FHA with 12.7 sec containment isolation, containment closed to AB, no Purge Filters

	Standard Core	TPC Once Burned	TPC Twice Burned	TPC Thrice Burned	limit
Gamma	1.065E-02	1.216E-02	9.169E-03	1.197E-02	5
Beta	8.782E-02	1.023E-01	8.024E-02	9.788E-02	30
Thyroid (ICRP-30)	4.896E+00	5.195E+00	4.054E+00	5.439E+00	30
TEDE	1.648E-01	2.592E-01	2.203E-01	1.832E-01	5

Containment FHA with 12.7 sec containment isolation, containment open to AB, No Purge Filters, with ABGTS
(these values are the sum of the previous 2 cases)

	Standard Core	TPC Once Burned	TPC Twice Burned	TPC Thrice Burned	limit
Gamma	5.042E-01	5.760E-01	4.342E-01	5.666E-01	5
Beta	4.156E+00	4.845E+00	3.800E+00	4.633E+00	30
Thyroid (ICRP-30)	6.436E+00	6.829E+00	5.329E+00	7.150E+00	30
TEDE	7.472E-01	4.818E+00	4.619E+00	8.368E-01	5

Containment FHA with Purge Filters (no containment isolation)

	Standard Core	TPC Once Burned	TPC Twice Burned	TPC Thrice Burned	limit
Gamma	2.677E-01	3.058E-01	2.305E-01	3.007E-01	5
Beta	2.207E+00	2.572E+00	2.018E+00	2.459E+00	30
Thyroid (ICRP-30)	5.209E+00	5.530E+00	4.315E+00	5.790E+00	30
TEDE	4.545E-01	2.619E+00	2.499E+00	5.085E-01	5

Note that the shine through the control room walls, ceiling and floor constitute < 1E7 rem and is therefore negligible.

Regulatory Guide 1.183 Alternate Source Term (AST)

Auxiliary Building FHA with ABI (ABGTS)

	Standard Core	TPC Once Burned	TPC Twice Burned	TPC Thrice Burned	limit
Gamma	2.543E-01	2.907E-01	2.190E-01	2.857E-01	5
Beta	2.029E+00	2.295E+00	1.768E+00	2.267E+00	30
Thyroid (ICRP-30)	5.305E-02	5.629E-02	4.393E-02	5.894E-02	30
TEDE	2.761E-01	7.684E-01	6.911E-01	3.101E-01	5

Auxiliary Building FHA with no ABI (Exhaust Through Auxiliary Building Vent)

	Standard Core	TPC Once Burned	TPC Twice Burned	TPC Thrice Burned	limit
Gamma	5.723E-01	6.543E-01	4.930E-01	6.431E-01	5
Beta	4.566E+00	5.153E+00	3.966E+00	5.101E+00	30
Thyroid (ICRP-30)	1.194E+01	1.266E+01	9.884E+00	1.326E+01	30
TEDE	9.632E-01	1.881E+00	1.628E+00	1.078E+00	5

The offsite doses were determined to be (rem):
Regulatory Guide 1.25:

Spent Fuel Pit/Auxiliary Building FHA, AB open or closed to containment

	Standard		TPC 1		TPC2		TPC3		
	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	limit
Gamma	3.994E-01	9.278E-02	4.554E-01	1.058E-01	3.435E-01	7.980E-02	4.482E-01	1.041E-01	6.25
Beta	1.177E+00	2.734E-01	1.371E+00	3.185E-01	1.074E+00	2.495E-01	1.312E+00	3.047E-01	75
Thyroid (ICRP-30)	1.577E+00	3.663E-01	1.674E+00	3.888E-01	1.306E+00	3.033E-01	1.752E+00	4.070E-01	75
TEDE	2.572E-01	5.974E-02	1.384E+00	3.216E-01	1.316E+00	3.056E-01	2.879E-01	6.688E-02	6.25

Containment FHA with 12.7 sec containment isolation, containment closed to AB, no Purge Filters

	Standard		TPC 1		TPC2		TPC3		
	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	limit
Gamma	4.322E-03	1.004E-03	4.896E-03	1.137E-03	3.704E-03	8.604E-04	4.845E-03	1.126E-03	6.25
Beta	1.167E-02	2.711E-03	1.357E-02	3.153E-03	1.063E-02	2.470E-03	1.301E-02	3.022E-03	75
Thyroid (ICRP-30)	1.536E+00	3.567E-01	1.630E+00	3.786E-01	1.272E+00	2.954E-01	1.706E+00	3.963E-01	75
TEDE	6.282E-02	1.459E-02	7.752E-02	1.801E-02	6.276E-02	1.458E-02	6.979E-02	1.621E-02	6.25

Containment FHA with 12.7 sec containment isolation, containment open to AB, No Purge Filters, with ABGTS

	Standard		TPC 1		TPC2		TPC3		
	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	limit
Gamma	4.037E-01	9.378E-02	4.603E-01	1.069E-01	3.472E-01	8.066E-02	4.530E-01	1.052E-01	6.25
Beta	1.189E+00	2.761E-01	1.385E+00	3.217E-01	1.085E+00	2.520E-01	1.325E+00	3.077E-01	75
Thyroid (ICRP-30)	3.113E+00	7.230E-01	3.304E+00	7.674E-01	2.578E+00	5.987E-01	3.458E+00	8.033E-01	75
TEDE	3.200E-01	7.433E-02	1.462E+00	3.396E-01	1.378E+00	3.202E-01	3.577E-01	8.309E-02	6.25

Containment FHA with Purge Filters

	Standard		TPC 1		TPC2		TPC3		
	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	limit
Gamma	4.102E-01	9.529E-02	4.669E-01	1.085E-01	3.525E-01	8.188E-02	4.602E-01	1.069E-01	6.25
Beta	1.182E+00	2.746E-01	1.377E+00	3.198E-01	1.079E+00	2.505E-01	1.318E+00	3.061E-01	75
Thyroid (ICRP-30)	3.942E+01	9.158E+00	4.185E+01	9.722E+00	3.266E+01	7.586E+00	4.382E+01	1.018E+01	75
TEDE	1.759E+00	4.085E-01	2.979E+00	6.921E-01	2.559E+00	5.945E-01	1.956E+00	4.545E-01	6.25

Regulatory Guide 1.183 Alternate Source Term (AST)

Auxiliary Building FHA with ABI (ABGTS)

	Standard		TPC 1		TPC2		TPC3		
	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	limit
Gamma	3.938E-01	9.147E-02	4.495E-01	1.044E-01	3.389E-01	7.871E-02	4.420E-01	1.027E-01	6.25
Beta	1.128E+00	2.620E-01	1.266E+00	2.953E-01	9.716E-01	2.271E-01	1.260E+00	2.927E-01	75
Thyroid (ICRP-30)	5.241E-01	1.217E-01	5.560E-01	1.292E-01	4.339E-01	1.008E-01	5.822E-01	1.352E-01	75
TEDE	2.136E-01	4.962E-02	3.107E-01	9.478E-02	2.516E-01	8.107E-02	2.395E-01	5.562E-02	6.25

series 4

Auxiliary Building FHA with no ABI

	Standard		TPC 1		TPC2		TPC3		
	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	2-hr EAB	30-day LPZ	limit
Gamma	4.082E-01	9.481E-02	4.648E-01	1.080E-01	3.508E-01	8.148E-02	4.579E-01	1.064E-01	6.25
Beta	1.135E+00	2.636E-01	1.273E+00	2.971E-01	9.773E-01	2.284E-01	1.268E+00	2.945E-01	75
Thyroid (ICRP-30)	5.241E+01	1.217E+01	5.560E+01	1.292E+01	4.339E+01	1.008E+01	5.822E+01	1.352E+01	75
TEDE	2.267E+00	5.266E-01	2.490E+00	6.010E-01	1.952E+00	4.760E-01	2.520E+00	5.854E-01	6.25

Conclusions

The control room operator doses resulting from a Fuel Handling Accident are less than the 10CFR50, Appendix A, GDC 19 limits of 5 rem gamma, 30 rem beta, 30 rem thyroid, and less than the 10CFR50.67 limit of 5 rem TEDE.

The 2 hour Site Boundary (SB)/Exclusion Area Boundary and 30 day Low Population Zone (LPZ) doses from a FHA are less than 25% of the 10CFR100 limits of 25 rem gamma, 300 rem beta, and 300 rem thyroid (=6.25 rem gamma, 75 rem beta, 75 rem thyroid, 6.25 rem TEDE). 10CFR50.67 provides the TEDE equivalence to the gamma limits.

It should be noted that the instrument loop response time is very conservative. For example the sample low flow alarm is at 4 cfm with a very conservative accuracy of ± 2 cfm, which was based on engineering judgment. This accounts for 5.5 seconds and could be lowered by approximately 1-2 seconds. Also the Response of the Beta Scintillator, Photomultiplier tube, and the pre-amplifier have been rounded up from nanoseconds to seconds. This accounts for 0.7 seconds and could be neglected.

Note on methodologies used:

This calculation determined the doses using different methodologies. The gamma, beta and Thyroid (ICRP-30) doses are all based on TID-14844 methodologies utilizing the ICRP-30 iodine dose conversion factors. The other methodology used is the TEDE (Total Effective Dose Equivalent). The TEDE presents an overall weighted dose and is more representative of the impact of all isotopes on the body as a whole. The TEDE dose is required for AST, however is not required for RG 1.25 methodology. It is important to note that tritium does not impact the thyroid doses utilizing the TID-14844 methodology, because only iodine is applied to the thyroid dose. However, in fact tritium does contribute to the thyroid dose, as well as other organs of the body. This is why the TEDE is a more representative dose when discussing the impact of tritium.

References

1. Discrepancy Report No. 274, R0, 10/14/88
2. 1-RE-90-130 R11, "Demonstrated Accuracy Calculation for Containment Building Purge Air Exhaust Monitors"
3. Regulatory Guide 1.52, "Design, Testing And Maintenance Criteria For Postaccident Engineered-Safety-Feature Atmosphere Cleanup System Air Filtration And Adsorption Units Of Light-Water-Cooled Nuclear Power Plants," Revision 2, March 1978.
4. Safety Guide 25, "Assumptions Used For Evaluating The Potential Radiological Consequences Of A Fuel Handling Accident In The Fuel Handling And Storage Facility For Boiling And Light Water Reactors," 3/23/72
5. TI-RPS-198 R17 "Dose to Control Room Personnel Due to a Regulatory Guide 1.4 Loss of Coolant Accident,"
6. Computer Code STP R6, Code I.D. 262165
7. Computer Code COROD ~~R5~~R6, Code I.D. 262347
8. Computer Code FENCDOSE R4, Code I.D. 262358
9. Discrepancy Report No.209, 10/07/88
10. WBN CCD drawing 1-47W866-4 R20 (note: the latest revision is at R36, but the value is from 20).
11. WB-DC-40-36.1 R4 "The Classification of Heating, Ventilating and Air Conditioning System"
12. WBN PER 01-000080-000
13. 0-RE-90-125 R10 "Demonstrated Accuracy Calculation For Main Control Room Air Intake Radiation Monitor 0-RE-90-125,-126, and Emergency Air Intake Radiation Monitor 0-RE-90-205, -206"
14. WBNAPS3-084 R0 "Source Terms For 1500 EFPD Burnup"
15. Code of Federal Regulations, Title 10, Chapters 50 and 100
16. System Description N3-79-4001 R4 "Fuel Handling and Storage System"
17. System Description N3-30AB-4002 R4 "Auxiliary Building - Heating, Ventilation and Air Conditioning System"
18. Watts Bar Technical Specifications Bases Section 3.9.4
19. TI-RPS-197 R17 "Offsite Doses Due to a Regulatory Guide 1.4 Loss of Coolant Accident"
20. WBPER930129 R0
21. EPM-RAV-081193 R2 "Isolation Damper Leakage Rate for the Aux Bldg Supply and Exhaust Fans"
22. DCN M-29141-D
23. WBPER960798
24. WBNAPS3-095 R0 "Offsite and Control Room Dose Due to a FHA with 15 Minutes Unfiltered Release and Various Flow Rates"
25. NUREG/CR-5009 "Assessment of the Use of Extended Burnup Fuel in Light Water Power Reactors" Feb. 1988
26. TTQP-1-091 R10 "Tritium Technology Program - Unclassified TPBAR Tritium Releases, Including Tritium" - Att. 4
27. N3-78-4001 R8 "Spent Fuel Pool Cooling and Cleaning System"

28a. Memorandum from James S. Chardos to Cheryl K. Thornhill, TVATP-00-068, October 23, 2000 "Verification of Design Inputs for Calculations of Breached TPBAR Leaching in the Spent Fuel Pool" – Att. 5
28b. Memorandum from Cheryl K. Thornhill to James S. Chardos, TTQP-00-175, September 19, 2000 "Verification of Design Inputs for Calculations of Breached TPBAR Leaching in the Spent Fuel Pool" –Att. 6

29. WBNAPS3-098 R0 "Source Terms for WBN Tritium Production Core"
30. TI-535 R2 "Max. Expected Airborne Concentration in Primary Containment, Turbine Building, Auxiliary Building, and Instrument Room During Normal Operation"

31a. WBNTSR-023 R5 "Response Time, Range, and Accuracy for the Spent Fuel Pool Radiation Monitors (TSFPRM)" - not used as design input, only for comparative purposes
31b. DCN W-23167-A
31c. WBNTSR-020 R3 "Safety Limit For the Spent Fuel Pool Radiation Monitors" - not used as design input, only for comparative purposes

32. CCD drawing 1-47W866-10 R29
33. Lederer and Shirley "Table of Isotopes" 7th edition
34. WBNAPS3-104 R0 "WBN Control Room X/Q"
35. TID-14844 "Calculation of Distance Factors For Power and Test Reactor Sites"
36. Regulatory Guide 1.183 R0 "Alternative Radiological Source Terms For Evaluating Design Basis Accidents At Nuclear Power Plants"
37. Regulatory Guide 1.140 R3, "Design, Inspection, and Testing Criteria for Air Filtration and Adsorption Units of Normal Atmosphere Cleanup Systems in Light-water-cooled Nuclear Power Plants"

Attachment 1

TRITIUM TECHNOLOGY PROGRAM

UNCLASSIFIED TPBAR RELEASES, INCLUDING TRITIUM

TTQP-1-091

Revision 10

Effective Date: ____

TTQP-1-091

TRITIUM TECHNOLOGY PROGRAM

UNCLASSIFIED TPBAR RELEASES, INCLUDING TRITIUM

Revision 10

Prepared By: DD Lanning
D.D. Lanning, Author
3/16/06
Date

Reviewed By: E R Gilbert
E.R. Gilbert, Independent Reviewer
3/16/06
Date

Concurrence:
E.F. Love, Authorized Derivative Classifier
3/24/06
Date

T.M. Brewer, Quality Engineer
3/17/06
Date

BD Reid
B.D. Reid, Design Task Manager
3/23/06
Date

Approval: CK Thornhill
C.K. Thornhill, TTP Project Manager
3/24/06
Date

1.0 INTRODUCTION

This document provides a complete listing of all unclassified tritium release values that should be assumed for unclassified analysis. Much of the information is brought forth from the related documents listed in Section 4.0 to provide a single-source listing of unclassified release values. Some information, however, is new or updated based on current design analysis and available experimental data.

This document provides unclassified information for a larger number of release scenarios than previously analyzed. This information is summarized in Tables 1, 2, and 3. In addition, a section is included to address lithium and aluminum release in the event of a 24-TPBAR breach in the spent fuel pool.

2.0 SUMMARY OF UNCLASSIFIED RELEASES, INCLUDING TRITIUM

All tritium-producing burnable absorber rod (TPBAR) analysis assumes a maximum of 1.2 grams of tritium per TPBAR will be generated during an 18-month operating cycle.

2.1 Intact TPBAR In-reactor Tritium Permeation

The in-reactor tritium permeation rate deduced from RCS tritium activity for the group of 240 TPBARs in Watts Bar Nuclear Cycle 6 averaged over a year extending to end-of-cycle, was 2.4 ± 1.8 Ci/TPBAR/year (95% confidence interval) (Lanning and Pagh, 2005). The 95% upper bound of 2.4 + 1.8 = 4.2 Ci/TPBAR/year is recommended as the basis for assessing the tritium release from intact TPBARs.

2.2 In-reactor Tritium Release from a Failed TPBAR

The first scenario involves a TPBAR that may have a fabrication defect or may be damaged prior to insertion into the reactor for irradiation. In this case, 100 percent of the tritium generated in the TPBAR is assumed to be released to the reactor coolant as it is generated.

2.3 TPBAR Releases from Spent Fuel Pool Accidents

2.3.1 Spent Fuel Pool Tritium Concentration Limit

It has been determined that following the simultaneous breach of 24 TPBARs, the Tennessee Valley Authority take-action limit for tritium concentration in the spent fuel pool water will not be exceeded. The concentration limit is 60 microcuries per milliliter. The best estimate of total tritium release in this event is less than 25% of the TPBAR inventory. ~~r. The best estimate tritium release is less than 25% of the TPBAR inventory.~~ The release will not be instantaneous, but will occur at a steady rate over a time period substantially greater than 8 hours. The rate will thus be less than 3% (of initial inventory) per hour.

2.3.2 Instantaneous Tritium Release per TPBAR

In particular, the instantaneous release of tritium from breached TPBARs in the spent fuel pool (as gas within the released gas from the TPBARs) will not exceed 0.001 Ci/TPBAR.

2.3.3 Lithium and Aluminum Release

In the event of a 24-TPBAR breach in the spent fuel, the following concentration limits for lithium and aluminum will not be exceeded:

- 400 ppb lithium
- 50 ppb aluminum.

2.4 Tritium Releases from TPBARs within Storage Canisters (<200°F)

The upper-bounding tritium partial pressure within storage canisters containing lead test assembly (LTA) TPBARs and sections is not expected to exceed 20 torr under nominal storage conditions (~86°F). The quoted bounding pressure for maximum temperatures (<200°F) is estimated by increasing this figure by the ratio of Kelvin temperatures, to 25 torr.

Tritium release from extracted TPBARs in storage will not exceed 1% of the declared post-extraction residual tritium (Clemmer et al. 1984; and Johnson et al. 1976).

In both cases, the form of the released tritium will be tritiated water vapor or condensate (HTO).

2.5 TPBAR Transportation Cask Event Releases

2.5.1 Intact TPBARs

2.5.1.1 For TPBAR temperatures ranging from ambient to less than 200°F, and for casks containing 1,200 or less TPBARs, the tritium release from the entire cask loading would be less than 0.19 mCi per hour, based on extrapolation from an in-reactor upper bound observed permeation rate of 4.2 Ci/TPBAR/year. The tritium would be released from the TPBARs in the form of molecular tritium gas (i.e., T_2 or HT).

2.5.1.2 For TPBAR temperatures ranging from 200°F to 650°F, the average tritium release would be less than 0.48 mCi per TPBAR per hour based on the upper-bound in-reactor release rate of 4.2 Ci/TPBAR/year. The tritium would be released from the TPBARs in the form of tritium gas.

2.5.1.3 For TPBAR temperatures ranging from 650°F up to 1050°F (565°C), the tritium release should be considered to be an instantaneous release of less than 0.5 Ci per TPBAR per hour. Again, the tritium would be released from the TPBARs in the form of tritium gas.

The potential for TPBAR rupture was assessed at 1050°F because this is one of the temperature break-points in the Modal Study matrix cited earlier (Laity 1998). It was determined that the TPBARs are unlikely to rupture at temperatures less than 1050°F, but may rupture at higher temperatures.

2.5.1.4 Helium release from intact TPBARs is negligible.

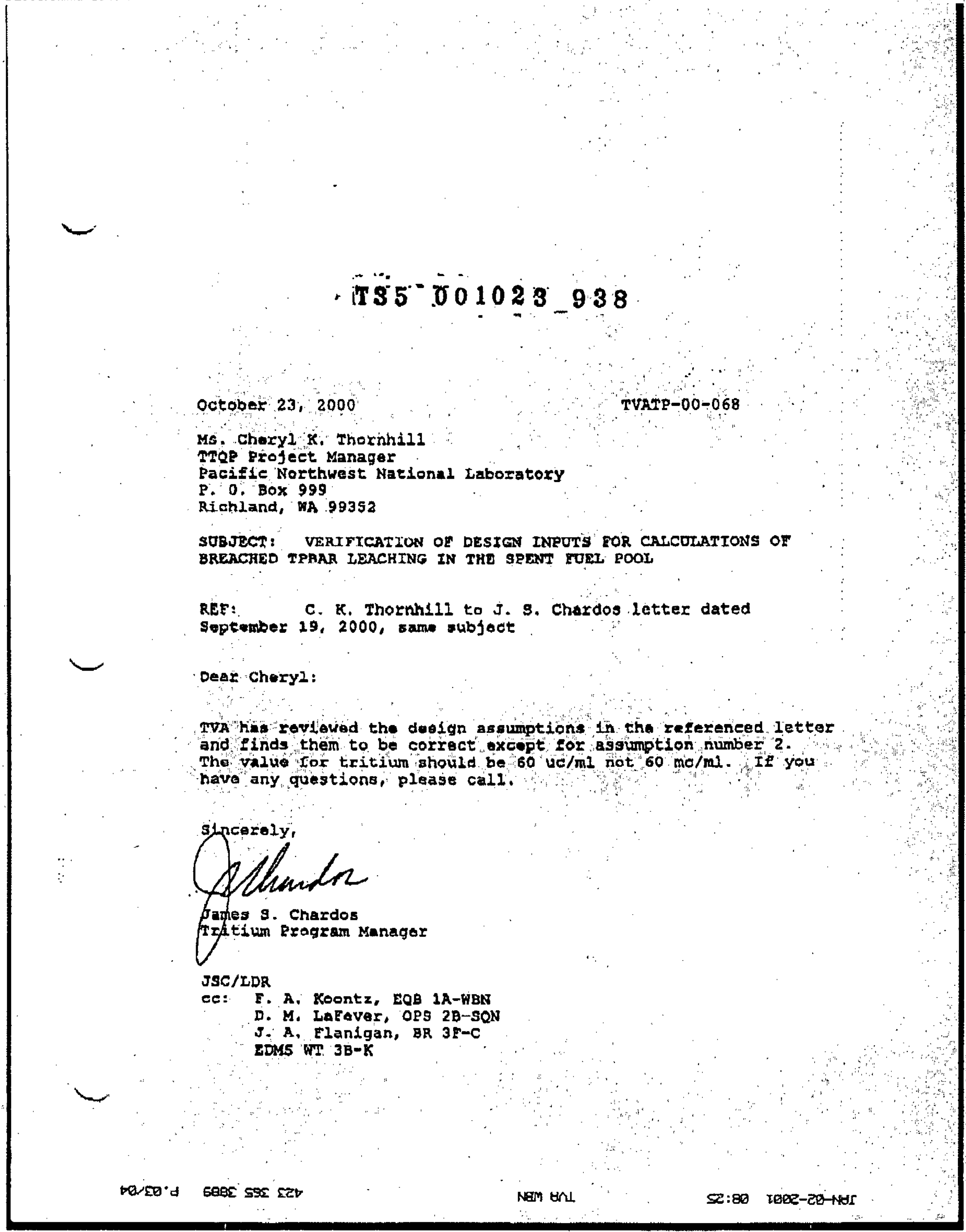
2.5.2 Event-failed TPBARs

2.5.2.1 For TPBAR temperatures ranging from ambient to 200°F, the tritium release from a TPBAR whose cladding fails mechanically (e.g., due to impact forces) after cask loading should be considered to be less than 0.1 Ci per TPBAR per hour, not to exceed 1% of the tritium inventory in the lithium aluminate pellets. The release should be considered to be in the form of tritiated water and a very small fraction of methane.

2.5.2.2 For TPBAR temperatures ranging from 200°F to 650°F, the tritium release from a TPBAR whose cladding fails mechanically (e.g., due to impact forces) after cask loading should be considered to be less than 55 curies total due to desorption release. The release should be considered to be in the form of tritiated water and a very small fraction of methane.

2.5.2.3 For TPBAR temperatures ranging from 650°F to 1050°F, the tritium release should be considered to be up to 100% of the TPBAR tritium inventory, in the form of tritiated water and methane.

Attachment 2



TS5 001023 938

October 23, 2000 TVATP-00-068

Ms. Cheryl K. Thornhill
TTQP Project Manager
Pacific Northwest National Laboratory
P. O. Box 999
Richland, WA 99352

SUBJECT: VERIFICATION OF DESIGN INPUTS FOR CALCULATIONS OF BREACHED TPBAR LEACHING IN THE SPENT FUEL POOL

REF: C. K. Thornhill to J. S. Chardos letter dated September 19, 2000, same subject

Dear Cheryl:

TVA has reviewed the design assumptions in the referenced letter and finds them to be correct except for assumption number 2. The value for tritium should be 60 uc/ml not 60 mc/ml. If you have any questions, please call.

Sincerely,

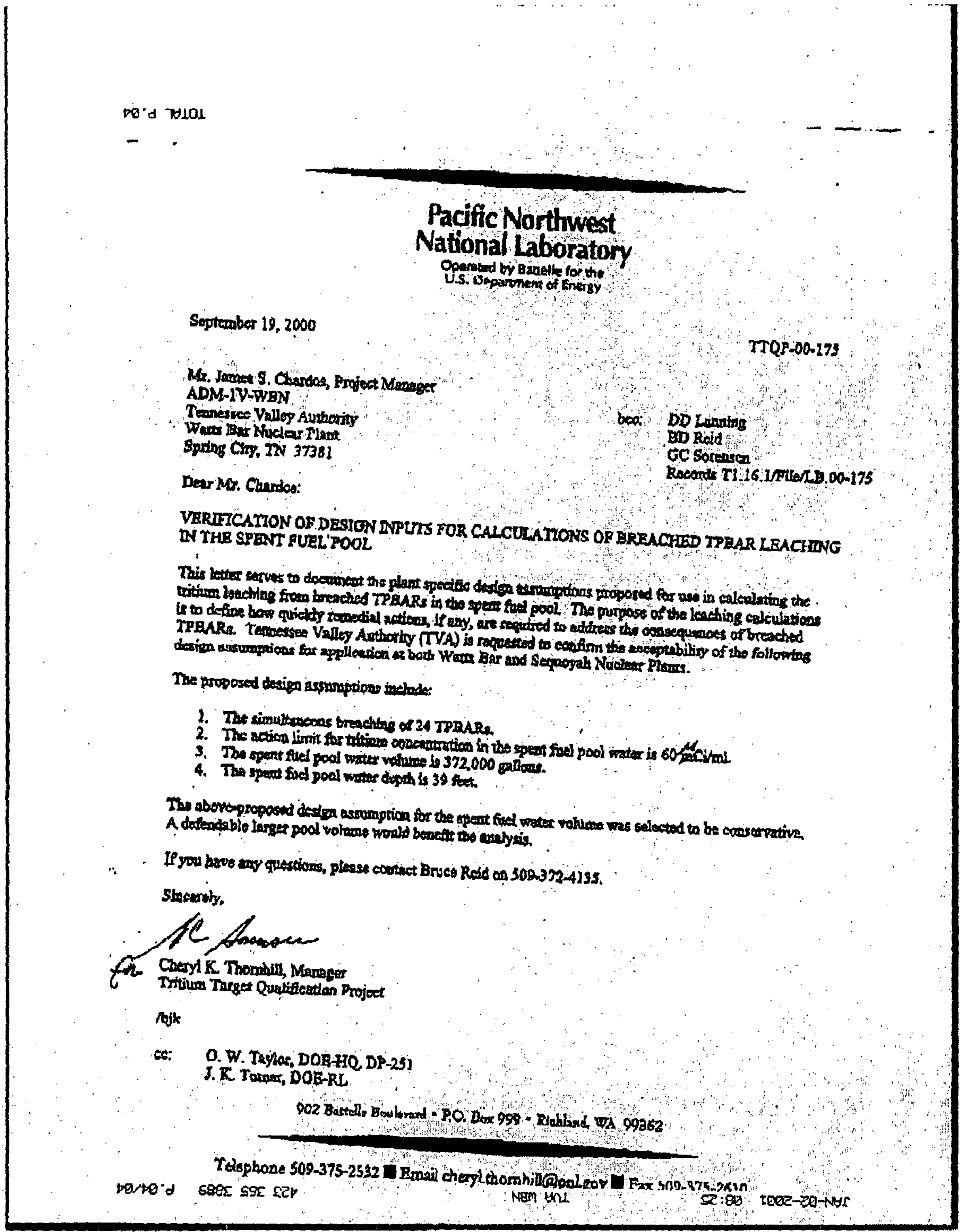
JChardos

James S. Chardos
Tritium Program Manager

JSC/LDR
cc: F. A. Koontz, EQB 1A-WBN
D. M. LaFever, OPS 2B-SQN
J. A. Flanigan, BR 3F-C
EDMS WT 3B-K

JAN-02-2001 08:25 TVA WBN 423 365 3889 P.03/04

Attachment 3



TOTAL P.04

Pacific Northwest
National Laboratory
Operated by Battelle for the
U.S. Department of Energy

September 19, 2000

TTQP-00-175

Mr. James S. Chardos, Project Manager
ADM-IV-WBN
Tennessee Valley Authority
Watts Bar Nuclear Plant
Spring City, TN 37381

bcc: DD Lanning
BD Reid
GC Sorensen
Records T1.16.1/File/LB.00-175

Dear Mr. Chardos:

VERIFICATION OF DESIGN INPUTS FOR CALCULATIONS OF BREACHED TPBAR LEACHING IN THE SPENT FUEL POOL

This letter serves to document the plant specific design assumptions proposed for use in calculating the tritium leaching from breached TPBARs in the spent fuel pool. The purpose of the leaching calculations is to define how quickly remedial actions, if any, are required to address the consequences of breached TPBARs. Tennessee Valley Authority (TVA) is requested to confirm the acceptability of the following design assumptions for application at both Watts Bar and Sequoyah Nuclear Plants.

The proposed design assumptions include:

1. The simultaneous breaching of 24 TPBARs.
2. The action limit for tritium concentration in the spent fuel pool water is 60 ~~m~~μCi/ml.
3. The spent fuel pool water volume is 372,000 gallons.
4. The spent fuel pool water depth is 39 feet.

The above-proposed design assumption for the spent fuel water volume was selected to be conservative. A defendable larger pool volume would benefit the analysis.

If you have any questions, please contact Bruce Reid on 509-372-4135.

Sincerely,

for Cheryl K. Thornhill, Manager
Tritium Target Qualification Project

/bjk

cc: O. W. Taylor, DOE-HQ, DP-251
J. K. Turner, DOE-RL

902 Battelle Boulevard • P.O. Box 999 • Richland, WA 99352

Telephone 509-375-2532 ■ Email cheryl.thornhill@pnl.gov ■ Fax 509-375-2610

JAN-02-2001 08:25 TVA WBN 423 365 3889 P.04/04

Attachment 7

TVA Nuclear Power Group Calculation

WBNTSR-080 R6

Control Room Operator and Offsite Doses Due to a Loss of AC Power

NPG CALCULATION COVERSHEET/CCRIS UPDATE

REV 0 EDMS/RIMS NO. B26 910626 201	EDMS TYPE: calculations(nuclear)	EDMS ACCESSION NO (N/A for REV. 0) T93100219004

Calc Title:

Control Room Operator and Offsite Doses Due to a Loss of AC Power

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	
CURRENT	CN	NUC	WBN	NTB	WBNTSR-080	5	6	REVISION APPLICABILITY
NEW	CN	NUC						Entire calc ☒ Selected pages ☐

ACTION	NEW ☐ REVISION ☒	DELETE ☐ RENAME ☐	SUPERSEDE ☐ DUPLICATE ☐	CCRIS UPDATE ONLY ☐ (Verifier Approval Signatures Not Required)	No CCRIS Changes ☐ (For calc revision, CCRIS been reviewed and no CCRIS changes required)

UNITS 1/2	SYSTEMS NA	UNIDS NA

DCN,EDC,N/A EDCR 54956	APPLICABLE DESIGN DOCUMENT(S) NA	CLASSIFICATION E

QUALITY RELATED? Yes ☒ No ☐	SAFETY RELATED? (If yes, QR = yes) Yes ☒ No ☐	UNVERIFIED ASSUMPTION Yes ☐ No ☒	SPECIAL REQUIREMENTS AND/OR LIMITING CONDITIONS? Yes ☐ No ☒	DESIGN OUTPUT ATTACHMENT? Yes ☐ No ☒	SAR/TS and/or ISFSI SAR/CoC AFFECTED Yes ☒ No ☐

PREPARER ID MCBERG	PREPARER PHONE NO 603-926-3810	PREPARING ORG (BRANCH) WorleyParsons/Polestar	VERIFICATION METHOD Design Review	NEW METHOD OF ANALYSIS ☐ Yes ☒ No

PREPARER SIGNATURE Marc C. Berg Marc C. Berg	DATE 1-29-10	CHECKER SIGNATURE Heather M. Lucek Heather M Lucek	DATE 1.29.10
VERIFIER SIGNATURE Heather M. Lucek Heather M Lucek	DATE 1.29.10	APPROVAL SIGNATURE DGF 2/18/2010 J S Thompson JSThompson	DATE 02/19/10

STATEMENT OF PROBLEM/ABSTRACT

A loss of AC power to the Watts Bar Nuclear Plant will result in a significant amount of steam release to the environment. This steam will contain radionuclides if a primary to secondary side leak occurs prior to the steam dump.

This calculation determined the control room operator and offsite doses following a Loss of AC Power. The inventory of radionuclides released to the environment was determined using the secondary steam inventories in WBNNAL3-003. The amount of steam dumped was obtained from Westinghouse for the new Steam Generators. The computer code COROD was used to determine the control room operator doses. Computer code FENCDOSE was used to determine the offsite doses. Design doses (~1% failed fuel) were determined by multiplying the realistic secondary steam inventory by 8. The results are provided in the results section.

The calculated offsite doses are substantially below (<10%) the regulatory limits of 25 rem whole body, 300 rem beta, 300 rem thyroid, and 25 rem TEDE. The control room operator doses are substantially below the regulatory limits of 5 rem gamma, 30 rem beta, 30 rem thyroid, and 5 rem TEDE.

The results of this calculation are direct input to FSAR Table 15.5-2

MICROFICHE/EFICHE Yes ☒ No ☐ FICHE NUMBER(S) TVA-F-W001413

☐ LOAD INTO EDMS AND DESTROY
☐ LOAD INTO EDMS AND RETURN CALCULATION TO CALCULATION LIBRARY. ADDRESS:
☐ LOAD INTO EDMS AND RETURN CALCULATION TO:

NPG CALCULATION COVERSHEET/CCRIS UPDATE

Page 2

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	REV
	CN	NUC	WBN	NTB	WBNTSR-080	6

ALTERNATE CALCULATION IDENTIFICATION

BLDG	ROOM	ELEV	COORD/AZIM	FIRM	Print Report Yes ☒
				Polestar	

CATEGORIES

KEY NOUNS (A-add, D-delete)

ACTION (A/D)	KEY NOUN	A/D	KEY NOUN

CROSS-REFERENCES (A-add, C-change, D-delete)

ACTION (A/C/D)	XREF CODE	XREF TYPE	XREF PLANT	XREF BRANCH	XREF NUMBER	XREF REV
A	P	VD	WBN	MEB	LTR-CRA-09-103	
A	P	VD	WBN	MEB	WBT-D-1202	
A	P	ED	WBN	MEB	EDCR 54956	

CCRIS ONLY UPDATES:
Following are required only when making keyword/cross reference CCRIS updates and page 1 of form NEDP-2-1 is not included:

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE

PREPARER PHONE NO.

EDMS ACCESSION NO.

NPG CALCULATION RECORD OF REVISION

CALCULATION IDENTIFIER WBNTSR-080

Title **Control Room Operator and Offsite Doses Due to a Loss of AC Power**

Revision No.	DESCRIPTION OF REVISION
0	Initial issue.
1	This revision was prepared to remove the FSAR as a reference and to apply the offsite dose limit of 10% of 10CFR100 per ANSI/ANS 51.1. Also, per OICP 92-1c, the results were compared to 10CFR20 exposure limits. The dose results as previously calculated in revision 0 of this calculation satisfy these limits. Therefore, the conclusion of the calculation remains the same. CCRIS was checked on 02/09/93, and no changes which impact this calculation were found. As no drawings were used, a DCCM review was not required. pages added: 3, 6a pages deleted: 3 pages changed: 1, 2, 4, 9, 10, 13, 14 total pages: 15 As this calculation is not used as a design input by any other discipline, an impact review is not required. The calculation results have not changed.
2	Revision 2 of this calculation was performed because the X/Q values changed. All pages were rewritten for legibility and renumbered. Only actual text changes are marked with a revision bar. pages changed: all pages added: none pages deleted: none
3	Revision 3 was performed because the control room makeup flow changed from 325 to 711 cfm. pages changed: 1-7, 9, 14, 15 pages added: none pages deleted: none R3 total pages = 15
4	Revision 4 implements EDC E50629A, which implements the use of a Tritium Production Core. The calculation was rewritten and renumbered, actual text changes are marked by a revision bar. The revision revised the methodology for determining the source terms for the steam release; the use of STP was replaced by using the source terms for secondary steam provided in WBNNAL3-003. The evaluations in this revision utilize the latest version of COROD and FENCDOSE, which calculate dose using ICRP-2 and the new ICRP-30 methodology as well as the TEDE. New χ/Q's are being used from the ARCON96 methodology in addition to the Halitsky values. Applicable changes to the FSAR are being handled via EDC E50629A Pages changed : 1-11, including 2a (old cover sheet) Pages added: all Pages deleted: all R4 total Pages = 22
5	Revision 5 is in support of the Steam Generator Replacement Project (DCN 51754). The mass releases have been changed and are thus updated in this calculation. PER 61493 was addressed in regards to operation with 2 trains of CREVS. An assumption was added that discussed the 2 trains of CREVS is beyond design basis. The FSAR and Technical Specifications impacts, if any, are addressed in the screening review for DCN 51754. FSAR Table 15.5-2 is directly affected by the revision. Pages changed : 1-10 Pages added: none Pages deleted: 2a, old page 5 (Design Verification Form), old page 7 (Output Info Sheet), Appendices A and B (2 pages), and Attachment 1 (8 pages) R4 total Pages = 10
6	Revision 6 is performed for a Unit 2 accident. The original steam generators are used, however Westinghouse has provided revised mass releases. The Unit 2 ARCON96 values were also used. The SAR has been reviewed by Marc Berg and this revision of the calculation affects Unit 2 SAR section Chapter 15 . A SAR change shall be processed in accordance with NGDC PP-10 to reflect the calculation results as part of EDCR 54956. Tech Specs have been reviewed and determined not to be affected. Pages added: design verification form (p.5), Appendix B (p 13, 14) Pages deleted: none Pages changed: 1-8, 10-12 R6: 14 total pages

NPG CALCULATION TABLE OF CONTENTS

Calculation Identifier: WBNTSR-080	Revision: 6

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SECTION TITLE PAGE

NPG CALCULATION VERIFICATION FORM

Calculation Identifier WBNTSR-080	Revision 6

Method of verification used:

1. Design Review ☒
2. Alternate Calculation ☐
3. Qualification Test ☐

Heather Lucek

Verifier Heather Lucek Date 1-29-2010

Comments:

I have reviewed WBNTSR-080 R6 and have found the calculation to have been completed in a technically sound an appropriate manner to address the Loss of AC Power in Unit 2. In conducting the verification I reviewed the methodology, design input, and assumptions which I found to be valid and conservative. I verified the computer code inputs for correctness and confirmed they only contained the changes as specified in this document. I also confirmed the correct output values were compiled in the results.

LEGIBILITY EVALUATED AND ACCEPTED FOR ISSUE. ALL PAGES

Scott Helm - 2/18/10

SIGNATURE REV 6 DATE

NPG COMPUTER INPUT FILE
STORAGE INFORMATION SHEET

Document WBNTSR-080	Rev.6	Plant: WBN	

Subject:
Control Room Operator and Offsite Doses Due to a Loss of AC Power

☐ Electronic storage of the input files for this calculation is not required. Comments:

☒ Input files for this calculation have been stored electronically and sufficient identifying information is provided below for each input file. (Any retrieved file requires re-verification of its contents before use.)

The R3 input files are stored in FILEKEEPER file # 263720

The R4 input files are stored in FILEKEEPER file # 303460 (FENCDOSE runs and ARCON96 COROD)
303556 (Halitsky COROD runs)

The R5 input files are stored in FILEKEEPER file # 308245

The R6 input files are stored in eFiche file TVA-F-W001413

☐ Microfiche/eFiche

NPG COMPUTER OUTPUT
MICROFICHE INFORMATION SHEET

Document	Rev.	Plant:	

Subject:
Control Room Operator and Offsite Doses Due to a Loss of AC Power

Microfiche Number	Description		
R0 : WRAD-27 R2 : TVA-F-C000079 R3 : TVA-F-C000118 R4 : TVA-F-C-000344 TVA-F-C000351 R5 : TVA-F-W000606			
	Filename	Code	Description
	TSR080FA5	FENCDOSE	Offsite Dose, Realistic Case – TPC
	TSR080FB5	FENCDOSE	Offsite Dose, 1% Case - TPC
	TSR080FC5	FENCDOSE	Offsite Dose, Realistic Case - Non-TPC
	TSR080FD5	FENCDOSE	Offsite Dose, 1% - Non-TPC
	TSR080CA5	COROD	Control Room operator dose, Realistic Case - TPC
	TSR080CB5	COROD	Control Room operator dose, 1 % Case - TPC
	TSR080CC5	COROD	Control Room operator dose, Realistic Case - Non-TPC
R6: TVA-F-W001413	TSR080CD5	COROD	Control Room operator dose, 1 % Case - Non-TPC
	TSR080FA6	FENCDOSE	Offsite Dose, Realistic Case – TPC
	TSR080FB6	FENCDOSE	Offsite Dose, 1% Case - TPC
	TSR080CA6	COROD	Control Room operator dose, Realistic Case - TPC
	TSR080CB6	COROD	Control Room operator dose, 1 % Case - TPC

Purpose

The purpose of this calculation is to determine the control room operator and offsite dose due to a Loss of AC Power. This calculation supports FSAR chapter 15.5. Revision 2 is performed because χ/Q values have changed. Revision 3 is performed because the control room makeup flow changed from 325 to 711 cfm. Revision 4 implements EDC E50629A to allow the use of a Tritium Production Core (TPC), it also revises the source inventory to the secondary steam in WBNNAL3-003 (ref.2), and utilizes new χ/Q values used from ARCON96 methodology in addition to the old Halitsky values. Revision 5 was performed as the mass releases changed due to replacement steam generators.

Revision 6 added the Unit 2 accident (see Appendix B). Unit 2 has the original steam generators, however Westinghouse provided revised mass releases. Also the Unit 2 ARCON96 X/Q values are used. Only the TPC was evaluated as it bounds the conventional core.

Introduction

A Loss of AC Power to the Watt's Bar Nuclear Plant will result in a significant steam release to the environment. The steam will contain radionuclides if a primary to secondary side leak occurs prior to the event. The secondary steam inventory from WBNNAL3-003 consists of expected radionuclide activity levels (ANS/ANSI-18.1-1984, ref.2). Computer code COROD (ref.4) will be used to determine the control room operator dose using the secondary steam inventory. Computer code FENCDOSE (ref.5) will be used to determine the offsite dose using the secondary steam inventory. The calculation will provide the control room operator and offsite dose for both the standard core and the TPC for both the realistic case and 1% failed fuel case.

It should be noted that there is no standard review plan or regulatory guide for this accident. This is a simple best estimate analysis. The 1% failed fuel case is a conservative analysis that utilizes a factor of 8 as a multiplier to the realistic case. This factor causes the inventories to exceed the technical specification values (which would have a multiplier of 7.965, ref.12). The 1% failed fuel is not exactly 1%. It is based on the realistic case being close to but not exactly 0.125% failed fuel, therefore 8 times 0.125% = 1 %. It should be considered just a label for a severe case.

The offsite dose limits are 10% (ref.16) of the following regulatory limits: 25 rem gamma (10CFR100.11), 300 rem thyroid (10CFR100.11), 300 rem beta, and 25 rem TEDE (10CFR50.67). SRP 6.4 in NUREG 0800 shows that the thyroid dose and beta dose limits are equivalent for the control room, therefore the offsite beta dose limit can be assumed the same as the offsite thyroid dose limit, 300 rem. 10CFR20.1201 also states that the organ (thyroid) dose and skin (beta) dose are equivalent. The control room dose limits are 5 rem gamma (10CFR50 Appendix A GDC19), 30 rem thyroid (SRP 6.4), 30 rem beta (SRP 6.4), and 5 rem TEDE (10CFR50.67).

Design Input

The amount of steam released to the environment due to the loss of AC power is provided below as given in ref.10.

0 - 2 hours	455,718 lbs.
2 - 8 hours	962,213 lbs.

The following are the χ/Q values used in the computer code models:

Offsite (ref.12): 30 day LPZ : 1.41E-4 0-2hr; 6.68E-5 2-8hr; 4.59E-5 8-24 hr; 2.04E-5 1-4 days; 6.35E-04 4-30 days
2 hr EAB : 6.07E-4

Control Room (ref. 13): 4.03E-3 0-2hr; 3.35E-3 2-8hr; 2.27E-4 8-24hr; 1.81E-4 1-4 day; 1.45E-4 4-30 day

Assumptions

1. The secondary side source consists of expected/realistic radionuclide activity levels for a reactor based on ANSI/ANS 18.1-1984, as calculated in WBNNAL3-003 (ref.2).
2. WBNNAL3-003 (ref.2) provides the inventory for tritium in a TPC. Only the 2 TPBAR failure source term is used for each case, as the tritium has only a small impact on the result and using the 2 TPBAR failure source term is conservative since additional failed fuel has no impact on tritium from a failed TPBAR.
3. Only one train of CREVS is in operation. Normally, each CREVS train takes suction from separate intakes with no cross communication between trains. This leads to one contaminated train, and one uncontaminated train. The only way a 2 CREVS operation could result in higher doses would be for both trains to take suction from the same vent. For

this to happen, one intake path would require a failed closed intake path **AND** a fail open of normally closed passive manual damper at the beginning of the accident. An active failure of a train plus a failure of a passive component in less than 24 hours is beyond design basis.

Special Requirements/Limiting Conditions

There are no special requirements or limiting conditions in this calculation.

Calculations

The radionuclide inventory is provided in μCi/g in WBNNAL3-003. The releases, in Ci, are determined for each isotope per the following equation and are provided in the table below (the table also provides the 1% values by multiplying the realistic values by 8 except for tritium):

Ci (isotope) = μCi/g (isotope) * (Ci/1E6 μCi) * 453.59 gm/lb. * steam released lbs.

Secondary Side Steam Inventory From WBNNAL3-003

		Realistic Inventory			1% Failed Fuel	
Isotope	μCi/g	(0-2 hr) Ci	(2-8 hr) Ci		(0-2 hr) Ci	(2-8 hr) Ci
Kr-83m	0.000E+00	0.000E+00	0.000E+00		0.000E+00	0.000E+00
Kr-85m	3.630E-08	7.504E-06	1.584E-05		6.003E-05	1.267E-04
Kr-85m	5.510E-08	1.139E-05	2.405E-05		9.112E-05	1.924E-04
Kr-87	3.220E-08	6.656E-06	1.405E-05		5.325E-05	1.124E-04
Kr-88	6.310E-08	1.304E-05	2.754E-05		1.043E-04	2.203E-04
Kr-89	0.000E+00	0.000E+00	0.000E+00		0.000E+00	0.000E+00
Xe-131m	1.340E-07	2.770E-05	5.848E-05		2.216E-04	4.679E-04
Xe-133m	1.540E-08	3.183E-06	6.721E-06		2.547E-05	5.377E-05
Xe-133m	5.250E-07	1.085E-04	2.291E-04		8.682E-04	1.833E-03
Xe-135m	2.900E-08	5.995E-06	1.266E-05		4.796E-05	1.013E-04
Xe-135m	1.910E-07	3.948E-05	8.336E-05		3.159E-04	6.669E-04
Xe-137	7.620E-09	1.575E-06	3.326E-06		1.260E-05	2.661E-05
Xe-138	2.680E-08	5.540E-06	1.170E-05		4.432E-05	9.357E-05
I-131	1.410E-08	2.915E-06	6.154E-06		2.332E-05	4.923E-05
I-132	3.370E-08	6.966E-06	1.471E-05		5.573E-05	1.177E-04
I-133	4.030E-08	8.330E-06	1.759E-05		6.664E-05	1.407E-04
I-134	2.930E-08	6.057E-06	1.279E-05		4.845E-05	1.023E-04
I-135	6.190E-08	1.280E-05	2.702E-05		1.024E-04	2.161E-04
H-3 2-Rod	9.840E-02	2.034E+01	4.295E+01		2.034E+01	4.295E+01

For each case the released radionuclides are input into computer code FENCDOSE (ref. 3) to calculate the Low Population Zone (LPZ) offsite dose. The FENCDOSE model is taken from WBNAPS3-077 (ref. 12).

For each case the released radionuclides are also input into computer code COROD (ref. 4) to determine the control room operator dose. The COROD model is taken from WBNAPS3-077 (ref. 12). The χ/Q values used are from WBNAPS3-104 (ref.13) for the SGTR accident, because the steam release points are the same.

Results

Unit 1 Doses Due to Loss of AC Power (Rem)

Non-TPC

Realistic Inventory	Offsite		
	2 hr EAB	30 day LPZ	Control Room
gamma	1.75E-08	8.13E-09	8.26E-09
Beta	1.02E-08	4.72E-09	9.24E-08
Inhalation (ICRP-30)	1.07E-06	4.99E-07	7.62E-07
TEDE*	7.94E-08	3.69E-08	3.69E-08

1% Failed Fuel	Offsite		
	2 hr EAB	30 day LPZ	Control Room
gamma	1.40E-07	6.50E-08	6.61E-08
Beta	8.12E-08	3.77E-08	7.39E-07
Inhalation (ICRP-30)	8.59E-06	3.99E-05	6.10E-06
TEDE*	6.35E-07	2.95E-07	2.95E-07

TPC

Realistic Inventory	Offsite		
	2 hr EAB	30 day LPZ	Control Room
gamma	1.75E-08	8.13E-09	8.26E-09
Beta	1.61E-05	7.50E-06	2.92E-04
Inhalation (ICRP-30)	1.07E-06	4.99E-07	7.62E-07
TEDE*	2.64E-04	1.23E-04	4.78E-03

1% Failed Fuel	Offsite		
	2 hr EAB	30 day LPZ	Control Room
gamma	1.40E-07	6.50E-08	6.61E-08
Beta	1.62E-05	7.53E-06	2.93E-04
Inhalation (ICRP-30)	8.59E-06	3.99E-06	6.10E-06
TEDE*	2.65E-04	1.23E-04	4.78E-03

Notes for Table:

* COROD R6 does not include in the TEDE, the dose due to direct shine from outside the control room. The value is manually added to arrive at the total TEDE.

$\text{TEDE}_{\text{total}} = \text{TEDE}_{\text{air}} + \text{gamma}_{\text{shine}} + \text{TEDE}_{\text{In/Egress}}$

where gamma shine > 0 but is negligible

Discussion and Conclusion

The calculated offsite doses are substantially below (< 10%, ref.16) the regulatory limits of 25 rem whole body, 300 rem beta, 300 rem thyroid, and 25 rem TEDE. The control room operator doses are substantially below the regulatory limits of 5 rem gamma, 30 rem beta, 30 rem thyroid, and 5 rem TEDE. The calculated offsite TEDE dose is also less than the 10CFR20.1301 (ref.14) limit of 0.1 rem. The Unit 1 accident bound the Unit 2 accident. |

References

1. DCN 51754, Steam Generator Replacement (I/O)
2. WBNNAL3-003 R4 " Reactor Coolant Activities in Accordance with ANS/ANSI-18.1-1984"
3. Deleted in revision 4
4. Computer code COROD R7, code ID 262347 |
5. Computer code FENCDOSE R5, code ID 262358 |
6. Deleted in revision 4
7. Deleted in revision 4
8. Deleted in revision 4
9. Deleted in revision 4
10. WCAP-16286-P, January 1005, "Watts Bar Unit 1 Replacement Steam Generator Program NSSS Engineering Report"
11. Deleted in revision 4
12. WBNAPS3-077 R10, "Offsite and Control Room Operator Doses Due to a Main Steam Line Break" |
13. WBNAPS3-104 R0, "WBN Control Room χ/Q"
14. 10CFR20, section 20.1301, "Dose Limits for Individual Members of the Public"
15. EDC E50629A
16. ANS/ANSI 51.1-1983, "Nuclear Safety Criteria for the Design of Stationary Pressurized Water Reactor Plants"

17a. WBT-D-1202 October 22, 2009 "WBS 5.2.11 Revised Steam Releases for Dose" |
17b. LTR-CRA-09-103 Rev.1 "Watts Bar Unit 2 Completion Project – Results of Steam Releases for Dose Calculations" |
18. EDCR 54956 |

Appendix A
Original Steam Generator Results, Unit 1.

The following are the results for the original steam generators (R4 of this calculation).

Realistic Case - Non-TPC			Control Room Operator	
	30 day LPZ	2 hr EAB	ARCON96	Halitsky
Gamma (whole body)	9.625E-09	2.399E-08	9.344E-09	8.012E-09
Beta	5.583E-09	1.392E-08	1.046E-07	8.967E-08
Iodine (thyroid)-ICRP-2	1.130E-06	2.818E-06	1.499E-06	1.301E-06
Iodine (thyroid)-ICRP-30	5.908E-07	1.473E-06	8.227E-07	7.144E-07
TEDE*	4.365E-08	1.088E-07	4.004E-08	3.443E-08

1% Failed Fuel Case - Non-TPC			Control Room Operator	
	30 day LPZ	2 hr EAB	ARCON96	Halitsky
Gamma (whole body)	7.696E-08	1.919E-07	7.447E-08	6.389E-08
Beta	4.452E-08	1.113E-07	8.301E-07	7.126E-07
Iodine (thyroid)-ICRP-2	9.045E-06	2.255E-05	1.199E-05	1.041E-05
Iodine (thyroid)-ICRP-30	4.727E-06	1.178E-05	6.583E-06	5.716E-06
TEDE*	3.492E-07	8.705E-07	3.200E-07	2.752E-07

Realistic Case - TPC (2 TPBAR Failure)			Control Room Operator	
	30 day LPZ	2 hr EAB	ARCON96	Halitsky
Gamma (whole body)	9.625E-09	2.399E-08	9.344E-09	8.012E-09
Beta	8.880E-06	2.214E-05	3.314E-04	2.842E-04
Iodine (thyroid)-ICRP-2	1.130E-06	2.818E-06	1.499E-06	1.301E-06
Iodine (thyroid)-ICRP-30	5.908E-07	1.473E-06	8.227E-07	7.144E-07
TEDE*	1.453E-04	3.623E-04	5.415E-03	4.644E-03

1% Failed Fuel Case - TPC (2 TPBAR Failure)			Control Room Operator	
	30 day LPZ	2 hr EAB	ARCON96	Halitsky
Gamma (whole body)	7.696E-08	1.919E-07	7.447E-08	6.389E-08
Beta	8.919E-06	2.224E-05	3.321E-04	2.849E-04
Iodine (thyroid)-ICRP-2	9.045E-06	2.255E-05	1.199E-05	1.041E-05
Iodine (thyroid)-ICRP-30	4.727E-06	1.178E-05	6.583E-06	5.716E-06
TEDE*	1.456E-04	3.631E-04	5.415E-03	4.644E-03

Appendix B: Unit 2 Loss of AC Power

This appendix evaluates the Unit 2 Loss of AC Power. The steam generators are the original steam generators, however Westinghouse has revised the mass releases.

Using the same methodology as in the main text, with the TPC only (since that bounds the conventional core), and with Unit 2 ARCON96 X/Q values (2.87E-3 sec/cum 0-2 hr, 2.46E-3 sec/cum, ref.13):

The amount of steam released to the environment due to the loss of AC power is provided below as given in ref.17.

0 - 2 hours	444,875 lbs.
2 - 8 hours	903,530 lbs.

Unit 2 Loss of AC Power Releases

	Secondary Side Concentration	Realistic Release		1% Failed Fuel Release	
Isotope	uCi/g	(0-2 hr) Ci	(2-8 hr) Ci	(0-2 hr) Ci	(2-8 hr) Ci
Kr-83m	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Kr-85m	3.630E-08	7.325E-06	1.488E-05	5.860E-05	1.190E-04
Kr-85m	5.510E-08	1.112E-05	2.258E-05	8.895E-05	1.807E-04
Kr-87	3.220E-08	6.498E-06	1.320E-05	5.198E-05	1.056E-04
Kr-88	6.310E-08	1.273E-05	2.586E-05	1.019E-04	2.069E-04
Kr-89	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Xe-131m	1.340E-07	2.704E-05	5.492E-05	2.163E-04	4.393E-04
Xe-133m	1.540E-08	3.108E-06	6.311E-06	2.486E-05	5.049E-05
Xe-133m	5.250E-07	1.059E-04	2.152E-04	8.475E-04	1.721E-03
Xe-135m	2.900E-08	5.852E-06	1.189E-05	4.682E-05	9.508E-05
Xe-135m	1.910E-07	3.854E-05	7.828E-05	3.083E-04	6.262E-04
Xe-137	7.620E-09	1.538E-06	3.123E-06	1.230E-05	2.498E-05
Xe-138	2.680E-08	5.408E-06	1.098E-05	4.326E-05	8.787E-05
I-131	1.410E-08	2.845E-06	5.779E-06	2.276E-05	4.623E-05
I-132	3.370E-08	6.800E-06	1.381E-05	5.440E-05	1.105E-04
I-133	4.030E-08	8.132E-06	1.652E-05	6.506E-05	1.321E-04
I-134	2.930E-08	5.912E-06	1.201E-05	4.730E-05	9.606E-05
I-135	6.190E-08	1.249E-05	2.537E-05	9.993E-05	2.029E-04
H-3 2-Rod	9.840E-02	1.986E+01	4.033E+01	1.986E+01	4.033E+01

Results

The results for Unit 2 Loss of AC Power were (rem):

Realistic Case

	Control Room	Offsite 2-hr EAB	Offsite 30-day LPZ
Gamma	7.05E-09	1.69E-08	7.74E-09
Beta	2.52E-04	1.58E-05	7.18E-06
Thyroid (ICRP-30)	5.51E-07	1.05E-06	4.78E-07
TEDE	4.12E-03	2.58E-04	1.18E-04

1% Failed Fuel Case

	Control Room	Offsite 2-hr EAB	Offsite 30-day LPZ
Gamma	4.57E-08	1.37E-07	6.23E-08
Beta	2.03E-04	1.58E-05	7.21E-06
Thyroid (ICRP-30)	4.22E-06	8.39E-06	3.82E-06
TEDE	3.31E-03	2.59E-04	1.18E-04

Discussion and Conclusion

The calculated offsite doses are substantially below (< 10%, ref.16) the regulatory limits of 25 rem whole body, 300 rem beta, 300 rem thyroid, and 25 rem TEDE. The control room operator doses are substantially below the regulatory limits of 5 rem gamma, 30 rem beta, 30 rem thyroid, and 5 rem TEDE. The calculated offsite TEDE dose is also less than the 10CFR20.1301 (ref.14) limit of 0.1 rem. The Unit 2 accident is bounded by the Unit 1 accident.

Attachment 8

FENCDOSE File

TSR80FA6.txt

Time Dependent Releases realistic case

```
1
          FFFFFFFFFF  EEEEEEEEEE  NN      NN    CCCCCC    DDDDDDDD      OOOOOO
SSSSSS    EEEEEEEEEE
          FFFFFFFFFF  EEEEEEEEEE  NNN     NN   CCCCCCCC   DDDDDDDDD    OOOOOOOO
SSSSSSSS   EEEEEEEEEE
          FF          EE          NNNN    NN  CC      CC  DD      DD  OO      OO  SS
     SS  EE
          FF          EE          NN NN   NN  CC          DD      DD  OO      OO  SS
         EE
          FFFFFFFF    EEEEEEEE    NN  NN  NN  CC          DD      DD  OO      OO
SSSSSSSSS   EEEEEEEE
          FFFFFFFF    EEEEEEEE    NN   NN NN  CC          DD      DD  OO      OO
SSSSSSSSS  EEEEEEEE
          FF          EE          NN    NNNN  CC          DD      DD  OO      OO
     SS  EE
          FF          EE          NN     NNN  CC      CC  DD      DD  OO      OO  SS
     SS  EE
          FF          EEEEEEEEEE  NN      NN   CCCCCCCC   DDDDDDDDD    OOOOOOOO
SSSSSSSS   EEEEEEEEEE
          FF          EEEEEEEEEE  NN      NN    CCCCCC    DDDDDDDD      OOOOOO
SSSSSS    EEEEEEEEEE


          RRRRRRRR    EEEEEEEEEE  VV      VV              5555555555

          RRRRRRRRR   EEEEEEEEEE  VV      VV              5555555555

          RR      RR  EE           VV    VV               55

          RR      RR  EE           VV    VV               55

          RRRRRRRRR   EEEEEEEE      VV  VV                 5555555

          RRRRRRRR    EEEEEEEE      VV  VV                  5555555

          RR   RR     EE             VVVV                         55

          RR    RR    EE             VVVV                 55      55

          RR     RR   EEEEEEEEEE      VV                   55555555

          RR      RR  EEEEEEEEEE      VV                    555555


          WW      WW    IIIIII    NN      NN    999999    5555555555  NN      NN
QQQQQQ      AAAAAA
          WW      WW    IIIIII    NNN     NN   99999999   5555555555  NNN     NN
QQQQQQQQ    AAAAAAAA
          WW      WW      II      NNNN    NN  99      99  55          NNNN    NN  QQ
     QQ  AA      AA
          WW      WW      II      NN NN   NN  99      99  55          NN NN   NN  QQ
     QQ  AA      AA
          WW      WW      II      NN  NN  NN   999999999  5555555     NN  NN  NN  QQ
     QQ  AA      AA
          WW  WW  WW      II      NN   NN NN    99999999    5555555   NN   NN NN  QQ
  Q  QQ  AAAAAAAAAA
          WW WWWW WW      II      NN    NNNN          99          55  NN    NNNN  QQ
   Q QQ  AAAAAAAAAA
          WWWW  WWWW      II      NN     NNN  99      99  55      55  NN     NNN  QQ
    QQQ  AA      AA
          WWW     WWW     IIIIII  NN      NN   99999999   55555555    NN      NN
QQQQQQQQ   AA      AA
```

```
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QQQQQQ Q  AA      AA


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 11        00000
           0000000       111             //    22222222    99999999          //
111       0000000
          00     00     1111            //    22      22  99      99        //
1111      00     00
          00     00       11           //             22  99      99       //
 11      00     00
          00     00       11          //        2222222    999999999      //
 11      00     00
          00     00       11         //        2222222      99999999     //
 11      00     00
          00     00       11        //        22                  99    //
 11      00     00
          00     00       11       //         22          99      99   //
 11      00     00
           0000000      111111    //          2222222222   99999999   //
111111     0000000
            00000       111111    /           2222222222    999999    /
111111      00000


              11            44                  333333        11
00000           44
             111           444                 33333333      111
0000000         444
            1111          4444        ::      33      33    1111          ::      00
    00       4444
              11         44 44        ::              33      11          ::      00
    00      44 44
              11        44  44                    33333       11                  00
    00     44  44
              11       44   44                    33333       11                  00
    00    44   44
              11      4444444444      ::              33      11          ::      00
    00   4444444444
              11      4444444444      ::      33      33      11          ::      00
    00   4444444444
            111111          44                 33333333     111111
0000000          44
            111111          44                  333333      111111
00000            44

1


1
 REPRODUCTION OF INPUT DATA DECK


 +         +         +         +         +         +         +         +

 1
 KRM-83  KRM-85  KR-85
 KR-87   KR-88   KR-89
 XEM-131 XEM-133 XE-133 XEM-135 XE-135 XE-137 XE-138
 I-131   I-132   I-133  I-134   I-135 H-3
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T
.141E-3  .668E-4  .459E-4  .204E-4  .635E-5  6.07E-4
LOSS OF AC POWER
TIME TO 7200 SEC
    9  'ENVIRONMENT                        ' $ TN=  0.2000E+01
         1 0.0          2 0.0          3 1.112E-05    4 6.498E-06    5 1.273E-05
         6 0.0          7 2.704E-05    8 3.108E-06    9 1.059E-04   10 5.852E-06
        11 3.854E-05   12 1.538E-06   13 5.408E-06   14 2.845E-06   15 6.800E-06
        16 8.132E-06   17 5.912E-06   18 1.249E-05   19 1.986E+01
LOSS OF AC POWER
TIME TO 8 HOUR
    9  'ENVIRONMENT                        ' $ TN=  0.8000E+01
         1 0.0          2 1.488E-05    3 2.258E-05    4 1.320E-05    5 2.586E-05
         6 0.0          7 5.492E-05    8 6.311E-06    9 2.152E-04   10 1.189E-05
        11 7.828E-05   12 3.123E-06   13 1.098E-05   14 5.779E-06   15 1.381E-05
        16 1.652E-05   17 1.201E-05   18 2.537E-05   19 4.033E+01
LOSS OF AC POWER
TIME TO 24 HR
    9  'ENVIRONMENT                        ' $ TN=  0.2400E+02
         1 0.0          2 0.0          3 0.0          4 0.0          5 0.0
         6 0.0          7 0.0          8 0.0          9 0.0         10 0.0
        11 0.0         12 0.0         13 0.0         14 0.0         15 0.00
        16 0.0         17 0.0         18 0.0         19 0.0
LOSS OF AC POWER
TIME TO 96 HR
    9  'ENVIRONMENT                        ' $ TN=  0.9600E+02
         1 0.0          2 0.0          3 0.0          4 0.0          5 0.0
         6 0.0          7 0.0          8 0.0          9 0.0         10 0.0
        11 0.0         12 0.0         13 0.0         14 0.0         15 0.00
        16 0.0         17 0.0         18 0.0         19 0.0
LOSS OF AC POWER
TIME TO 720 HR
    9  'ENVIRONMENT                        ' $ TN=  0.7200E+03
         1 0.0          2 0.0          3 0.0          4 0.0          5 0.0
         6 0.0          7 0.0          8 0.0          9 0.0         10 0.0
        11 0.0         12 0.0         13 0.0         14 0.0         15 0.00
        16 0.0         17 0.0         18 0.0         19 0.0

 +         +         +         +         +         +         +         +


1                                                             PROGRAM FENCDOSE
0                                                            REVISION NUMBER:5
0                                                      REVISION DATE: 31 JUL 2009
0                                                            TODAY IS: 01/29/10
0                                                       STARTING TIME IS: 14:31:04


1ISOTOPE        GAMMA ENERGY     BETA ENERGY
                 (MEV/DIS)        (MEV/DIS)
 KRM-83            0.0025           0.0371
 KRM-85            0.1586           0.2529
 KR-85             0.0022           0.2506
 KR-87             0.7928           1.3237
 KR-88             1.9629           0.3750
 KR-89             2.0837           1.2310
 XEM-131           0.0201           0.1428
 XEM-133           0.0416           0.1898
 XE-133            0.0454           0.1354
 XEM-135           0.4318           0.0950
 XE-135            0.2470           0.3168
 XE-137            0.1936           1.6420
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 XE-138              1.1830          0.6058
 I-131               0.3810          0.1943
 I-132               2.3332          0.5143
 I-133               0.6100          0.4080
 I-134               2.5928          0.6102
 I-135               1.5802          0.3680
 H-3                 0.0000          0.0057


0CHI/Q
   1.410E-04   6.680E-05   4.590E-05   2.040E-05   6.350E-06
   6.070E-04


1
0LOSS OF AC POWER
 TIME TO 7200 SEC
 COMPONENT  9 ENVIRONMENT                           , TIME =   2.
 1ISOTOPE

 KRM-83          0.0000E+00
 KRM-85          0.0000E+00
 KR-85           0.1112E-04
 KR-87           0.6498E-05
 KR-88           0.1273E-04
 KR-89           0.0000E+00
 XEM-131         0.2704E-04
 XEM-133         0.3108E-05
 XE-133          0.1059E-03
 XEM-135         0.5852E-05
 XE-135          0.3854E-04
 XE-137          0.1538E-05
 XE-138          0.5408E-05
 I-131           0.2845E-05
 I-132           0.6800E-05
 I-133           0.8132E-05
 I-134           0.5912E-05
 I-135           0.1249E-04
 H-3             0.1986E+02
0LOSS OF AC POWER
 TIME TO 8 HOUR
 COMPONENT  9 ENVIRONMENT                           , TIME =   8.
 1ISOTOPE

 KRM-83          0.0000E+00
 KRM-85          0.1488E-04
 KR-85           0.2258E-04
 KR-87           0.1320E-04
 KR-88           0.2586E-04
 KR-89           0.0000E+00
 XEM-131         0.5492E-04
 XEM-133         0.6311E-05
 XE-133          0.2152E-03
 XEM-135         0.1189E-04
 XE-135          0.7828E-04
 XE-137          0.3123E-05
 XE-138          0.1098E-04
 I-131           0.5779E-05
 I-132           0.1381E-04
 I-133           0.1652E-04
 I-134           0.1201E-04
 I-135           0.2537E-04
 H-3             0.4033E+02
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0LOSS OF AC POWER
 TIME TO 24 HR
 COMPONENT  9 ENVIRONMENT                            , TIME = 24.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.0000E+00
 KR-85          0.0000E+00
 KR-87          0.0000E+00
 KR-88          0.0000E+00
 KR-89          0.0000E+00
 XEM-131        0.0000E+00
 XEM-133        0.0000E+00
 XE-133         0.0000E+00
 XEM-135        0.0000E+00
 XE-135         0.0000E+00
 XE-137         0.0000E+00
 XE-138         0.0000E+00
 I-131          0.0000E+00
 I-132          0.0000E+00
 I-133          0.0000E+00
 I-134          0.0000E+00
 I-135          0.0000E+00
 H-3            0.0000E+00
0LOSS OF AC POWER
 TIME TO 96 HR
 COMPONENT  9 ENVIRONMENT                            , TIME = 96.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.0000E+00
 KR-85          0.0000E+00
 KR-87          0.0000E+00
 KR-88          0.0000E+00
 KR-89          0.0000E+00
 XEM-131        0.0000E+00
 XEM-133        0.0000E+00
 XE-133         0.0000E+00
 XEM-135        0.0000E+00
 XE-135         0.0000E+00
 XE-137         0.0000E+00
 XE-138         0.0000E+00
 I-131          0.0000E+00
 I-132          0.0000E+00
 I-133          0.0000E+00
 I-134          0.0000E+00
 I-135          0.0000E+00
 H-3            0.0000E+00
0LOSS OF AC POWER
 TIME TO 720 HR
 COMPONENT  9 ENVIRONMENT                            , TIME =720.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.0000E+00
 KR-85          0.0000E+00
 KR-87          0.0000E+00
 KR-88          0.0000E+00
 KR-89          0.0000E+00
 XEM-131        0.0000E+00
 XEM-133        0.0000E+00
 XE-133         0.0000E+00
 XEM-135        0.0000E+00
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 XE-135         0.0000E+00
 XE-137         0.0000E+00
 XE-138         0.0000E+00
 I-131          0.0000E+00
 I-132          0.0000E+00
 I-133          0.0000E+00
 I-134          0.0000E+00
 I-135          0.0000E+00
 H-3            0.0000E+00

1INPUT CONCENTRATION
 KRM-83       0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 KRM-85       0.0000E+00    1.4880E-05    0.0000E+00    0.0000E+00    0.0000E+00
 KR-85        1.1120E-05    2.2580E-05    0.0000E+00    0.0000E+00    0.0000E+00
 KR-87        6.4980E-06    1.3200E-05    0.0000E+00    0.0000E+00    0.0000E+00
 KR-88        1.2730E-05    2.5860E-05    0.0000E+00    0.0000E+00    0.0000E+00
 KR-89        0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 XEM-131      2.7040E-05    5.4920E-05    0.0000E+00    0.0000E+00    0.0000E+00
 XEM-133      3.1080E-06    6.3110E-06    0.0000E+00    0.0000E+00    0.0000E+00
 XE-133       1.0590E-04    2.1520E-04    0.0000E+00    0.0000E+00    0.0000E+00
 XEM-135      5.8520E-06    1.1890E-05    0.0000E+00    0.0000E+00    0.0000E+00
 XE-135       3.8540E-05    7.8280E-05    0.0000E+00    0.0000E+00    0.0000E+00
 XE-137       1.5380E-06    3.1230E-06    0.0000E+00    0.0000E+00    0.0000E+00
 XE-138       5.4080E-06    1.0980E-05    0.0000E+00    0.0000E+00    0.0000E+00
 I-131        2.8450E-06    5.7790E-06    0.0000E+00    0.0000E+00    0.0000E+00
 I-132        6.8000E-06    1.3810E-05    0.0000E+00    0.0000E+00    0.0000E+00
 I-133        8.1320E-06    1.6520E-05    0.0000E+00    0.0000E+00    0.0000E+00
 I-134        5.9120E-06    1.2010E-05    0.0000E+00    0.0000E+00    0.0000E+00
 I-135        1.2490E-05    2.5370E-05    0.0000E+00    0.0000E+00    0.0000E+00
 H-3          1.9860E+01    4.0330E+01    0.0000E+00    0.0000E+00    0.0000E+00

1LOSS OF AC POWER


0GAMMA DOSE FOR EACH ISOTOPE AND TIME PERIOD (REM)

   ID   ISOTOPE       0-2 HRS      2-8 HRS     8-24 HRS     1-4 DAYS     4-30 DAYS
2-HR EAB

   1    KRM-83       0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   2    KRM-85       0.000E+00    3.942E-11    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   3    KR-85        8.664E-13    8.334E-13    0.000E+00    0.000E+00    0.000E+00
3.730E-12
   4    KR-87        1.816E-10    1.748E-10    0.000E+00    0.000E+00    0.000E+00
7.818E-10
   5    KR-88        8.808E-10    8.477E-10    0.000E+00    0.000E+00    0.000E+00
3.792E-09
   6    KR-89        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   7    XEM-131      1.912E-11    1.840E-11    0.000E+00    0.000E+00    0.000E+00
8.230E-11
   8    XEM-133      4.553E-12    4.380E-12    0.000E+00    0.000E+00    0.000E+00
1.960E-11
   9    XE-133       1.694E-10    1.631E-10    0.000E+00    0.000E+00    0.000E+00
7.294E-10
  10    XEM-135      8.906E-11    8.573E-11    0.000E+00    0.000E+00    0.000E+00
3.834E-10
  11    XE-135       3.355E-10    3.228E-10    0.000E+00    0.000E+00    0.000E+00
1.444E-09
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  12    XE-137        1.049E-11   1.009E-11   0.000E+00   0.000E+00   0.000E+00
4.518E-11
  13    XE-138        2.255E-10   2.169E-10   0.000E+00   0.000E+00   0.000E+00
9.708E-10
  14    I-131         3.821E-11   3.677E-11   0.000E+00   0.000E+00   0.000E+00
1.645E-10
  15    I-132         5.593E-10   5.381E-10   0.000E+00   0.000E+00   0.000E+00
2.408E-09
  16    I-133         1.749E-10   1.683E-10   0.000E+00   0.000E+00   0.000E+00
7.527E-10
  17    I-134         5.403E-10   5.200E-10   0.000E+00   0.000E+00   0.000E+00
2.326E-09
  18    I-135         6.957E-10   6.695E-10   0.000E+00   0.000E+00   0.000E+00
2.995E-09
  19    H-3           0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
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 TOTAL                3.925E-09   3.817E-09   0.000E+00   0.000E+00   0.000E+00
1.690E-08
0BETA DOSE FOR EACH ISOTOPE AND TIME PERIOD (REM)

   ID   ISOTOPE        0-2 HRS     2-8 HRS    8-24 HRS    1-4 DAYS    4-30 DAYS
2-HR EAB

   1    KRM-83        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   2    KRM-85        0.000E+00   5.782E-11   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   3    KR-85         9.037E-11   8.694E-11   0.000E+00   0.000E+00   0.000E+00
3.890E-10
   4    KR-87         2.789E-10   2.685E-10   0.000E+00   0.000E+00   0.000E+00
1.201E-09
   5    KR-88         1.548E-10   1.490E-10   0.000E+00   0.000E+00   0.000E+00
6.665E-10
   6    KR-89         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   7    XEM-131       1.252E-10   1.205E-10   0.000E+00   0.000E+00   0.000E+00
5.391E-10
   8    XEM-133       1.913E-11   1.840E-11   0.000E+00   0.000E+00   0.000E+00
8.236E-11
   9    XE-133        4.650E-10   4.477E-10   0.000E+00   0.000E+00   0.000E+00
2.002E-09
  10    XEM-135       1.803E-11   1.735E-11   0.000E+00   0.000E+00   0.000E+00
7.761E-11
  11    XE-135        3.960E-10   3.810E-10   0.000E+00   0.000E+00   0.000E+00
1.705E-09
  12    XE-137        8.190E-11   7.879E-11   0.000E+00   0.000E+00   0.000E+00
3.526E-10
  13    XE-138        1.062E-10   1.022E-10   0.000E+00   0.000E+00   0.000E+00
4.574E-10
  14    I-131         1.793E-11   1.725E-11   0.000E+00   0.000E+00   0.000E+00
7.717E-11
  15    I-132         1.134E-10   1.091E-10   0.000E+00   0.000E+00   0.000E+00
4.882E-10
  16    I-133         1.076E-10   1.036E-10   0.000E+00   0.000E+00   0.000E+00
4.632E-10
  17    I-134         1.170E-10   1.126E-10   0.000E+00   0.000E+00   0.000E+00
5.036E-10
  18    I-135         1.491E-10   1.434E-10   0.000E+00   0.000E+00   0.000E+00
6.417E-10
  19    H-3           3.658E-06   3.519E-06   0.000E+00   0.000E+00   0.000E+00
1.575E-05
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 TOTAL                   3.661E-06   3.522E-06   0.000E+00   0.000E+00   0.000E+00
1.576E-05
0INHALATION DOSE FOR EACH IODINE AND TIME PERIOD (REM) (ICRP 2 DATA

   ID   ISOTOPE         0-2 HRS     2-8 HRS    8-24 HRS    1-4 DAYS    4-30 DAYS
2-HR EAB

   1    I-131            2.060E-07   1.983E-07   0.000E+00   0.000E+00   0.000E+00
8.869E-07
   2    I-132            1.780E-08   1.713E-08   0.000E+00   0.000E+00   0.000E+00
7.663E-08
   3    I-133            1.591E-07   1.532E-07   0.000E+00   0.000E+00   0.000E+00
6.851E-07
   4    I-134            7.231E-09   6.960E-09   0.000E+00   0.000E+00   0.000E+00
3.113E-08
   5    I-135            7.578E-08   7.292E-08   0.000E+00   0.000E+00   0.000E+00
3.262E-07
                         ---------   ---------   ---------   ---------   ---------
---------
 TOTAL                   4.660E-07   4.484E-07   0.000E+00   0.000E+00   0.000E+00
2.006E-06
0INHALATION DOSE FOR EACH IODINE AND TIME PERIOD (REM) (ICRP 30 DATA)

   ID   ISOTOPE         0-2 HRS     2-8 HRS    8-24 HRS    1-4 DAYS    4-30 DAYS
2-HR EAB

   1    I-131            1.503E-07   1.447E-07   0.000E+00   0.000E+00   0.000E+00
6.472E-07
   2    I-132            2.143E-09   2.062E-09   0.000E+00   0.000E+00   0.000E+00
9.224E-09
   3    I-133            7.162E-08   6.893E-08   0.000E+00   0.000E+00   0.000E+00
3.083E-07
   4    I-134            3.095E-10   2.979E-10   0.000E+00   0.000E+00   0.000E+00
1.332E-09
   5    I-135            1.913E-08   1.841E-08   0.000E+00   0.000E+00   0.000E+00
8.234E-08
                         ---------   ---------   ---------   ---------   ---------
---------
 TOTAL                   2.435E-07   2.344E-07   0.000E+00   0.000E+00   0.000E+00
1.048E-06
0AT 2 HOUR EXCLUSION AREA BOUNDARY (EAB)


 TOTAL GAMMA DOSE =  1.690E-08 REM
 TOTAL BETA DOSE =  1.576E-05 REM
 TOTAL INHALATION DOSE (ICRP-2) =  2.006E-06 REM
 TOTAL INHALATION DOSE (ICRP-30) =  1.048E-06 REM

0AT 30 DAY LPZ BOUNDARY


 TOTAL GAMMA DOSE =  7.742E-09 REM
 TOTAL BETA DOSE =  7.182E-06 REM
 TOTAL INHALATION DOSE (ICRP-2) =  9.144E-07 REM
 TOTAL INHALATION DOSE (ICRP-30) =  4.779E-07 REM

 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
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 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
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 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.


1LOSS OF AC POWER


0TEDE FOR EACH ISOTOPE AND TIME PERIOD (REM)

   ID   ISOTOPE       0-2 HRS      2-8 HRS     8-24 HRS     1-4 DAYS     4-30 DAYS
2-HR EAB

   1    KRM-83       0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   2    KRM-85       0.000E+00    2.568E-11    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   3    KR-85        5.662E-13    5.447E-13    0.000E+00    0.000E+00    0.000E+00
2.437E-12
   4    KR-87        1.298E-10    1.249E-10    0.000E+00    0.000E+00    0.000E+00
5.588E-10
   5    KR-88        6.482E-10    6.238E-10    0.000E+00    0.000E+00    0.000E+00
2.790E-09
   6    KR-89        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   7    XEM-131      5.189E-12    4.993E-12    0.000E+00    0.000E+00    0.000E+00
2.234E-11
   8    XEM-133      2.069E-12    1.991E-12    0.000E+00    0.000E+00    0.000E+00
8.909E-12
   9    XE-133       8.295E-11    7.986E-11    0.000E+00    0.000E+00    0.000E+00
3.571E-10
  10    XEM-135      5.730E-11    5.516E-11    0.000E+00    0.000E+00    0.000E+00
2.467E-10
  11    XE-135       2.113E-10    2.034E-10    0.000E+00    0.000E+00    0.000E+00
9.098E-10
  12    XE-137       6.626E-12    6.374E-12    0.000E+00    0.000E+00    0.000E+00
2.853E-11
  13    XE-138       1.525E-10    1.467E-10    0.000E+00    0.000E+00    0.000E+00
6.565E-10
  14    I-131        5.906E-09    5.683E-09    0.000E+00    0.000E+00    0.000E+00
2.542E-08
  15    I-132        1.305E-09    1.256E-09    0.000E+00    0.000E+00    0.000E+00
5.618E-09
  16    I-133        4.778E-09    4.598E-09    0.000E+00    0.000E+00    0.000E+00
2.057E-08
  17    I-134        7.178E-10    6.908E-10    0.000E+00    0.000E+00    0.000E+00
3.090E-09
  18    I-135        3.962E-09    3.813E-09    0.000E+00    0.000E+00    0.000E+00
1.706E-08
  19    H-3          5.989E-05    5.762E-05    0.000E+00    0.000E+00    0.000E+00
2.578E-04
                     ---------    ---------    ---------    ---------    ---------
---------
 TOTAL               5.991E-05    5.764E-05    0.000E+00    0.000E+00    0.000E+00
2.579E-04
 TOTAL TEDE =  1.176E-04
0THIS RUN IS DATED 01/29/10. THE TOTAL ELAPSED TIME IS  0.0 MINUTES.  0.0 SECONDS.
```

Attachment 9

FENCDOSE File

TSR80FB6.txt

Time Dependent Releases
1% failed fuel case

```
1
          FFFFFFFFFF  EEEEEEEEEE  NN      NN    CCCCCC    DDDDDDDD      OOOOOO
SSSSSS    EEEEEEEEEE
          FFFFFFFFFF  EEEEEEEEEE  NNN     NN   CCCCCCCC   DDDDDDDDD    OOOOOOOO
SSSSSSSS   EEEEEEEEEE
          FF          EE          NNNN    NN  CC      CC  DD      DD  OO      OO  SS
     SS  EE
          FF          EE          NN NN   NN  CC          DD      DD  OO      OO  SS
         EE
          FFFFFFFF    EEEEEEEE    NN  NN  NN  CC          DD      DD  OO      OO
SSSSSSSSS   EEEEEEEE
          FFFFFFFF    EEEEEEEE    NN   NN NN  CC          DD      DD  OO      OO
SSSSSSSSS  EEEEEEEE
          FF          EE          NN    NNNN  CC          DD      DD  OO      OO
     SS  EE
          FF          EE          NN     NNN  CC      CC  DD      DD  OO      OO  SS
     SS  EE
          FF          EEEEEEEEEE  NN      NN   CCCCCCCC   DDDDDDDDD    OOOOOOOO
SSSSSSSS   EEEEEEEEEE
          FF          EEEEEEEEEE  NN      NN    CCCCCC    DDDDDDDD      OOOOOO
SSSSSS    EEEEEEEEEE


          RRRRRRRR    EEEEEEEEEE  VV      VV              5555555555

          RRRRRRRRR   EEEEEEEEEE  VV      VV              5555555555

          RR      RR  EE           VV    VV               55

          RR      RR  EE           VV    VV               55

          RRRRRRRRR   EEEEEEEE      VV  VV                 5555555

          RRRRRRRR    EEEEEEEE      VV  VV                  5555555

          RR   RR     EE             VVVV                         55

          RR    RR    EE             VVVV                 55      55

          RR     RR   EEEEEEEEEE      VV                   55555555

          RR      RR  EEEEEEEEEE      VV                    555555



          WW      WW    IIIIII    NN      NN    999999    5555555555  NN      NN
QQQQQQ      AAAAAA
          WW      WW    IIIIII    NNN     NN   99999999   5555555555  NNN     NN
QQQQQQQQ    AAAAAAAA
          WW      WW      II      NNNN    NN  99      99  55          NNNN    NN  QQ
     QQ  AA      AA
          WW      WW      II      NN NN   NN  99      99  55          NN NN   NN  QQ
     QQ  AA      AA
          WW      WW      II      NN  NN  NN   999999999    5555555     NN  NN  NN  QQ
     QQ  AA      AA
          WW  WW  WW      II      NN   NN NN    99999999    5555555   NN   NN NN  QQ
  Q  QQ  AAAAAAAAAA
          WW WWWW WW      II      NN    NNNN          99          55  NN    NNNN  QQ
   Q QQ  AAAAAAAAAA
          WWWW  WWWW      II      NN     NNN  99      99  55      55  NN     NNN  QQ
    QQQ  AA      AA
          WWW    WWW    IIIIII    NN      NN   99999999    55555555   NN      NN
QQQQQQQQ   AA      AA
```

```
          WW      WW    IIIIII    NN      NN    999999      555555    NN      NN
QQQQQQ Q  AA      AA


            00000             11              //    222222      999999            //
 11        00000
           0000000           111             //    22222222    99999999          //
111        0000000
          00      00        1111            //    22      22  99      99        //
1111      00      00
          00      00          11           //             22  99      99       //
 11      00      00
          00      00          11          //        2222222    999999999      //
 11      00      00
          00      00          11         //        2222222      99999999     //
 11      00      00
          00      00          11        //      22                    99    //
 11      00      00
          00      00          11       //       22            99      99   //
 11      00      00
           0000000          111111    //        2222222222    99999999   //
111111     0000000
            00000           111111    /         2222222222      999999   /
111111      00000


              11              44                333333        11
 11      7777777777
             111             444               33333333      111
111      7777777777
            1111            4444        ::    33      33    1111          ::
1111             77
              11           44 44        ::            33      11          ::
 11               77
              11          44  44                 33333        11
 11              77
              11         44   44                 33333        11
 11             77
              11        4444444444      ::            33      11          ::
 11            77
              11        4444444444      ::    33      33      11          ::
 11           77
            111111            44               33333333     111111
111111        77
            111111            44                333333      111111
111111        77

1


1
 REPRODUCTION OF INPUT DATA DECK


 +         +         +         +         +         +         +         +

 1
 KRM-83  KRM-85  KR-85
 KR-87   KR-88   KR-89
 XEM-131 XEM-133 XE-133 XEM-135 XE-135 XE-137 XE-138
 I-131   I-132   I-133  I-134   I-135 H-3
```

```
T
.141E-3  .668E-4  .459E-4  .204E-4  .635E-5  6.07E-4
LOSS OF AC POWER
TIME TO 7200 SEC
    9  'ENVIRONMENT                         ' $ TN=  0.2000E+01
         1 0.0           2 5.860E-05    3 8.895E-05    4 5.198E-05    5 1.019E-04
         6 0.0           7 2.163E-04    8 2.486E-05    9 8.475E-04   10 4.682E-05
        11 3.083E-04    12 1.230E-05   13 4.326E-05   14 2.276E-05   15 5.440E-05
        16 6.506E-05    17 4.730E-05   18 9.993E-05   19 1.986E+01
LOSS OF AC POWER
TIME TO 8 HOUR
    9  'ENVIRONMENT                         ' $ TN=  0.8000E+01
         1 0.0           2 1.190E-04    3 1.807E-04    4 1.056E-04    5 2.069E-04
         6 0.0           7 4.393E-04    8 5.049E-05    9 1.721E-03   10 9.508E-05
        11 6.262E-04    12 2.498E-05   13 8.787E-05   14 4.623E-05   15 1.105E-04
        16 1.321E-04    17 9.606E-05   18 2.029E-04   19 4.033E+01
LOSS OF AC POWER
TIME TO 24 HR
    9  'ENVIRONMENT                         ' $ TN=  0.2400E+02
         1 0.0           2 0.0          3 0.0              4 0.0          5 0.0
         6 0.0           7 0.0          8 0.0              9 0.0         10 0.0
        11 0.0          12 0.0         13 0.0             14 0.0         15 0.00
        16 0.0          17 0.0         18 0.0             19 0.0
LOSS OF AC POWER
TIME TO 96 HR
    9  'ENVIRONMENT                         ' $ TN=  0.9600E+02
         1 0.0           2 0.0          3 0.0              4 0.0          5 0.0
         6 0.0           7 0.0          8 0.0              9 0.0         10 0.0
        11 0.0          12 0.0         13 0.0             14 0.0         15 0.00
        16 0.0          17 0.0         18 0.0             19 0.0
LOSS OF AC POWER
TIME TO 720 HR
    9  'ENVIRONMENT                         ' $ TN=  0.7200E+03
         1 0.0           2 0.0          3 0.0              4 0.0          5 0.0
         6 0.0           7 0.0          8 0.0              9 0.0         10 0.0
        11 0.0          12 0.0         13 0.0             14 0.0         15 0.00
        16 0.0          17 0.0         18 0.0             19 0.0

 +         +         +         +         +         +         +         +


1                                                              PROGRAM FENCDOSE
0                                                            REVISION NUMBER:5
0                                                       REVISION DATE: 31 JUL 2009
0                                                            TODAY IS: 01/29/10
0                                                        STARTING TIME IS: 14:31:17


1ISOTOPE        GAMMA ENERGY     BETA ENERGY
                 (MEV/DIS)        (MEV/DIS)
 KRM-83            0.0025           0.0371
 KRM-85            0.1586           0.2529
 KR-85             0.0022           0.2506
 KR-87             0.7928           1.3237
 KR-88             1.9629           0.3750
 KR-89             2.0837           1.2310
 XEM-131           0.0201           0.1428
 XEM-133           0.0416           0.1898
 XE-133            0.0454           0.1354
 XEM-135           0.4318           0.0950
 XE-135            0.2470           0.3168
 XE-137            0.1936           1.6420
```

```
 XE-138           1.1830         0.6058
 I-131            0.3810         0.1943
 I-132            2.3332         0.5143
 I-133            0.6100         0.4080
 I-134            2.5928         0.6102
 I-135            1.5802         0.3680
 H-3              0.0000         0.0057


0CHI/Q
   1.410E-04   6.680E-05   4.590E-05   2.040E-05   6.350E-06
   6.070E-04


1
0LOSS OF AC POWER
 TIME TO 7200 SEC
 COMPONENT  9 ENVIRONMENT                        , TIME =  2.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.5860E-04
 KR-85          0.8895E-04
 KR-87          0.5198E-04
 KR-88          0.1019E-03
 KR-89          0.0000E+00
 XEM-131        0.2163E-03
 XEM-133        0.2486E-04
 XE-133         0.8475E-03
 XEM-135        0.4682E-04
 XE-135         0.3083E-03
 XE-137         0.1230E-04
 XE-138         0.4326E-04
 I-131          0.2276E-04
 I-132          0.5440E-04
 I-133          0.6506E-04
 I-134          0.4730E-04
 I-135          0.9993E-04
 H-3            0.1986E+02
0LOSS OF AC POWER
 TIME TO 8 HOUR
 COMPONENT  9 ENVIRONMENT                        , TIME =  8.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.1190E-03
 KR-85          0.1807E-03
 KR-87          0.1056E-03
 KR-88          0.2069E-03
 KR-89          0.0000E+00
 XEM-131        0.4393E-03
 XEM-133        0.5049E-04
 XE-133         0.1721E-02
 XEM-135        0.9508E-04
 XE-135         0.6262E-03
 XE-137         0.2498E-04
 XE-138         0.8787E-04
 I-131          0.4623E-04
 I-132          0.1105E-03
 I-133          0.1321E-03
 I-134          0.9606E-04
 I-135          0.2029E-03
 H-3            0.4033E+02
```

```
0LOSS OF AC POWER
 TIME TO 24 HR
 COMPONENT  9 ENVIRONMENT                           , TIME = 24.
 1ISOTOPE

 KRM-83          0.0000E+00
 KRM-85          0.0000E+00
 KR-85           0.0000E+00
 KR-87           0.0000E+00
 KR-88           0.0000E+00
 KR-89           0.0000E+00
 XEM-131         0.0000E+00
 XEM-133         0.0000E+00
 XE-133          0.0000E+00
 XEM-135         0.0000E+00
 XE-135          0.0000E+00
 XE-137          0.0000E+00
 XE-138          0.0000E+00
 I-131           0.0000E+00
 I-132           0.0000E+00
 I-133           0.0000E+00
 I-134           0.0000E+00
 I-135           0.0000E+00
 H-3             0.0000E+00
0LOSS OF AC POWER
 TIME TO 96 HR
 COMPONENT  9 ENVIRONMENT                           , TIME = 96.
 1ISOTOPE

 KRM-83          0.0000E+00
 KRM-85          0.0000E+00
 KR-85           0.0000E+00
 KR-87           0.0000E+00
 KR-88           0.0000E+00
 KR-89           0.0000E+00
 XEM-131         0.0000E+00
 XEM-133         0.0000E+00
 XE-133          0.0000E+00
 XEM-135         0.0000E+00
 XE-135          0.0000E+00
 XE-137          0.0000E+00
 XE-138          0.0000E+00
 I-131           0.0000E+00
 I-132           0.0000E+00
 I-133           0.0000E+00
 I-134           0.0000E+00
 I-135           0.0000E+00
 H-3             0.0000E+00
0LOSS OF AC POWER
 TIME TO 720 HR
 COMPONENT  9 ENVIRONMENT                           , TIME =720.
 1ISOTOPE

 KRM-83          0.0000E+00
 KRM-85          0.0000E+00
 KR-85           0.0000E+00
 KR-87           0.0000E+00
 KR-88           0.0000E+00
 KR-89           0.0000E+00
 XEM-131         0.0000E+00
 XEM-133         0.0000E+00
 XE-133          0.0000E+00
 XEM-135         0.0000E+00
```

```
 XE-135         0.0000E+00
 XE-137         0.0000E+00
 XE-138         0.0000E+00
 I-131          0.0000E+00
 I-132          0.0000E+00
 I-133          0.0000E+00
 I-134          0.0000E+00
 I-135          0.0000E+00
 H-3            0.0000E+00


1INPUT CONCENTRATION
 KRM-83       0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 KRM-85       5.8600E-05    1.1900E-04    0.0000E+00    0.0000E+00    0.0000E+00
 KR-85        8.8950E-05    1.8070E-04    0.0000E+00    0.0000E+00    0.0000E+00
 KR-87        5.1980E-05    1.0560E-04    0.0000E+00    0.0000E+00    0.0000E+00
 KR-88        1.0190E-04    2.0690E-04    0.0000E+00    0.0000E+00    0.0000E+00
 KR-89        0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 XEM-131      2.1630E-04    4.3930E-04    0.0000E+00    0.0000E+00    0.0000E+00
 XEM-133      2.4860E-05    5.0490E-05    0.0000E+00    0.0000E+00    0.0000E+00
 XE-133       8.4750E-04    1.7210E-03    0.0000E+00    0.0000E+00    0.0000E+00
 XEM-135      4.6820E-05    9.5080E-05    0.0000E+00    0.0000E+00    0.0000E+00
 XE-135       3.0830E-04    6.2620E-04    0.0000E+00    0.0000E+00    0.0000E+00
 XE-137       1.2300E-05    2.4980E-05    0.0000E+00    0.0000E+00    0.0000E+00
 XE-138       4.3260E-05    8.7870E-05    0.0000E+00    0.0000E+00    0.0000E+00
 I-131        2.2760E-05    4.6230E-05    0.0000E+00    0.0000E+00    0.0000E+00
 I-132        5.4400E-05    1.1050E-04    0.0000E+00    0.0000E+00    0.0000E+00
 I-133        6.5060E-05    1.3210E-04    0.0000E+00    0.0000E+00    0.0000E+00
 I-134        4.7300E-05    9.6060E-05    0.0000E+00    0.0000E+00    0.0000E+00
 I-135        9.9930E-05    2.0290E-04    0.0000E+00    0.0000E+00    0.0000E+00
 H-3          1.9860E+01    4.0330E+01    0.0000E+00    0.0000E+00    0.0000E+00


1LOSS OF AC POWER


0GAMMA DOSE FOR EACH ISOTOPE AND TIME PERIOD (REM)

   ID   ISOTOPE       0-2 HRS      2-8 HRS     8-24 HRS     1-4 DAYS     4-30 DAYS
2-HR EAB

   1    KRM-83       0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   2    KRM-85       3.277E-10    3.152E-10    0.000E+00    0.000E+00    0.000E+00
1.411E-09
   3    KR-85        6.930E-12    6.670E-12    0.000E+00    0.000E+00    0.000E+00
2.983E-11
   4    KR-87        1.453E-09    1.398E-09    0.000E+00    0.000E+00    0.000E+00
6.254E-09
   5    KR-88        7.051E-09    6.782E-09    0.000E+00    0.000E+00    0.000E+00
3.035E-08
   6    KR-89        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   7    XEM-131      1.529E-10    1.472E-10    0.000E+00    0.000E+00    0.000E+00
6.584E-10
   8    XEM-133      3.642E-11    3.504E-11    0.000E+00    0.000E+00    0.000E+00
1.568E-10
   9    XE-133       1.356E-09    1.304E-09    0.000E+00    0.000E+00    0.000E+00
5.837E-09
  10    XEM-135      7.126E-10    6.856E-10    0.000E+00    0.000E+00    0.000E+00
3.068E-09
  11    XE-135       2.684E-09    2.583E-09    0.000E+00    0.000E+00    0.000E+00
1.155E-08
```

```
  12    XE-137       8.392E-11   8.075E-11   0.000E+00   0.000E+00   0.000E+00
3.613E-10
  13    XE-138       1.804E-09   1.736E-09   0.000E+00   0.000E+00   0.000E+00
7.766E-09
  14    I-131        3.056E-10   2.941E-10   0.000E+00   0.000E+00   0.000E+00
1.316E-09
  15    I-132        4.474E-09   4.306E-09   0.000E+00   0.000E+00   0.000E+00
1.926E-08
  16    I-133        1.399E-09   1.346E-09   0.000E+00   0.000E+00   0.000E+00
6.022E-09
  17    I-134        4.323E-09   4.159E-09   0.000E+00   0.000E+00   0.000E+00
1.861E-08
  18    I-135        5.566E-09   5.354E-09   0.000E+00   0.000E+00   0.000E+00
2.396E-08
  19    H-3          0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
                     ---------   ---------   ---------   ---------   ---------
---------
 TOTAL               3.174E-08   3.053E-08   0.000E+00   0.000E+00   0.000E+00
1.366E-07
0BETA DOSE FOR EACH ISOTOPE AND TIME PERIOD (REM)

   ID   ISOTOPE       0-2 HRS     2-8 HRS    8-24 HRS    1-4 DAYS    4-30 DAYS
2-HR EAB

   1    KRM-83       0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   2    KRM-85       4.806E-10   4.624E-10   0.000E+00   0.000E+00   0.000E+00
2.069E-09
   3    KR-85        7.229E-10   6.957E-10   0.000E+00   0.000E+00   0.000E+00
3.112E-09
   4    KR-87        2.231E-09   2.148E-09   0.000E+00   0.000E+00   0.000E+00
9.606E-09
   5    KR-88        1.239E-09   1.192E-09   0.000E+00   0.000E+00   0.000E+00
5.335E-09
   6    KR-89        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   7    XEM-131      1.002E-09   9.638E-10   0.000E+00   0.000E+00   0.000E+00
4.312E-09
   8    XEM-133      1.530E-10   1.472E-10   0.000E+00   0.000E+00   0.000E+00
6.587E-10
   9    XE-133       3.721E-09   3.580E-09   0.000E+00   0.000E+00   0.000E+00
1.602E-08
  10    XEM-135      1.442E-10   1.388E-10   0.000E+00   0.000E+00   0.000E+00
6.210E-10
  11    XE-135       3.167E-09   3.048E-09   0.000E+00   0.000E+00   0.000E+00
1.364E-08
  12    XE-137       6.550E-10   6.302E-10   0.000E+00   0.000E+00   0.000E+00
2.820E-09
  13    XE-138       8.499E-10   8.179E-10   0.000E+00   0.000E+00   0.000E+00
3.659E-09
  14    I-131        1.434E-10   1.380E-10   0.000E+00   0.000E+00   0.000E+00
6.174E-10
  15    I-132        9.073E-10   8.731E-10   0.000E+00   0.000E+00   0.000E+00
3.906E-09
  16    I-133        8.608E-10   8.281E-10   0.000E+00   0.000E+00   0.000E+00
3.706E-09
  17    I-134        9.360E-10   9.006E-10   0.000E+00   0.000E+00   0.000E+00
4.029E-09
  18    I-135        1.193E-09   1.147E-09   0.000E+00   0.000E+00   0.000E+00
5.134E-09
  19    H-3          3.658E-06   3.519E-06   0.000E+00   0.000E+00   0.000E+00
1.575E-05
```

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                      ---------    ---------    ---------    ---------    ---------
---------
 TOTAL                3.677E-06    3.537E-06    0.000E+00    0.000E+00    0.000E+00
1.583E-05
0INHALATION DOSE FOR EACH IODINE AND TIME PERIOD (REM) (ICRP 2 DATA

   ID   ISOTOPE        0-2 HRS      2-8 HRS     8-24 HRS     1-4 DAYS     4-30 DAYS
2-HR EAB

   1    I-131         1.648E-06    1.586E-06    0.000E+00    0.000E+00    0.000E+00
7.095E-06
   2    I-132         1.424E-07    1.370E-07    0.000E+00    0.000E+00    0.000E+00
6.130E-07
   3    I-133         1.273E-06    1.225E-06    0.000E+00    0.000E+00    0.000E+00
5.481E-06
   4    I-134         5.786E-08    5.567E-08    0.000E+00    0.000E+00    0.000E+00
2.491E-07
   5    I-135         6.063E-07    5.832E-07    0.000E+00    0.000E+00    0.000E+00
2.610E-06
                      ---------    ---------    ---------    ---------    ---------
---------
 TOTAL                3.728E-06    3.587E-06    0.000E+00    0.000E+00    0.000E+00
1.605E-05
0INHALATION DOSE FOR EACH IODINE AND TIME PERIOD (REM) (ICRP 30 DATA)

   ID   ISOTOPE        0-2 HRS      2-8 HRS     8-24 HRS     1-4 DAYS     4-30 DAYS
2-HR EAB

   1    I-131         1.203E-06    1.157E-06    0.000E+00    0.000E+00    0.000E+00
5.177E-06
   2    I-132         1.714E-08    1.650E-08    0.000E+00    0.000E+00    0.000E+00
7.379E-08
   3    I-133         5.730E-07    5.512E-07    0.000E+00    0.000E+00    0.000E+00
2.467E-06
   4    I-134         2.476E-09    2.382E-09    0.000E+00    0.000E+00    0.000E+00
1.066E-08
   5    I-135         1.530E-07    1.472E-07    0.000E+00    0.000E+00    0.000E+00
6.588E-07
                      ---------    ---------    ---------    ---------    ---------
---------
 TOTAL                1.948E-06    1.875E-06    0.000E+00    0.000E+00    0.000E+00
8.387E-06
0AT 2 HOUR EXCLUSION AREA BOUNDARY (EAB)


 TOTAL GAMMA DOSE =  1.366E-07 REM
 TOTAL BETA DOSE =  1.583E-05 REM
 TOTAL INHALATION DOSE (ICRP-2) =  1.605E-05 REM
 TOTAL INHALATION DOSE (ICRP-30) =  8.387E-06 REM

0AT 30 DAY LPZ BOUNDARY


 TOTAL GAMMA DOSE =  6.227E-08 REM
 TOTAL BETA DOSE =  7.214E-06 REM
 TOTAL INHALATION DOSE (ICRP-2) =  7.315E-06 REM
 TOTAL INHALATION DOSE (ICRP-30) =  3.823E-06 REM

 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
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 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.


1LOSS OF AC POWER


0TEDE FOR EACH ISOTOPE AND TIME PERIOD (REM)

   ID   ISOTOPE       0-2 HRS      2-8 HRS     8-24 HRS     1-4 DAYS     4-30 DAYS
2-HR EAB

   1    KRM-83       0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   2    KRM-85       2.135E-10    2.054E-10    0.000E+00    0.000E+00    0.000E+00
9.189E-10
   3    KR-85        4.529E-12    4.359E-12    0.000E+00    0.000E+00    0.000E+00
1.950E-11
   4    KR-87        1.038E-09    9.993E-10    0.000E+00    0.000E+00    0.000E+00
4.470E-09
   5    KR-88        5.188E-09    4.991E-09    0.000E+00    0.000E+00    0.000E+00
2.234E-08
   6    KR-89        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   7    XEM-131      4.151E-11    3.994E-11    0.000E+00    0.000E+00    0.000E+00
1.787E-10
   8    XEM-133      1.655E-11    1.593E-11    0.000E+00    0.000E+00    0.000E+00
7.126E-11
   9    XE-133       6.639E-10    6.387E-10    0.000E+00    0.000E+00    0.000E+00
2.858E-09
  10    XEM-135      4.584E-10    4.411E-10    0.000E+00    0.000E+00    0.000E+00
1.974E-09
  11    XE-135       1.691E-09    1.627E-09    0.000E+00    0.000E+00    0.000E+00
7.278E-09
  12    XE-137       5.299E-11    5.099E-11    0.000E+00    0.000E+00    0.000E+00
2.281E-10
  13    XE-138       1.220E-09    1.174E-09    0.000E+00    0.000E+00    0.000E+00
5.252E-09
  14    I-131        4.725E-08    4.546E-08    0.000E+00    0.000E+00    0.000E+00
2.034E-07
  15    I-132        1.044E-08    1.005E-08    0.000E+00    0.000E+00    0.000E+00
4.494E-08
  16    I-133        3.822E-08    3.677E-08    0.000E+00    0.000E+00    0.000E+00
1.645E-07
  17    I-134        5.743E-09    5.526E-09    0.000E+00    0.000E+00    0.000E+00
2.472E-08
  18    I-135        3.170E-08    3.050E-08    0.000E+00    0.000E+00    0.000E+00
1.365E-07
  19    H-3          5.989E-05    5.762E-05    0.000E+00    0.000E+00    0.000E+00
2.578E-04
                     ---------    ---------    ---------    ---------    ---------
---------
 TOTAL               6.004E-05    5.776E-05    0.000E+00    0.000E+00    0.000E+00
2.585E-04
 TOTAL TEDE =  1.178E-04
0THIS RUN IS DATED 01/29/10. THE TOTAL ELAPSED TIME IS  0.0 MINUTES.  0.0 SECONDS.
```

Attachment 10

TVA Nuclear Power Group Calculation

WBNAPS3-077 R11

Offsite and Control Room Operator Doses Due to a Main Steam Line Break

NPG CALCULATION COVERSHEET/CCRIS UPDATE

Page 1

REV 0 EDMS/RIMS NO. B26 931014 409	EDMS TYPE: calculations(nuclear)	EDMS ACCESSION NO (N/A for REV. 0) T93100219002

Calc Title:

Offsite and Control Room Operator Doses Due to a Main Steam Line Break

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISION APPLICABILITY
CURRENT	CN	NUC	WBN	NTB	WBNAPS3-077	10	11	Entire calc ☒ Selected pages ☐
NEW	CN	NUC						

ACTION	NEW ☐ REVISION ☒	DELETE ☐ RENAME ☐	SUPERSEDE ☐ DUPLICATE ☐	CCRIS UPDATE ONLY ☐ (Verifier Approval Signatures Not Required)	No CCRIS Changes ☐ (For calc revision, CCRIS been reviewed and no CCRIS changes required)

UNITS 1/2	SYSTEMS NA	UNIDS NA

DCN,EDC,N/A EDCR 54956	APPLICABLE DESIGN DOCUMENT(S) NA	CLASSIFICATION E

QUALITY RELATED?	SAFETY RELATED? (If yes, QR = yes)	UNVERIFIED ASSUMPTION	SPECIAL REQUIREMENTS AND/OR LIMITING CONDITIONS?	DESIGN OUTPUT ATTACHMENT?	SAR/TS and/or ISFSI SAR/CoC AFFECTED
Yes ☒ No ☐	Yes ☒ No ☐	Yes ☐ No ☒	Yes ☐ No ☒	Yes ☐ No ☒	Yes ☒ No ☐

PREPARER ID	PREPARER PHONE NO	PREPARING ORG (BRANCH)	VERIFICATION METHOD	NEW METHOD OF ANALYSIS
MCBERG	603-926-3810	WorleyParsons/Polestar	Design Review	☐ Yes ☒ No

PREPARER SIGNATURE Marc C. Berg Marc C. Berg	DATE 1-29-10	CHECKER SIGNATURE Heather M. Lucek Heather M Lucek	DATE 1·29·10
VERIFIER SIGNATURE Heather M. Lucek Heather M Lucek	DATE 1·29·10	APPROVAL SIGNATURE BEF 2/18/2010 for JSThompson JSThompson	DATE 02/19/10

STATEMENT OF PROBLEM/ABSTRACT

This calculation is performed to show that the offsite and control room operator doses do not exceed the 10CFR100 and 10CFR50 App.A GDC 19 dose limits due to a Main Steam Line Break at the Watts Bar Nuclear Plant. The computer code STP determines the activity releases. The STP output is used as input to computer codes FENCDOSE and COROD which determine the offsite and control room doses.

There are several cases modeled. Each case has two sets. One set has a pre-accident iodine spike where the iodine level in the reactor coolant is at the 48 hour maximum allowable 21 μCi/gm I-131 equivalent. The other set has the reactor coolant at the maximum steady state I-131 equivalent of 0.265 μCi/gm with an accident initiated iodine spike consisting of a 500 increase in the rate of iodine release from the fuel. In both sets, the primary to secondary side leak is 150 gpd in the unfaulted loops, and the secondary side activity is at the Technical Specification limit of 0.1μCi/gm. The Tritium Production Core (TPC) was used. The X/Q values using the ARCON96 methodology were used. The ARCON96 X/Q values give more limiting results. Revision ~~10~~ 11 BEF 2/18/2010 analyzed the Unit 2 MSLB.

The following results should ultimately be reflected in FSAR Table 15.5-7 and Technical Specifications:

using ICRP-30 the following are the limitations:

21 μCi/gm I-131 equivalent 48 hour limit
0.265 μCi/gm I-131 equivalent equilibrium limit
0.1 μCi/gm I-131 equivalent in the secondary side
The maximum primary to secondary side leak rate in the unfaulted steam generators is 150 gpd/steam generator
10 gpm identified primary to secondary side leakage
1 gpm unidentified primary to secondary side leakage

See Appendix G for other cases.

The Tritium Production Core (TPC) does not affect the limits above, because the limiting doses are the thyroid doses. The tritium affects only the beta dose and TEDE. The TPC obviously bounds the non-TPC configuration.

MICROFICHE/EFICHE Yes ☒ No ☐ FICHE NUMBER(S) TVA-F-W001412

☐ LOAD INTO EDMS AND DESTROY
☐ LOAD INTO EDMS AND RETURN CALCULATION TO CALCULATION LIBRARY. ADDRESS:
☐ LOAD INTO EDMS AND RETURN CALCULATION TO:

NPG CALCULATION COVERSHEET/CCRIS UPDATE

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	REV
	CN	NUC	WBN	NTB	WBNAPS3-077	11

ALTERNATE CALCULATION IDENTIFICATION

BLDG	ROOM	ELEV	COORD/AZIM	FIRM	Print Report Yes ☒
				Polestar	

CATEGORIES

KEY NOUNS (A-add, D-delete)

ACTION (A/D)	KEY NOUN	A/D	KEY NOUN

CROSS-REFERENCES (A-add, C-change, D-delete)

ACTION (A/C/D)	XREF CODE	XREF TYPE	XREF PLANT	XREF BRANCH	XREF NUMBER	XREF REV
A	P	VD	WBN	MEB	LTR-CRA-09-103	
A	P	VD	WBN	MEB	WBT-D-1202	
A	P	ED	WBN	MEB	EDCR 54956	

CCRIS ONLY UPDATES:
Following are required only when making keyword/cross reference CCRIS updates and page 1 of form NEDP-2-1 is not included:

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE

PREPARER PHONE NO.

EDMS ACCESSION NO.

NPG CALCULATION RECORD OF REVISION

CALCULATION IDENTIFIER **WBNAPS3-077**

Title **Offsite and Control Room Operator Doses Due to a Main Steam Line Break**

Revision No.	DESCRIPTION OF REVISION
0	Initial Issue
1	Revision 1 is performed because the X/Q values have changed. R1 pages 6 and 7 are new, and all pages are renumbered. Only changed text have revision bars. pages added: 6, 7 pages changed: all pages deleted: none
2	Revision 2 was performed because of new control room makeup flow (711 cfm). pages added: none pages deleted: none pages changed: 1-7, 9, 13
3	Revision 3 was performed to incorporate larger Technical Specification primary to secondary side leakage as part of the alternate steam generator tube plugging project. Since the final leakage value has not been established, a 5 gpm and a 10 gpm case was performed. All pages were renumbered, however only pages with text changes will have revision bars and will be listed as having been changed: Pages added: none pages deleted: classification forms pages changed: 1-9, 12 R3: 13 total pages
4	Revision 4 was performed to change the iodine partition factor for the faulted steam generator from 100 to 1 to account for steam generator dryout. The steady state preaccident leakage is changed to 150 gpd/steam generator. A preaccident iodine spike of 60 uCi/gm is applied to the reactor coolant. An accident initiated spiking factor of 500 increase in iodine release from the fuel to the reactor coolant was incorporated in the STP model. This revision is part of the corrective action for WBN PER 99-017510-000. Pages added: new coversheet (page 1) Pages deleted: none Pages changed: 1a (old coversheet page 1), 1b (old page 1a), 2-9, 12 R4: 15 total pages
5	Revision 5 is performed to incorporate new iodine production rates, split the iodine spiking model into two separate cases, and also to perform an additional analysis for a maximum Technical Specification limit of 0.35 µCi/gm I-131 equivalent (steady state). The non-steady state maximum limit of 60 µCi/gm I-131 * 0.35 = 21 µCi/gm I-131 is also analyzed. Additionally, the maximum allowable primary to secondary side leakage is determined for all cases. Justification for usage of the ANSI-ANS 18.1-1984 spectrum is also provided. Due to the nature of the revision, all pages were changed, with significant additions (Appendix A, and Attachment 1). Pages added: all pages deleted: all pages changed: all R5: 27 total pages
6	Revision 6 is performed to add the Tritium Production Core (TPC) with a two TPBAR failure, add a 0.265 and 0.177 µCi/gm I-131 equivalent steady state with factor of 500 iodine spike case (and deleted the 0.35 µCi/gm case), add 21 µCi/gm I-131 equivalent 48 hour maximum case, change the noble gas inventories to the maximum allowable based on 100/Ebar, add ARCON96 X/Q values (also use Halitsky X/Q values), and to use the latest versions of COROD (R5) and FENCDOSE (R4) which now determine thyroid doses based on ICRP-2 and ICRP-30 as well as now determines the TEDE. Add a second actual measurement of reactor coolant inventories. Incorporated NISYS and Westinghouse 3rd party review comments. Due to the nature of the changes, all pages were renumbered. Actual text changes are indicated with revision bars. **The results of this calculation affect the FSAR and Technical Specifications. These changes will be incorporated by the corrective action plan for PER 00-012545-000.** Pages added: all Pages deleted: all Pates changed: all R6: 60 total pages
7	Revision 7 is performed to increase the Steam Generator leakage post accident. In order to accommodate a later decision on the actual leakage, several different leakages were analyzed. The calculation methodology from R6 was unchanged. Revision 6 results were preserved by placing them in Appendix G. **The results of this calculation affect the FSAR.** The SAR change package number is 1770. Pages added: none Pages deleted: all old coversheets Pages changed: 1-8, 13, 14, 18-25, 41, 45, 48, 49 R7: 61 total pages

NPG CALCULATION RECORD OF REVISION

CALCULATION IDENTIFIER **WBNAPS3-077**

Title **Offsite and Control Room Operator Doses Due to a Main Steam Line Break**

Revision No.	DESCRIPTION OF REVISION
8	Revision 8 is performed to add a 1.4 gpm SG leak case. The results of this calculation may affect the FSAR depending on establishment of final allowable leakage rate. Pages added: none Pages deleted: none Pages changed: 1-3, 5-8, 14, 19, 21, 23 R8: 61 total pages
9	Revision 9 is performed to address the new Replacement Steam Generators (DCN 51754). The number of cases analyzed has been reduced to only the preaccident and accident initiated Iodine spike with no additional post accident Steam Generator leakage (alternate repair criteria). The new steam generators have different inventories and mass releases. The previous original steam generator cases used in the FSAR (10 gpm known + 1 gpm unknown + 3 gpm post accident leakage) can be found in Appendix G (COROD results were corrected). In addition, the COROD model recirculation rate was corrected as part of corrective action PER 61493. Two CREVS train operation is addressed in assumption 14. The COROD time increments were corrected (PER 94426). Due to the nature of the revision, all pages were renumbered. Actual text changes are marked with revision bars. The results of this calculation will result in changes to ch.15 of the FSAR. The full impact to the FSAR and TS are discussed in the screening review for DCN 51754. Pages added: 4 Pages changed: 1, 2, 5-10, 13-20, 29-35 Pages deleted: design verification form R9: 46 total page
10	Revision 010 of this calculation was created to add/update Unit 2 applicability. This calculation is applicable to Unit 2 based on the following: • Appendix H of this calculation was added (1) to evaluate the recent Westinghouse steam releases during a Main Steam Line Break (MSLB); and (2) to install Revision 006 (original steam generator) as Appendix H, because it contains more conservative results than Revision 009 which are applicable to Unit 2. This calculation supports Chapter 15 of the FSAR. Affected design inputs were reviewed and (1) were found to be correct, or (2) were corrected as necessary. The effect of Unit 2 operation on Unit 1 margins has been reviewed with no impact. Ultimate heat sink (UHS) temperature was not used as an input to the calculation analyses. Therefore, existing calculation results will not be affected by changing the UHS technical specification temperature. FSAR AND TECHNICAL SPECIFICATIONS HAVE BEEN REVIEWED AND FSAR SECTION 15.5.4 CHANGE PAGES ARE PART OF FSAR AMENDMENT 97. Reviewer: ____________________ Pages Added: 1A, 4A, 4B, H-1 to H-15 Pages Revised: 5A Pages Replaced: 2 Pages Deleted: none Total number of pages in this revision: 64 pages (46 + 18) (Appendix A – 2 pages; Appendix B – 6 pages; Appendix C – 2 pages; Appendix D – 2 pages; Appendix E – 1 page; Appendix F – 1 page; Appendix G – 1 page; Appendix H – 15 pages; Attachment 1 – 11 pages)
11	Revision 11 is performed to explicitly evaluate Unit 2, which has the original steam generators. This is performed in Appendix H and replaces the previous Appendix H added in revision 10. Westinghouse provided revised mass releases. Also, the Unit 2 specific ARCON96 X/Q values were used. The SAR has been reviewed by Marc Berg and this revision of the calculation affects Unit 2 SAR section Chapter 15.5.4 , A SAR change shall be processed in accordance with NGDC PP-10 to reflect the calculation results as part of EDCR 54956. Tech Specs have been reviewed and determined not to be affected. Pages added: design verification form (p.6) Pages deleted: none Pages changed: 1, 2, 4-9, 19-21, 37-40 R11: 51 total pages

NPG CALCULATION TABLE OF CONTENTS

Calculation Identifier: **WBNAPS3-077**	Revision: 11	

TABLE OF CONTENTS

SECTION TITLE PAGE

NPG CALCULATION VERIFICATION FORM

Calculation Identifier **WBNAPS3-077** Revision 11

Method of verification used:

1. Design Review ☒
2. Alternate Calculation ☐
3. Qualification Test ☐

Heather Lucek

Verifier Heather Lucek Date 1-29-2010

Comments:

I have reviewed WBNAPS3-077 R11 and have found the calculation to have been completed in a technically sound an appropriate manner to address the main steam line break in Unit 2. In conducting the verification I reviewed the methodology, design input, and assumptions which I found to be valid and conservative. I verified the computer code inputs for correctness and confirmed they only contained the changes as specified in this document. I also confirmed the correct output values were compiled in the results.

LEGIBILITY EVALUATED AND ACCEPTED FOR ISSUE. ALL PAGES

Scott Helm 2/18/10

SIGNATURE REV 11 DATE

NPG COMPUTER INPUT FILE
STORAGE INFORMATION SHEET

Document **WBNAPS3-077**	Rev. 11	Plant: WBN	

Subject:
Offsite and Control Room Operator Doses Due to a Main Steam Line Break

☐ Electronic storage of the input files for this calculation is not required. Comments:

☒ Input files for this calculation have been stored electronically and sufficient identifying information is provided below for each input file. (Any retrieved file requires re-verification of its contents before use.)

The R1 input files are archived on FILEKEEPER under reference I.D.# 263447
The R2 input files are archived on FILEKEEPER under reference I.D.# 263715
The R3 input files are permanently stored in FILEKEEPER file # 302577
The R4 input files are permanently stored in FILEKEEPER file # 302740
The R5 input files are permanently stored in FILEKEEPER file # 303180
The R6 input files are permanently stored in FILEKEEPER file # 303611
The R7 input files are permanently stored in FILEKEEPER file # 304905
The R8 input files are permanently stored in FILEKEEPER file # 305986
The R9 input files are permanently stored in FILEKEEPER file # 308282
The R11 input files are permanently stored in eFiche file # TVA-F-W001412

☐ Microfiche/eFiche

NPG COMPUTER OUTPUT
MICROFICHE INFORMATION SHEET

Document **WBNAPS3-077**	Rev. 11	Plant: WBN

Subject:
Offsite and Control Room Operator Doses Due to a Main Steam Line Break

Microfiche Number	Description
R0:TVA-F-G104614	R0 Computer Runs see R5 for listing
R1:TVA-F-C000078	R1 Computer Runs see R5 for listing
R2:TVA-F-C000119	R2 Computer Runs see R5 for listing
R3:TVA-F-C000294	R3: Computer Runs see R5 for listing
R4:TVA-F-C000301	R4: Computer Runs see R5 for listing
R5:TVA-F-C000316	R5: Computer Runs see R5 for listing
R6:TVA-F-W000220	R6: Computer Runs: See R9 for listing
R7: TVA-F-W000290	R7: Computer Runs: APS77S7# STP source terms APS77C7# COROD control room dose APS77F7# FENCDOSE offsite dose where #=: A, E, I, M, Q, U = 21 μCi/gm with 10+1 gpm primary to secondary side leak,, Halitsky X/Q B, F, J, N, R, V = 0.265 μCi/gm with 10+1 gpm prim to secondary leak, 500 I spike, Halitsky X/Q C, G, K, O, S, W = same as A, E, I, M, Q, U but with ARCON96 X/Q D, H, L, P, T, X = same as B, F, J, N, R, V but with ARCON96 X/Q And A, B, C, D = 5.4 gpm SG leak E, F, G, H = 1.0 gpm SG leak I, J, K, L= 2.0 gpm SG leak M, N, O, P= 3.0 gpm SG leak Q, R, S, T= 4.0 gpm SG leak U, V, W, X= 5.0 gpm SG leak
R8: TVA-F-W000360	R8: Computer Runs: APS77S8# STP source terms, 1.4 gpm SG leak APS77C8# COROD control room dose APS77F8# FENCDOSE offsite dose where #=: A = 21 μCi/gm with 10+1 gpm primary to secondary side leak,, Halitsky X/Q B = 0.265 μCi/gm with 10+1 gpm prim to secondary leak, 500 I spike, Halitsky X/Q C = same as A but with ARCON96 X/Q D = same as B but with ARCON96 X/Q
R9: TVA-F-W000611	R9: Computer Runs: APS77S9# STP source terms APS77C9# COROD control room dose APS77F9# FENCDOSE offsite dose where #=: A, E =21 μCi/gm with 10+1 gpm primary to secondary side leak ARCON96 X/Q, B,F=0.265 μCi/gm with 10+1 gpm prim to secondary leak, 500 I spike, ARCON96 X/Q A,B=replacement SG, E,F= original SG
R11: TVA-F-W001412	R11: Computer Runs: APS77S10# STP source terms APS77C10# COROD control room dose APS77F10# FENCDOSE offsite dose where #=: A=21 μCi/gm with 10+1 gpm primary to secondary side leak Unit 2 ARCON96 X/Q, B=0.265 μCi/gm with 10+1 gpm prim to secondary leak, 500 I spike, Unit 2 ARCON96 X/Q

Purpose

The purpose of this calculation is to determine the offsite and control room operator dose due to a Main Steam Line Break (MSLB). The results will be used in FSAR ch.15.5 to show compliance with 10CFR100 and 10CFR50 App.A GDC 19. This calculation also establishes the maximum primary to secondary side leakage and the maximum I-131 equivalent concentrations in the primary and secondary side coolant.

Revision 9 is performed due to the replacement of the steam generators. The new steam generators have different mass inventories and mass releases than the original steam generators. Also, the post accident leakage due to Alternate Repair Criteria is eliminated. Therefore only one leakage case is analyzed, utilizing the Tritium Production Core (TPC). The original steam generator cases used in the FSAR are archived in Appendix G. There are two cases modeled. One case has a pre-accident iodine spike where the iodine level is the reactor coolant at the 48 hour maximum allowable 21 μCi/gm I-131 equivalent. The other case has the reactor coolant at the maximum steady state I-131 equivalent of 0.265 μCi/gm I-131 equivalent with an accident initiated iodine spike consisting of a 500 increase in the rate of iodine release from the fuel. In both sets, the primary to secondary side leak is 150 gpd in the unfaulted loops, and secondary side activity is at the Technical Specification limit of 0.1 μCi/gm. The Tritium Production Core (TPC) was used. The control room X/Q values using ARCON96 methodology was used. COROD (R6) and FENCDOSE (R4) were used to determine the thyroid doses based on ICRP-2, ICRP-30 and also the TEDE. Only one train of CREVS is utilized (see assumption 14).

Revision 11 is performed to evaluate the Unit 2 MSLB. Unit 2 has the original steam generators, however Westinghouse has provided revised mass releases. Also the Unit 2 ARCON96 X/Q values are used. The results are found in Appendix H.

Introduction

A Main Steam Line Break at the Watts Bar Nuclear Plant will result in a significant steam release to the environment. The steam will contain radionuclides if a primary to secondary side leak occurs prior to the MSLB event. This calculation is performed to show that the offsite and control room operator doses do not exceed the 10CFR100 and 10CFR50 App.A GDC 19 dose limits.

This calculation uses the computer code STP (ref.3) to determine the activity releases. The STP output is used as input to computer codes FENCDOSE and COROD. Computer code FENCDOSE (ref.4) is used to determine the offsite dose. Computer code COROD (ref.5) is used to determine the control room operator dose. The base FENCDOSE and COROD models are taken from WBNTSR-008 (ref.9).

There are 2 cases modeled. The first case has a pre-accident iodine spike where the iodine level in the reactor coolant is at the maximum allowable of 21 μCi/gm I-131 equivalent (ref.1). The second has the reactor coolant at the maximum steady state I-131 equivalent of 0.265 μCi/gm with an accident initiated iodine spike consisting of a 500 increase in the rate of iodine release from the fuel. In both cases, the primary to secondary side leak is 150 gpd in the unfaulted loops (ref.21), and the secondary side activity is at the Technical Specification limit of 0.1μCi/gm (ref.23). There is no additional steam generator leakage post accident, however the preaccident 1 gpm ("unknown") leakage in the faulted steam generator and the 150 gpd/unfaulted steam generator continues post accident. To establish the Iodine release rate rate from the fuel, a preaccident 10 gpm known reactor coolant leak is used with a 1 gpm unknown leak for a total of 11 gpm. Additional cases are performed in Appendix G with other leakage rates and other iodine concentrations. These extra cases were performed so as to give additional information for possible future changes in Technical Specifications. The relative isotopic spectrum is taken from WBNNAL3-003 (Reactor Coolant Activities in Accordance with ANSI/ANS-18.1-1984). Justification of the usage of this spectrum as opposed to the historical design spectrum as found in chapter 11 of the FSAR can be found in Appendix A.

Assumptions

1. The primary side to secondary side leakage is 150 gpd/steam generator, steady state, with 1 gpm in the faulted steam generator (steady state). The 1 gpm in the faulted steam generator and the 150 gpd/unfaulted steam generators continue following the accident. No additional leakage is assumed.
Technical Justification: 150 gpd/steam generator and the 1 gpm are the maximum Technical Specification leakages. Having the 1 gpm in the faulted loop is conservative.
2. The maximum letdown of 120 gpm (ref.16) + 4.39 gpm uncertainty for a total of 124.39 gpm is used.

Technical Justification: This will maximize the removal rate of iodines from the primary coolant, and therefore will maximize the production rate of iodine (production = removal at steady state) and is consistent with NSAL-00-004. See Calculation section for the formulas used. Note, this value is used for calculation of iodine production/removal rates. The letdown is assumed to be isolated at the beginning of the accident to maximize the reactor coolant inventories. The uncertainty of 4.39 gpm is determined in Appendix B.

3. The primary to secondary side leak rates and letdown flow rates are based on Standard Temperature and Pressure (STP).

Technical Justification: STP conditions will result in higher densities, therefore higher masses, especially when determining the production rate of iodines.

4. It is assumed that the faulted steam generator dries out at the start of the accident, resulting in an iodine partition factor of 1.0 per ref.10.

Technical Justification: Following an accident, the Main Steam Line will be isolated and the Main and Auxiliary Feedwater will also be isolated. Since the worst case accident occurs with the line associated with a Steam Generator with Technical Specification leakage, that Steam Generator will dry out. In reality, this dry out will not occur until all feedwater has been isolated, and the water boiled off. Assuming dry out conditions at time zero is clearly conservative.

5. In the intact steam generators, the iodine partition factor is assumed to be 100.

Technical Justification: The mass of primary to secondary leakage which occurs to the intact steam generators is small relative to the mass of secondary coolant. Therefore none of this leakage is assumed to flash and the release to the environment is through the steaming process. Reference 10 allows a partition factor of 100 for such cases.

6. A preaccident iodine spike of 21 μCi/gm I-131 equivalent is assumed at the start of the accident. In other cases, an accident initiated iodine spike of 500 increase in the iodine release rate from the fuel is assumed in the accident initiated case with the reactor coolant starting at 0.265 μCi/gm I-131 equivalent.

Technical Justification: SRP 15.1.5 subsection 4a specifies the maximum allowable preaccident spike is required (21 μCi/gm is permissible for 48 hours). SRP 15.1.5 subsection 4b specifies that following an accident, the iodine release rate from the fuel to the reactor coolant is increased by a factor of 500.

7. The letdown demineralizer efficiency is assumed to be 1 for iodines.

Technical Justification: This will maximize iodine removal (=production) rate, and therefore result in larger iodine spiking.

8. The control room isolates in 20.6 seconds (ref.9) due to high radiation in the Control Building Ventilation intake (400 cpm, ref.18). This will result in an unfiltered puff into the control room for that 20.6 seconds.

Technical Justification: This is based on 14 seconds closure time of the dampers, plus 6.6 seconds instrument response time.

9. The tritium inventory in the TPC assumes 2 TPBAR failures (98.4 μCi/gm in the reactor coolant, per WBNNAL3-003, ref.2).

Technical Justification: This will maximize the tritium release.

10. The iodine production rate is based on 10 gpm identified primary side leakage (all leaks) plus 1 gpm unidentified leak, for a total of 11 gpm.

Technical Justification: This is per Technical Specification 3.4.13 (ref.21), and maximizes the iodine production rates. This methodology is consistent with NSAL-00-004, ref.22.

11. It is assumed that the secondary side concentrations are at the maximum of 0.1 μCi/gm I-131 equivalent.

Technical Justification: This is the maximum allowed by the Technical Specifications (ref.23) and is conservative.

12. The noble gas inventories are maximized by scaling them up to 100/Ebar.

Technical Justification: This maximizes the noble gas inventories. 100/Ebar is the Technical Specification limit.

13. It is assumed that there are no fuel failures associated with the accident.

Technical Justification: This accident will not uncover the core, therefore the core will not see extreme temperatures which would lead to fuel failure.

14. Only one train of CREVS is in operation.

Technical Justification: Normally, each CREVS train takes suction from separate intakes with no cross contamination between trains. This leads to on contaminated train, and one uncontaminated train. The only was a 2 CREVS operation could result in higher doses would be for both trains to take suction from the same vent. For this to happen, one intake path would require a failed closed intake path AND a fail open of normally close passive manual damper at the beginning of the accident. An active failure of a train plus a failure of a passive component in less than 24 hours is beyond design basis.

Special Requirements/Limiting Conditions

There are no special requirements or limiting conditions in this calculation.

Calculations

The STP models consist of a pre-accident iodine spike (see figure 1) model and an accident initiated iodine spike model (see figure 2). The model(s) consist of the following:

Volumes:
#1: Reactor Coolant: 5.78E5 lb (ref.2) = 2.622E8 gm
#2: Steam Generator w/Leak: 5.31E7 gm (ref.6)
#3: Steam Generators w/out Leak: 1.593E8 (ref.6).
#4: Environment: 1 gm (arbitrary) (This volume is made into an accumulator through the "A" card to suppress radioactive decay)

Step Sources:

The following equation is used to set up the initial activities (in Ci) for each component using the initial ANSI/ANS-18.1-1984 source modified for WBN operational parameters (which is in units of μCi/gm):

S = Component Volume [gm] * 1E-6 Ci/μCi * I-131 equivalent conversion factor

To obtain the I-131 equivalent conversion factor, the ANSI/ANS-18.1-1984 spectrum must be converted to I-131 equivalence. See Appendix A for justification for using the ANSI/ANS-18.1-1984 spectrum. From WBNTSR-008, the I-131 equivalence is:

I-131 equivalent = dose conversion factor (D/A) * concentration / I-131 dose conversion factor

	D/A mrads/Ci (ref.9)	μCi/gm coolant ANSI-18.1 (ref.2)	I-131 equivalent μCi/gm	1 μCi/gm I-131 equivalent (validation)
1-131	1.48E+09	4.77E-02	4.77E-02	3.80E-01
1-132	5.35E+07	2.25E-01	8.13E-03	6.48E-02
1-133	4.00E+08	1.49E-01	4.03E-02	3.21E-01
1-134	2.50E+07	3.64E-01	6.15E-03	4.90E-02
1-135	1.24E+08	2.78E-01	2.33E-02	1.86E-01
total		1.06E+00	1.255E-01	1.000E+00
		inverse	7.965E+00	

The above table shows that the I-131 equivalent concentration of the initial RCS ANSI 18.1 source term is 0.1255 uCi/gm, as compared to 1 uCi/gm when the RCS is at the TS allowable concentration. Consequently, to ratio the initial source term up to the TS allowable values, the ANSI 18.1 concentrations must be multiplied by 1/0.1255 or 7.965. Note: this equivalence is based on ICRP-2 iodine dose conversion factors because this is what Chemistry uses. Some of the final dose results are based on ICRP-30. Utilizing the different ICRP conversion factors in this case is appropriate because in the above case, the ICRP-2 establishes the inventories, which is independent of determination of doses due to releases.

For the secondary side concentrations from WBNNAL3-003, the same procedure is performed to determine the I-131 equivalence:

	D/A mrads/Ci	μCi/gm secondary side, water ANSI 18.1	I-131 equivalent μCi/gm
1-131	1.48E+09	1.41E-06	1.41E-06
1-132	5.35E+07	3.37E-06	1.22E-07
1-133	4.00E+08	4.03E-06	1.09E-06
1-134	2.50E+07	2.93E-06	4.95E-08
1-135	1.24E+08	6.19E-06	5.19E-07
total		1.79E-05	3.189E-06
		inverse	3.136E+05

To convert to I-131 equivalence, the secondary side I-131 equivalent conversion factor is (1/3.189E-6) = 3.136E5 gm/μCi (Note: since there is no Technical Specification limit on gross activity for the secondary side like the 100/Ebar for the primary side, this factor is also applied to the secondary side noble gasses in order to retain the proper isotopic ratios).

The isotopes other than iodine in the primary coolant must also be scaled up. In NUREG-0800 R2 Chapter 15.6.3, section III.5 states "The reviewer assumes the primary and secondary coolant activity concentrations allowed by the technical specifications." Reference 3 (of the NUREG-0800) states the following "The specific activity of the reactor coolant shall be limited to: a. Less than or equal to 1 microCurie per gram DOSE EQUIVALENT I-131, and b. Less than or equal to 100/E microCuries per gram of gross activity."

Given the above considerations, the isotopic spectrum found in WBNNAL3-003 was examined. The 100/E values for this particular spectrum are determined in the following Table:

Table 2: Determination of 100/EBAR

Isotope	A(i) Activity [uCi/gm]	E(i) Beta Energy [MeV/dis]	E(i) Gamma Energy [MeV/dis]	E(i) Total	A(i)*E(i)
Kr-85m	1.71E-01	2.5290E-01	1.5862E-01	4.1152E-01	7.04E-02
Kr-85	2.66E-01	2.5060E-01	2.2102E-03	2.5281E-01	6.73E-02
Kr-87	1.61E-01	1.3237E+00	7.9284E-01	2.1165E+00	3.40E-01
Kr-88	3.00E-01	3.7500E-01	1.9629E+00	2.3379E+00	7.01E-01
Xe-131m	6.54E-01	1.4280E-01	2.0058E-02	1.6286E-01	1.06E-01
Xe-133m	7.17E-02	1.8980E-01	4.1559E-02	2.3136E-01	1.66E-02
Xe-133	2.53E+00	1.3540E-01	4.5385E-02	1.8079E-01	4.57E-01
Xe-135m	1.39E-01	9.5000E-02	4.3176E-01	5.2676E-01	7.35E-02
Xe-135	9.04E-01	3.1680E-01	2.4696E-01	5.6376E-01	5.10E-01
Br-84	1.72E-02	1.2842E+00	1.6816E+00	2.9658E+00	5.09E-02
Rb-88	2.04E-01	2.0617E+00	6.8631E-01	2.7480E+00	5.60E-01
Cs-134	7.39E-03	1.5690E-01	1.0361E+00	1.1930E+00	8.82E-03
Cs-136	9.08E-04	1.0140E-01	2.1985E+00	2.2999E+00	2.09E-03
Cs-137	9.79E-03	1.8840E-01	0.0000E+00	1.8840E-01	1.84E-03
Na-24	4.99E-02	5.5460E-01	4.1216E+00	4.6762E+00	2.33E-01
Cr-51	3.26E-03	3.7540E-03	3.2763E-02	3.6517E-02	1.19E-04
Mn-54	1.68E-03	4.1670E-03	8.3592E-01	8.4009E-01	1.41E-03
Fe-55	1.26E-03	4.1920E-03	1.5291E-03	5.7211E-03	7.22E-06
Fe-59	3.16E-04	1.1800E-01	1.1923E+00	1.3103E+00	4.14E-04
Co-58	4.84E-03	2.0490E-01	9.7586E-01	1.1808E+00	5.72E-03
Co-60	5.58E-04	9.6840E-02	2.5043E+00	2.6011E+00	1.45E-03
Zn-65	5.37E-04	6.8940E-03	5.8169E-01	5.8858E-01	3.16E-04
Sr-89	1.47E-04	5.7300E-01	1.3636E-04	5.7314E-01	8.44E-05
Sr-90	1.26E-05	1.9630E-01	0.0000E+00	1.9630E-01	2.48E-06
Sr-91	1.02E-03	6.5050E-01	6.9508E-01	1.3456E+00	1.37E-03
Y-90	1.26E-05	9.3610E-01	0.0000E+00	9.3610E-01	1.18E-05
Y-91m	4.93E-04	0.0000E+00	5.5557E-01	5.5557E-01	2.74E-04
Y-91	5.47E-06	6.0600E-01	3.6147E-03	6.0961E-01	3.34E-06
Y-93	4.46E-03	1.1721E+00	8.9414E-02	1.2615E+00	5.63E-03
Zr-95	4.10E-04	1.1990E-01	7.3474E-01	8.5464E-01	3.51E-04
Nb-95	2.95E-04	4.4970E-02	7.6430E-01	8.0927E-01	2.38E-04
Mo-99	6.75E-03	3.9570E-01	1.6238E-01	5.5808E-01	3.77E-03
Tc-99m	5.01E-03	4.8500E-03	1.4263E-01	1.4748E-01	7.38E-04
Ru-103	7.89E-03	6.7400E-02	4.8394E-01	5.5134E-01	4.35E-03
Ru-106	9.47E-02	1.0100E-02	0.0000E+00	1.0100E-02	9.57E-04

Determination of 100/EBAR - continued

Isotope	A(i) Activity [uCi/gm]	E(i) Beta Energy [MeV/dis]	E(i) Gamma Energy [MeV/dis]	E(i) Total	A(i)*E(i)
Rh-103m	7.89E-03	3.4620E-02	2.2148E-05	3.4642E-02	2.73E-04
Rh-106	9.47E-02	7.0960E-01	2.0348E-01	9.1308E-01	8.65E-02
Te-129m	2.00E-04	1.9150E-01	9.4832E-02	2.8633E-01	5.73E-05
Te-129	2.57E-02	5.2260E-01	5.9948E-02	5.8255E-01	1.50E-02
Te-131m	1.59E-03	2.1240E-01	1.4092E+00	1.6216E+00	2.57E-03
Te-131	8.26E-03	7.5970E-01	4.1616E-01	1.1759E+00	9.71E-03
Te-132	1.79E-03	1.0020E-01	2.0507E-01	3.0527E-01	5.47E-04
Ba-137m	9.79E-03	6.4260E-02	5.9729E-01	6.6155E-01	6.48E-03
Ba-140	1.37E-02	3.1500E-01	1.9522E-01	5.1022E-01	6.98E-03
La-140	2.64E-02	5.4050E-01	2.3074E+00	2.8479E+00	7.52E-02
Ce-141	1.58E-04	1.6930E-01	1.0181E-01	2.7111E-01	4.28E-05
Ce-143	2.96E-03	3.8420E-01	3.4335E-01	7.2755E-01	2.15E-03
Ce-144	4.21E-03	9.1300E-02	3.2865E-02	1.2417E-01	5.23E-04
Pr-143	2.96E-03	3.1430E-01	0.0000E+00	3.1430E-01	9.30E-04
Pr-144	4.21E-03	1.2258E+00	3.1010E-02	1.2568E+00	5.29E-03
Np-239	2.32E-03	1.2380E-01	2.0845E+00	2.2083E+00	5.13E-03
Total	5.82E+00				3.44E+00
				EBAR	5.91E-01
			RCS Specific Activity Limit		169.14

The definition of EBAR or E is as follows: "E shall be the average (weighted in proportion to the concentration of each radionuclide in the reactor coolant at the time of sampling) of the sum of the average beta and gamma energies per disintegration (in MeV) for isotopes, other than iodines, with half lives greater than 15 minutes, making up at least 95% of the total non-iodine activity in the coolant."

The values for E_i in the above table were obtained from reference 9 and the values for A_i are from WBNNAL3-003. The value of E is determined as follows:

$$\text{Ebar} = E = (\Sigma A_i E_i) / (\Sigma A_i)$$

The value for E calculated in Table 2 is 0.591 MeV/dis. This results in a non-iodine specific activity limit (100/E) of 169.14 µCi/g. The total specific activity of the expected coolant is 5.82 µCi/g.

Therefore, the values for noble gasses in the design reactor coolant will have to be increased by a factor of 169.14/5.82 = 29.06.

The step sources (Ci-gm/μCi) to initialize the reactor coolant and the secondary side activities are:

All cases:

S=2.622E8 gm*1E-6 Ci/μCi * 29.06 =7.6195E3 (noble gasses)
S=2.622E8 gm*1E-6 Ci/μCi = 2.622E2 (tritium)
Pre-accident iodine spike case (initial concentration = 21 μCi/gm):
S=2.622E8 gm*1E-6 Ci/μCi * 7.965[μCi/gm I-131]$^{-1}$ *21μCi/gm I-131 = 4.386E4 (iodines)
Accident initiated iodine spike case (initial concentration = 0.265 μCi/gm):
S=2.622E8 gm*1E-6 Ci/μCi * 7.965 [μCi/gm I-131]$^{-1}$*0.265 μCi/gm I-131= 5.170E2

Secondary side, all cases, steam generator w/ leak, release to environment. (concentration = 0.1μCi/gm) which is due to dryout (from reference 8, the initial steam from the defective steam generator is 117,200 lb):

S = 117,200 lb *453.59 g/lb * 1E-6 Ci/μCi * 3.136E5 [μCi/gm I-131]$^{-1}$* 0.1μCi/gm I-131 = 1.667E6
S = 117,200 lb *453.59 g/lb * 1E-6 Ci/μCi = 6.8039E1 (tritium)
Secondary side, all cases, steam generators without leak (initial concentration = 0.1 μCi/gm):
S = 1.593E8 gm * 1E-6 Ci/μCi * 3.136E5 [μCi/gm I-131]$^{-1}$* 0.1μCi/gm I-131 = 4.996E6
S = 1.593E8 gm*1E-6 Ci/μCi = 1.593E2 (tritium)

Continuous Sources:

For the accident initiated iodine spike case, the iodine spike is 500 times the iodine release rate from the fuel. At steady state, the iodine release (production) rate is equal to the removal rate. The iodine removal is due to a) radioactive decay, b) removal by the letdown system, and c) removal through reactor coolant leakage. These terms are expressed as:

$P = \Sigma$removal rates = decay + letdown + leakage
or $P = \lambda + f_L\varepsilon/V + p_s/V$
where P = production rate [hr^{-1}]
λ = decay constant for the isotope in question [hr^{-1}] = ln(2)/$T_{1/2}$
f_L = letdown flow rate = 120 gpm + 4.39 gpm = 124.39 gpm
ε = letdown demineralizer efficiency = 1 (assumed so as to maximize removal/production rate)
V = volume of primary coolant = 5.78E5 lb = 2.62E8 gm
p_s = removal rate of iodine from the primary side due to preaccident primary side leakage
= 11 gpm (10 gpm identified + 1 gpm unidentified)
$T_{1/2}$ = halflife taken from ref.15

Note: all the above flow rates are converted to mass flow rates at STP:

Production Rates for a Reactor Coolant Leak of 11 gpm (10 gpm identified + 1 gpm unidentified)

	Half Life	λ [1/hr]	$f_L\varepsilon/V$ [1/hr]	p_s/V [1/hr]	prod rate P [1/hr]	500*P
I-131	8.04 d	3.59E-03	1.08E-01	9.53E-03	0.1209	60.44
I-132	2.28 h	3.04E-01	1.08E-01	9.53E-03	0.4213	210.65
I-133	20.9 h	3.32E-02	1.08E-01	9.53E-03	0.1505	75.23
I-134	52.6 m	7.91E-01	1.08E-01	9.53E-03	0.9080	453.98
I-135	6.61 h	1.05E-01	1.08E-01	9.53E-03	0.2222	111.08

The accident initiated iodine spike of 500 times the increase in the iodine release (production) rate from the fuel is modeled as a continuous source:

C = Volume * 1E-6 Ci/μCi * Prod. Rate * 500 * 1 μCi/gm I-131 equiv. conversion factor*I-131 equiv.
where Volume = 2.622E8 gm
Prod Rate = see table above
1 μCi/gm I-131 equivalent conversion factor = 7.965 (value determined above, this is to get the ANSI/ANS-18.1-1984 source into 1 μCi/gm I-131 equivalent
I-131 equiv. = 0.265 μCi/gm I-131

Continuous Source [gm-Ci/μCi-hr] for Accident Initiated Iodine Spike:

Reactor Coolant Leak of 11 gpm (10 gpm identified + 1 gpm unidentified)

case:	0.265 μCi/gm I-131
I-131	3.345E+04
I-132	1.166E+05
I-133	4.163E+04
I-134	2.512E+05
I-135	6.147E+04

Flow Rates:

The following flow rates/leakage rates for each component are:

Flow from Reactor Coolant #1 to Environment #4 all classes (consists of 1 gpm and is for leak in the steam generators, however the production rate of iodines is based on a total RCS leakage of 11 gpm (=10gpm identified +1gpm unidentified):
F = 1.0 gpm * 60 min/hr * 3785.48 cc/gal * 1g/cc = 2.271E5 g/hr
Flow from Reactor Coolant #1 to Steam Generator w/ no Leak #3 all classes:
F = 3 steam generators * 150 gpd * 3785.48 cc/gal / 24 hr/day * 1g/cc = 7.098E4 g/hr

From reference 25, the initial steam released from the defective steam generator is 117,200 lb. From the non-defective steam generators (= "steam generators without leak" in this model) the mass release is 442,083 lb (0-2 hr), and 922,918 lb (2-8 hr). The accident releases end at eight hours. To take into account uncovery of the faulted steam generator, there is no iodine partitioning in the release to the environment (iodine partition coefficient = 1). The mass release representing 1 gpm primary to secondary side leak is a flow directly to the environment.

The reactor coolant release to the unfaulted steam generator is small relative to the secondary side mass, therefore partitioning is allowed per the SRP. The iodine partition coefficient due to steaming for the unfaulted steam generators to the environment is 100. These mass releases translate into the following flows:

Flow from Steam Generators w/out Leak #3 to Environment #4:
F = (442,083 lb)(453.59 g/lb)/(2 hr) = 1.0026E8 g/hr (0-2 hr, noble gasses, tritium)
F = (442,083 lb)(453.59 g/lb)/(100*2 hr) = 1.0026E6 g/hr (0-2 hr, iodines)
F = (922,918 lb)(453.59 g/lb)/(6 hr) = 6.977E7 g/hr (2-8 hr) (noble gasses, tritium)
F = (922,918 lb)(453.59 g/lb)/(100*6 hr) = 6.977E5 g/hr (2-8 hr) (iodines)

The STP output is used as input to COROD (which determines control room operator dose) and FENCDOSE (which determines 30-day and 2-hour LPZ offsite dose).

Some pertinent information from the COROD and FENCDOSE models used (but not changed) in this analysis are (from ref.9):

30-day LPZ Offsite X/Q values [sec/cum]: 1.41E-4 0-2hr, 6.68E-5 2-8 hr, 4.59E-5 8-24 hr, 2.04E-5 1-4 day, 6.35E-6 4-30 day
2-hr EAB X/Q values: 6.07E-4
Control Room X/Q (ARCON96 method): 4.03E-3 0-2 hr, 3.35E-3 2-8 hr, 2.27E-4 8-24 hr, 1.81E-4 1-4 day, 1.45E-4 4-30 day
Control Room volume: 257198 cuft
Control Room makeup/pressurization flow: 711 cfm (3200 cfm prior to isolation, ref.24)

Control Room total flow: 3600 cfm
Control Room recirculation flow: 2889 cfm
Control Room unfiltered intake: 51 cfm
Control Room filter efficiency: 95% first pass, 70% second pass, 0% for tritium, 0% all elements prior to isolation
Control Room occupancy factors: 100% 0-24 hr, 60% 1-4 days, 40% 4-30 days
ICRP-2 and ICRP-30 dose conversion factors (internal to the codes)

Figure 1: STP Model
Pre-accident Iodine Spike

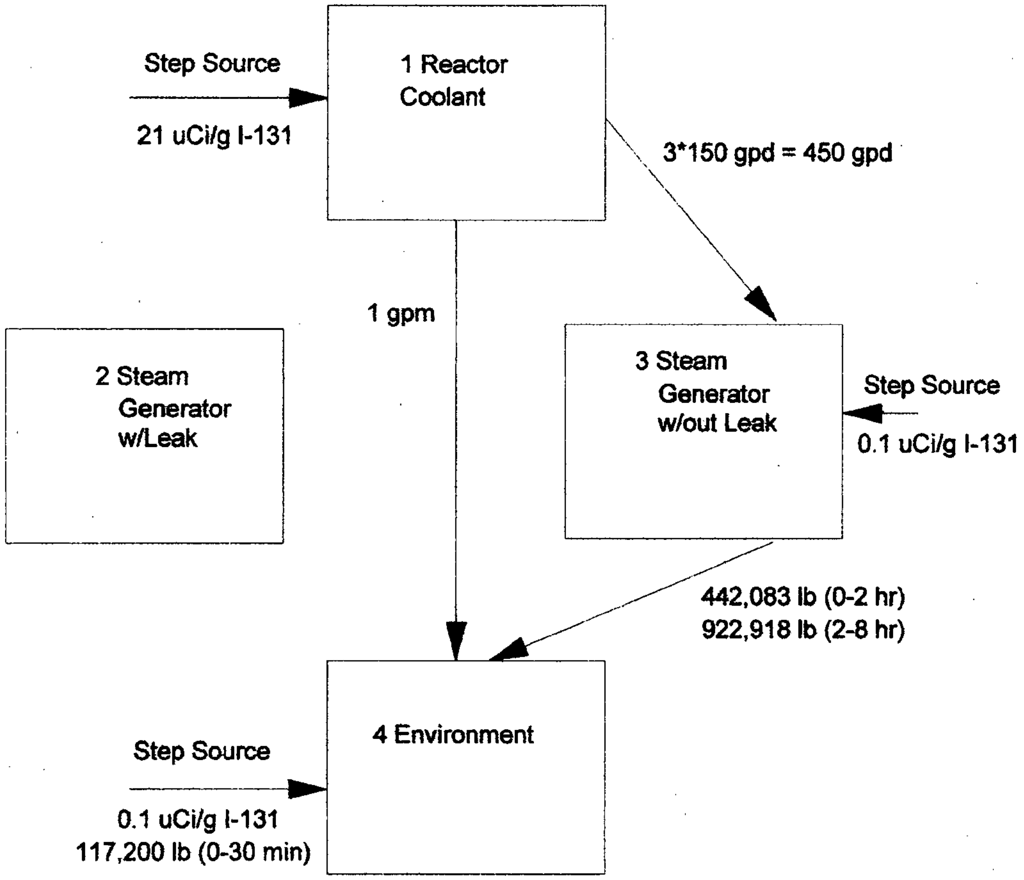
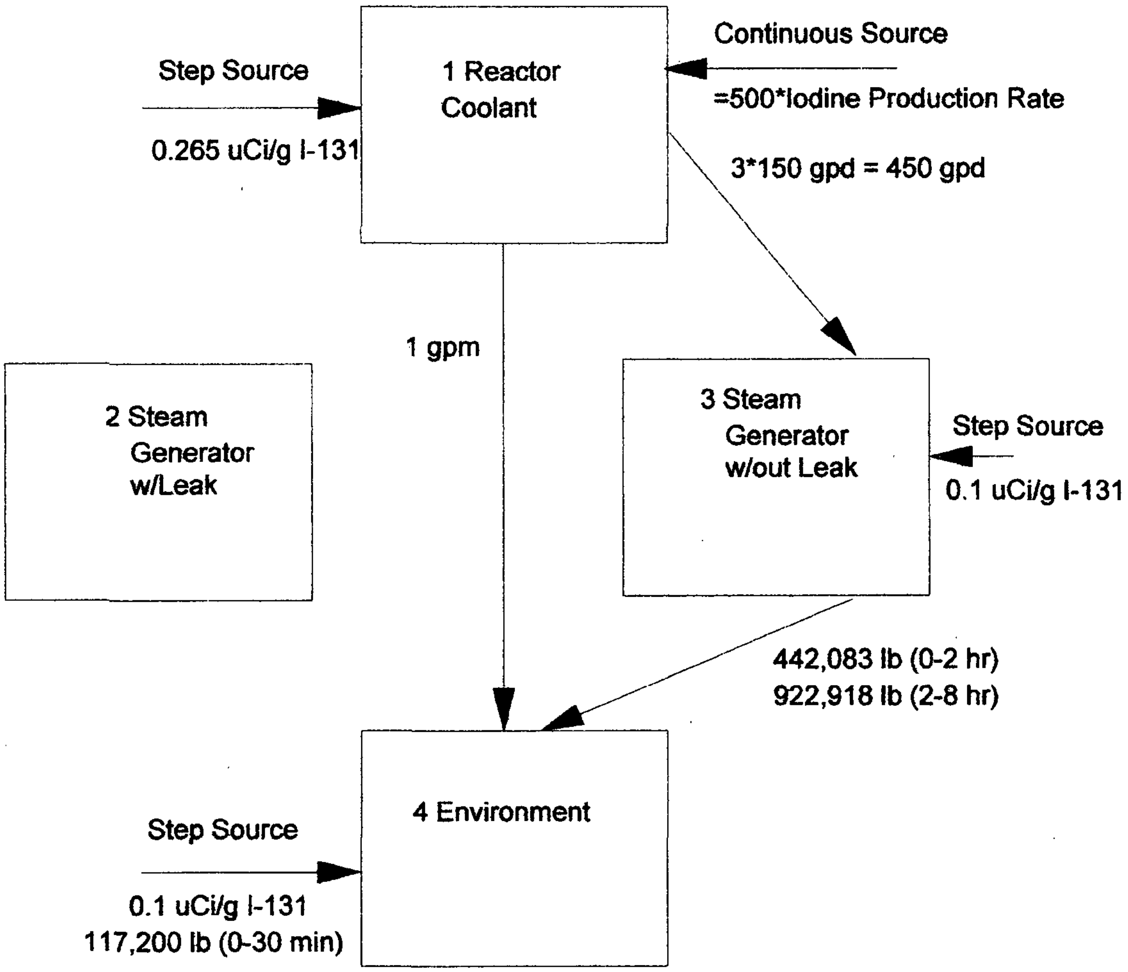


Figure 2: STP Model
Accident Initiated Iodine Spike



Results

The following results are based on a Tritium Production Core (TPC). The results from previous revisions showed that the TPC bounds the conventional core. In the following, the pre-accident reactor coolant lake rate is 11 gpm (10 gpm known + 1 gpm unknown), and the primary to secondary side steam generator post accident leak rate in the steam generators is 1 gpm (= the unknown leak rate). The Unit 2 results are found in Appendix H. The results were (rem):

Unit 1 MSLB Offsite Doses (rem):

Pre-accident Iodine spiking case

I-131 equivalent: 21 uCi/cc

	2-hr EAB	30-day LPZ	limit
gamma	2.604E-02	8.739E-03	25
beta	8.313E-03	3.270E-03	300
Inhalation (ICRP-2)	4.482E+00	1.815E+00	300
Inhalation (ICRP-30)	2.282E+00	9.543E-01	300
TEDE	1.680E-01	6.571E-02	25

Accident Initiated Iodine Spiking (500) case

I-131 equivalent: 0.265 uCi/cc

	2-hr EAB	30-day LPZ	limit
gamma	7.075E-02	6.682E-02	2.5
beta	1.784E-02	1.642E-02	30
Inhalation (ICRP-2)	5.168E+00	5.785E+00	30
Inhalation (ICRP-30)	2.197E+00	2.510E+00	30
TEDE	2.376E-01	2.552E-01	2.5

Unit 1 MSLB Control Room Doses (rem) Using ARCON96 X/Q values:

	Pre-accident Iodine Spiking	Accident Initiated Iodine Spiking	limit
Gamma	5.829E-03	8.693E-03	5
Beta	5.218E-02	7.062E-02	30
Thyroid (ICRP-2)	1.923E+01	2.356E+01	30
Thyroid (ICRP-30)	1.058E+01	1.250E+01	30
TEDE	3.699E-01	4.512E-01	5

Discussion and Conclusion

The offsite doses due to a MSLB with preaccident iodine spiking has 10CFR100 limits of 25 rem gamma, 300 rem beta, and 300 rem thyroid. The offsite doses due to a MSLB with accident initiated iodine spike (factor of 500) has limits of 10% of the 10CFR100 limits or 2.5 rem gamma, 30 rem beta, and 30 rem thyroid (ref.10). The control room operator doses limits from 10CFR50 App.A GDC 19 are 5 rem gamma, 30 rem beta, and 30 rem thyroid.

With the Technical Specification limits of 0.265 μCi/gm I-131 equivalent steady state (and 21 μCi/gm maximum), the control room and offsite doses exceed the limits with a 1 gpm leak in the faulted line and 150 gpd in the unfaulted lines. These apply to Unit 2 also.

Unit 1 doses bound the Unit 2 doses, except for the gamma, beta and TEDE offsite doses for the accident initiated iodine spike, and the gamma control room for the accident initiated iodine spike.

Note: these limits are based on a maximum 0.1 μCi/gm I-131 limit in the secondary side and using ARCON96 X/Q values. If the secondary side limit were to be reduced, then the primary to secondary side leakage and the primary side I-131 concentrations can increase.

The Tritium Production Core (TPC) does not affect the limits above, because the limiting doses are the thyroid doses. The tritium affects only the beta dose and TEDE. The TPC obviously bounds the non-TPC configuration.

This calculation is conservative because it models the mass releases as linear within each time interval. This allows larger iodine releases for the accident initiated iodine spiking cases because iodine increases over time in the reactor coolant. In reality, the mass releases are greater at the beginning of the accident, and decrease over time. For the pre-existing iodine spike (which is not the limiting case), this has little effect, since the decay of short lived isotopes is compensated by the buildup of iodine in the unfaulted steam generators due to reactor coolant leakage.

Note on methodologies used:

This calculation determined the doses using 3 different methodologies. The gamma, beta and Thyroid (ICRP-2) doses are all based on TID-14844 methodologies utilizing the ICRP-2 iodine dose conversion factors found in TID-14844. The second methodology uses the ICRP-30 iodine dose conversion factors which are less conservative than the ICRP-2 factors. This methodology is presented for potential future use. Finally, the third methodology used is the TEDE (Total Effective Dose Equivalent). The TEDE presents an overall weighted dose and is more representative of the impact of all isotopes on the body as a whole. It is important to note that tritium does not impact the thyroid doses utilizing the TID-14844 methodology, because only iodine is applied to the thyroid dose. However, in fact tritium does contribute to the thyroid dose, as well as other organs of the body. This is why the TEDE is a more representative dose when discussing the impact of tritium. It is up to the end user to choose the dose which is to be used, with the understanding that each methodology has a different meaning.

References

1. WBN Technical Specification 3.4.16, Amendment 11
2. WBNNAL3-003 R4 "Reactor Coolant Activities in Accordance with ANSI/ANS-18.1-1984"
3. Computer Code STP R7, code I.D. 262165
4. Computer Code FENCDOSE R5,code I.D. 262358
5. Computer Code COROD R7, code I.D. 262347
6. WBNAPS3-053 R2 "Steam Generator Leakage Detection with the Condenser Vacuum Pump Air Exhaust Monitor (1,2-RM-90-119)"
7. WBNAPS3-043 R1 "Shielding Calculation For the Steam Generator Blowdown Demineralizer System" RIMS# B26 900620 200
8. Memorandum from J.W. Irons to W.L. Elliott, WAT-D-9489, "Verification of Data in FSAR Table 15.5-16" RIMS# T33 930927 823
9. WBNTSR-008 R11 "Control Room Operator and Offsite Dose Due to a Steam Generator Tube Rupture"
10. NUREG-0800 R2 section 15.1.5
11. WAT-D-10690, Nov.9, 1999, Memorandum from John W. Irons to J.E. Maddox "SLB Leak Rates" RIMS# B44 991109 002
12. WAT-D-10724, February 10, 2000, Memorandum from John W. Irons to J.E. Maddox "SLB Leak Rates Conversion" RIMS# T71 000217 928
13. N3-15-4002 R5 System Description For "Steam Generator Blowdown System"
14. FSAR Table 11.1-2 (note: this information is used only for comparison with reference 2, and not used as design input).
15. Lederer and Shirley, "Table of Isotopes", seventh ed.
16. N3-62-4001 R5 System Description for "Chemical and Volume Control System"
17. WBNNAL3-002 R2 "100-Day LOCA-DBA Source Terms for the EGTS and ABGTS Filters, Containment, Sump, and Shield Building Annulus" Note: this calculation is currently at R3, however the information is found in R2.
18. WBNAPS3-050 R2 "Determine the Main Control Room Intake Monitor (0-RE-90-125, -126) Setpoints and Post Accident Air Intake Concentrations"
19. WB-DC-40-70 R1 "Accident Analysis Parameter Checklist (AAPC)", Figures 4.3.2-13 and -25
20. WBNAPS3-104 R0 "WBN Control Room X/Q"
21. WBN Technical Specification 3.4.13
22. NSAL-00-004 "Nonconservatisms in Iodine Spiking Calculations"
23. WBN Technical Specification 3.7.14
24. WBN drawing 1-47W866-4 R36
25. WCAP 16286-P "Watts Bar Unit 1 Replacement Steam Generator Program NSSS Engineering Report" January 2005

26a. WBT-D-1202 October 22, 2009 "WBS 5.2.11 Revised Steam Releases for Dose"

26b. LTR-CRA-09-103 Rev.1 "Watts Bar Unit 2 Completion Project – Results of Steam Releases for Dose Calculations"

27. EDCR 54956

Appendix A: Justification for Using ANSI/ANS-18.1-1984 Expected Coolant Spectrum

The choice of iodine spectrum is fairly important, since several isotopes have short halflives. Noble gas spectrum is not at important because the noble gasses contribute only to the gamma and beta doses which are orders of magnitude from the regulatory limits, whereas the limiting doses are thyroid (iodine influenced). Results may be affected when accident times are on the order of the decay of the short lived isotopes. There are several possible spectra available. The spectrum chosen for this analysis is the one that most closely resembles the actual spectrum present at WBN. From the surveillance tests 1-SI-68-28 performed on 7/10/00 and 4/9/01 (see Attachment 1), the following concentrations were determined:

RCS activities 7/10/00				RCS activities 4/9/01			
	µCi/gm RCS Gaseous		µCi/gram RCS Degassed		µCi/gm RCS Gaseous		µCi/gram RCS Degassed
Ar-41	1.303E-02	F-18	1.179E-01	Ar-41	2.696E-03	F-18	1.116E-01
Kr-85M	1.915E-04	Na-24	9.169E-04	Kr-85M	2.013E-04	Na-24	2.060E-03
Kr-87	4.575E-04	Mn-56	9.313E-05	Kr-87	4.809E-04	Mn-56	2.088E-04
Xe-133	9.565E-04	Co-58	5.019E-04	Kr-88	4.982E-04	Co-58	6.218E-04
Xe-135	1.429E-03	Nb-95	3.132E-05	Xe-133	1.202E-03	Co-60	2.776E-05
Xe-135M	7.364E-04	I-131	6.070E-05	Xe-135	1.676E-03	Nb-95	2.794E-05
Xe-138	1.796E-03	I-132	1.459E-03	Xe-135M	1.105E-03	I-131	3.881E-05
		I-133	8.208E-04			I-132	1.165E-03
		I-134	2.694E-03			I-133	6.105E-04
		I-135	1.608E-03			I-134	2.334E-03
		Xe-135	8.914E-05			I-135	1.158E-03
		Xe-135M	1.406E-02			Xe-135	1.380E-04
		Cs-138	2.395E-03			Xe-135M	1.972E-02
						Cs-138	2.195E-03

Two potential spectra are from WBNNAL3-003 (Reactor Coolant Activities in Accordance with ANSI/ANS-18.1-1984) and from the FSAR Table 11.1-2 (Historical Design Activities). The iodine concentrations and relative concentrations for each spectrum are as follows:

	7/10/00 WBN actual µCi/gm	7/10/00 WBN actual relative fraction	4/9/01 WBN actual µCi/gm	4/9/01 WBN actual relative fraction
I-131	6.070E-05	0.0091	3.881E-05	0.0073
I-132	1.459E-03	0.2196	1.165E-03	0.2195
I-133	8.208E-04	0.1236	6.105E-04	0.1151
I-134	2.694E-03	0.4056	2.334E-03	0.4399
I-135	1.608E-03	0.2421	1.158E-03	0.2182
sum:	6.643E-03		5.306E-03	

	ANS 18.1 µCi/gm	ANS 18.1 relative fraction	FSAR 11.1-2 µCi/gm	FSAR 11.1-2 relative fraction
I-131	0.0477	0.0448	2.5	0.2461
I-132	0.225	0.2115	0.9	0.0886
I-133	0.149	0.1401	4	0.3937
I-134	0.364	0.3422	0.56	0.0551
I-135	0.278	0.2614	2.2	0.2165
sum:	1.0637		10.16	

As can be seen, the FSAR historical design concentrations do not reflect the actual measured concentrations. The FSAR values are weighted too strongly in favor of I-131 (24.6% of total as opposed to < 1% of the actual total). By comparison, the ANSI/ANS-18.1-1984 fractions are very close to the actual fractions. The worst fit was for I-134 which was 40.1% actual versus ANSI/ANS-18.1-1984 34.22%. The I-131 is slightly over predicted by ANS-18.1 (0.9% on 7/10/00 and 0.7% on 4/9/01 versus 4.48%), however this difference is not as large compared to the FSAR fraction. The ANSI/ANS-18.1-1984 spectrum overall fit is much better than the FSAR spectrum, therefore it can be concluded that the use of the ANSI/ANS-18.1-1984 spectrum is acceptable.

Appendix B: Determination of Letdown Flow Rate Uncertainty

The purpose of this appendix is to determine bounding errors for the measurements performed on the orifice restrictor flows using the Letdown Heat Exchanger Flow loop (1-F-62-82) during Preop Test Instruction PTI-062-03 R0.

Following these tests, a loop check was performed for the computer point F0134A by injecting a signal into the transmitter and reading the display on the computer. To determine the total loop error, the unmeasurable errors must be combined with the errors present at the time of the loop check.

WBN NESSD 1-F-62-1 will be used as a guide for determining the unmeasurable errors for loop 1-F-62-82 since it contains the same model flow element and a similar model transmitter. According to EMPAC, the flow element is a Vickery Simms Model MK-52 and the transmitter is a Foxboro E-13DM.

Millers Flow Measurement Engineering Handbook, Third Edition, Chapter 6, Table 6.1 states that Square Edged orifice flowmeters have an accuracy of ±1-2%URV (upper range value) of the flow rate. A value of ±2% will be used for the orifice.

The loop check performed by WO 94-14264-10 (following pages) gives as found data. The largest error at 50 GPM was 1.36 GPM (50 - 48.64) or 0.68% CS (1.36/200 = 0.68%). The largest error at 100 GPM was 0.48 GPM (100 - 99.52) or 0.24% CS (0.48/200 = 0.24%). The largest error at 150 GPM was 0.06 GPM (150 - 149.94) or 0.03% CS (0.06/200 = 0.03%).

Since the plant had not been started at the time of these tests, radiation was not present and need not be considered. Errors for temperature and power supply effect will need to be included. Since there is no data on actual temperature conditions, an enveloping value must be used. Environmental drawing 47E235-46 R5 gives the max abnormal temperature range as 50 - 110 °F for coordinates UA6 / El 737 where the transmitter is located per EMPAC. The transmitter is a model E-13DM per EMPAC. The product specification sheets (following pages) give the ambient temperature effect as ±1% per 50 °F for any span between 200 to 850" water. The transmitter will normally be calibrated at room temperature which will be between 60 and 80 °F. A temperature shift of + or - 50 °F will encompass the temperature changes seen by the transmitter. Therefore for a temperature range of ±50 °F, the temperature effect will be ±1% CS d/p. The power supply effect is given as 0.1% CS for a 10% change in voltage. Thus Power supply effect is 0.1% CS d/p.

All errors for the computer should be reflected in the loop check.

Utilizing Equation 3-24.8 of W WCAP-12096, Rev. 8 "Westinghouse Setpoint Methodology for Protection Systems, Watts Bar Units 1 and 2, Eagle 21 Version," the unmeasured transmitter errors can be converted from percent error in full scale d/p to error in percent full span at a specified point, where Fm is the maximum flow rate of 200 GPM, and Fn is the nominal flow rate (i.e. 50, 100 or 150 GPM).

EPFS (Flow) = $(Ax_{XX} / 2) * (Fm / Fn)$
$Temp_{err}$(Flow)@50GPM = $(Temp_{err}$ (d/p) / 2) * (200 / 50) = ± 2% CS Flow
$Temp_{err}$(Flow)@100GPM = $(Temp_{err}$ (d/p) / 2) * (200 / 100) = ± 1% CS Flow
$Temp_{err}$(Flow)@150GPM = $(Temp_{err}$ (d/p) / 2) * (200 / 150) = ± 0.67% CS Flow

pwr $supp_{err}$(Flow)@50GPM = (pwr $supp_{err}$ (d/p) / 2) * (200 / 50) = ± 0.2% CS Flow
pwr $supp_{err}$(Flow)@100GPM = (pwr $supp_{err}$ (d/p) / 2) * (200 / 100) = ± 0.1% CS Flow
pwr $supp_{err}$(Flow)@150GPM = (pwr $supp_{err}$ (d/p) / 2) * (200 / 150) = ± 0.067% CS Flow

Thus total loop error = $(FE_{err}^2 + \text{Loop check}_{err}^{\ 2} + Temp_{err}\,(\text{Flow})^2 + \text{pwr } supp_{err}\,(\text{Flow})^2)^{0.5}$
Total loop error @ 50 GPM = $(2^2 + 0.68^2 + 2^2 + 0.2^2)^{0.5} = \pm 2.92\%$ CS = ±5.84 GPM
Total loop error @ 100 GPM = $(2^2 + 0.24^2 + 1^2 + 0.1^2)^{0.5} = \pm 2.25\%$ CS = ±4.5 GPM
Total loop error @ 150 GPM = $(2^2 + 0.03^2 + 0.67^2 + 0.067^2)^{0.5} = \pm 2.11\%$ CS = ±4.22 GPM

Total loop error at 120 GPM can be determined by linear interpolation between 100 and 150 GPM. The value will be conservative since the error is nonlinear and is a function of the square root of the d/p values above and the actual loop recorded values which also follow a square root curve.

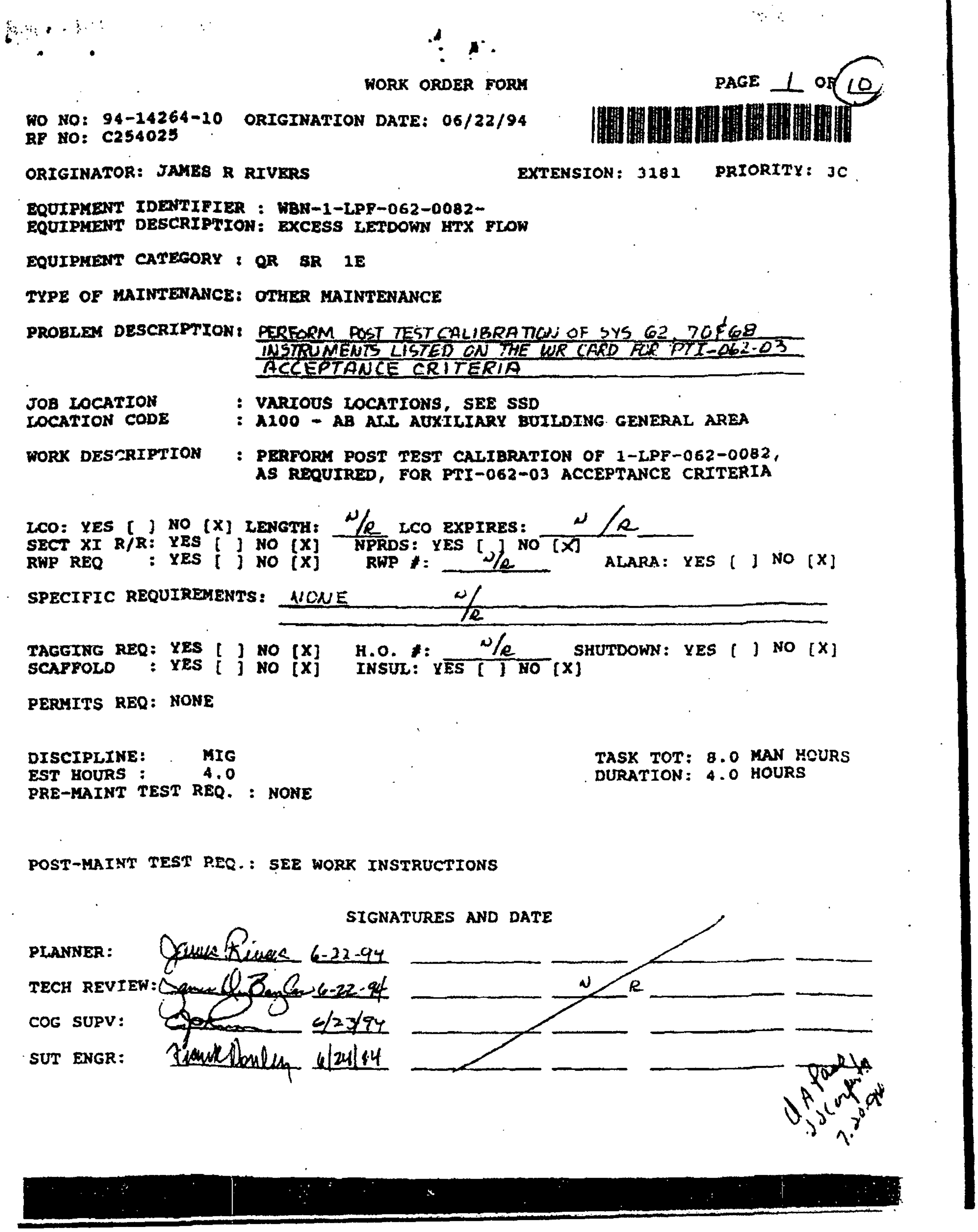
Total loop error @ 120 GPM = ±| error @ 100 GPM + 20(error @ 150 GPM - error @ 100 GPM) / (150 - 100) |
Total loop error @ 120 GPM = ±[4.5 GPM + 20(4.22 - 4.5)/50] = ±[4.5 GPM + (-0.11)] = ±4.39 GPM

The following references were used in preparation of this appendix. Revisions to these references will not impact this appendix; so the references are 'information only' in lieu of 'design input'.

1 WBN NESSD 1-F-62-1 R1 (Methodology & guidance)
2 EMPAC (Manufacturer, Model number and location)
3 Millers Flow Engineering Handbook, Third Edition, Chapter 6, Table 6.1 (Orifice accuracy)
4 WO 94-14264-10 (loop check data) - see next page
5 Drawing 47E235-46 R5 (environmental data)
6 Foxboro product specification sheets (transmitter accuracy data) - see next pages
7 WCAP-12096 R 8 (methodology for converting d/p error to flow error)

Prepared Lynn Cowan Date 6/4/01
Checked ____________ Date ______.

Supporting documents for Appendix B:



WORK ORDER FORM PAGE 1 OF 10

WO NO: 94-14264-10 ORIGINATION DATE: 06/22/94
RF NO: C254025

ORIGINATOR: JAMES R RIVERS EXTENSION: 3181 PRIORITY: 3C

EQUIPMENT IDENTIFIER : WBN-1-LPF-062-0082-
EQUIPMENT DESCRIPTION: EXCESS LETDOWN HTX FLOW

EQUIPMENT CATEGORY : QR SR 1E

TYPE OF MAINTENANCE: OTHER MAINTENANCE

PROBLEM DESCRIPTION: PERFORM POST TEST CALIBRATION OF SYS 62, 70 & 68 INSTRUMENTS LISTED ON THE WR CARD FOR PTI-062-03 ACCEPTANCE CRITERIA

JOB LOCATION : VARIOUS LOCATIONS, SEE SSD
LOCATION CODE : A100 - AB ALL AUXILIARY BUILDING GENERAL AREA

WORK DESCRIPTION : PERFORM POST TEST CALIBRATION OF 1-LPF-062-0082, AS REQUIRED, FOR PTI-062-03 ACCEPTANCE CRITERIA

LCO: YES [ ] NO [X] LENGTH: N/R LCO EXPIRES: N/R
SECT XI R/R: YES [ ] NO [X] NPRDS: YES [ ] NO [X]
RWP REQ : YES [ ] NO [X] RWP #: N/R ALARA: YES [ ] NO [X]

SPECIFIC REQUIREMENTS: NONE N/R

TAGGING REQ: YES [ ] NO [X] H.O. #: N/R SHUTDOWN: YES [ ] NO [X]
SCAFFOLD : YES [ ] NO [X] INSUL: YES [ ] NO [X]

PERMITS REQ: NONE

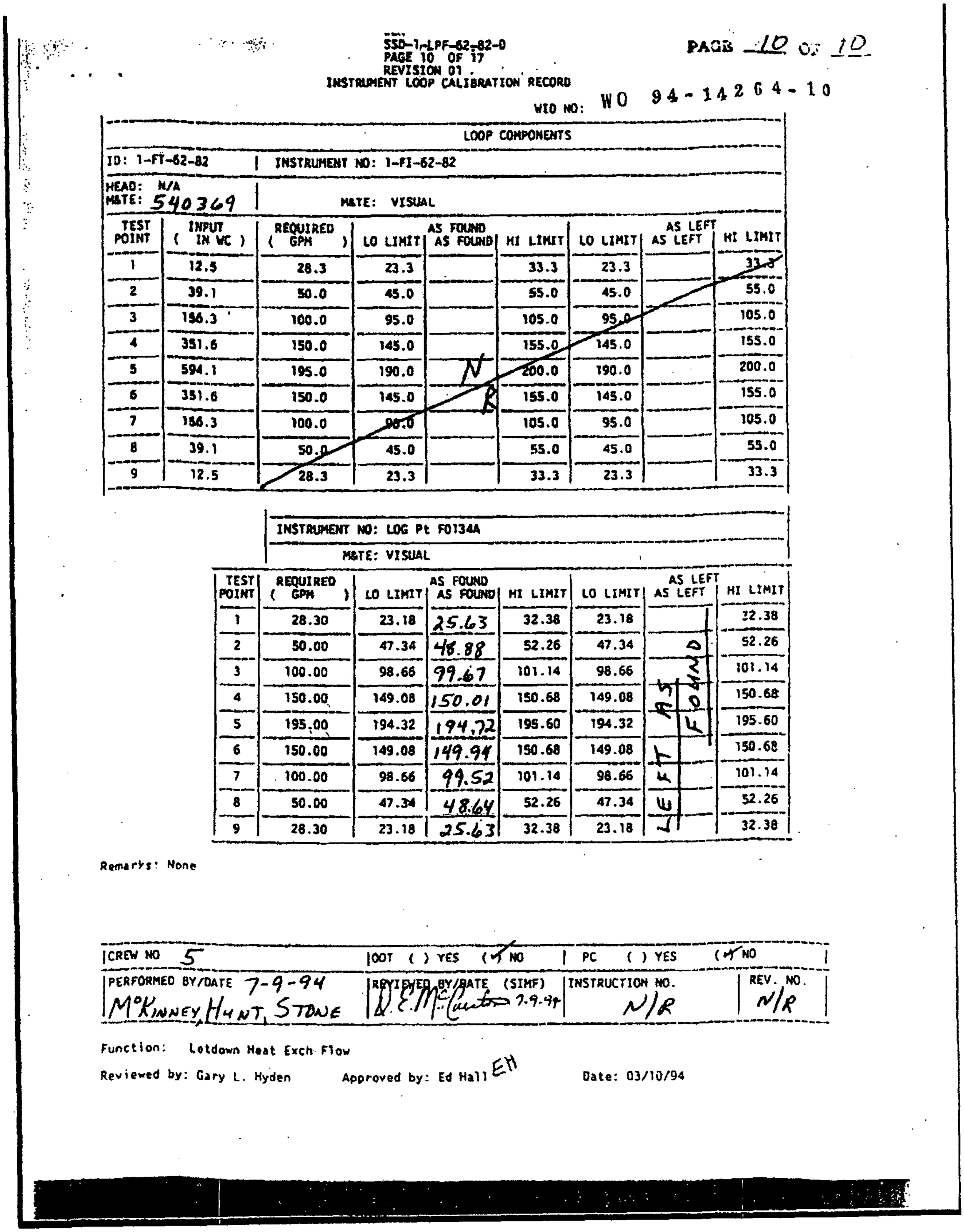
DISCIPLINE: MIG TASK TOT: 8.0 MAN HOURS
EST HOURS : 4.0 DURATION: 4.0 HOURS
PRE-MAINT TEST REQ. : NONE

POST-MAINT TEST REQ.: SEE WORK INSTRUCTIONS

SIGNATURES AND DATE

PLANNER:	James Rivers 6-22-94				
TECH REVIEW:	6-22-94		N/R		
COG SUPV:	6/23/94				
SUT ENGR:	Frank Donley 6/24/94				

[illegible] SS [illegible] 7.20.94



SSD-1-LPF-62-82-0
PAGE 10 OF 17
REVISION 01
INSTRUMENT LOOP CALIBRATION RECORD

PAGE 10 OF 10

WIO NO: WO 94-14264-10

LOOP COMPONENTS

ID: 1-FT-62-82	INSTRUMENT NO: 1-FI-62-82
HEAD: N/A M&TE: 540369	M&TE: VISUAL

TEST POINT	INPUT (IN WC)	REQUIRED (GPM)	AS FOUND LO LIMIT	AS FOUND AS FOUND	AS FOUND HI LIMIT	AS LEFT LO LIMIT	AS LEFT AS LEFT	AS LEFT HI LIMIT
1	12.5	28.3	23.3		33.3	23.3		33.3
2	39.1	50.0	45.0		55.0	45.0		55.0
3	156.3	100.0	95.0		105.0	95.0		105.0
4	351.6	150.0	145.0		155.0	145.0		155.0
5	594.1	195.0	190.0	N	200.0	190.0		200.0
6	351.6	150.0	145.0	R	155.0	145.0		155.0
7	156.3	100.0	95.0		105.0	95.0		105.0
8	39.1	50.0	45.0		55.0	45.0		55.0
9	12.5	28.3	23.3		33.3	23.3		33.3

INSTRUMENT NO: LOG Pt F0134A

M&TE: VISUAL

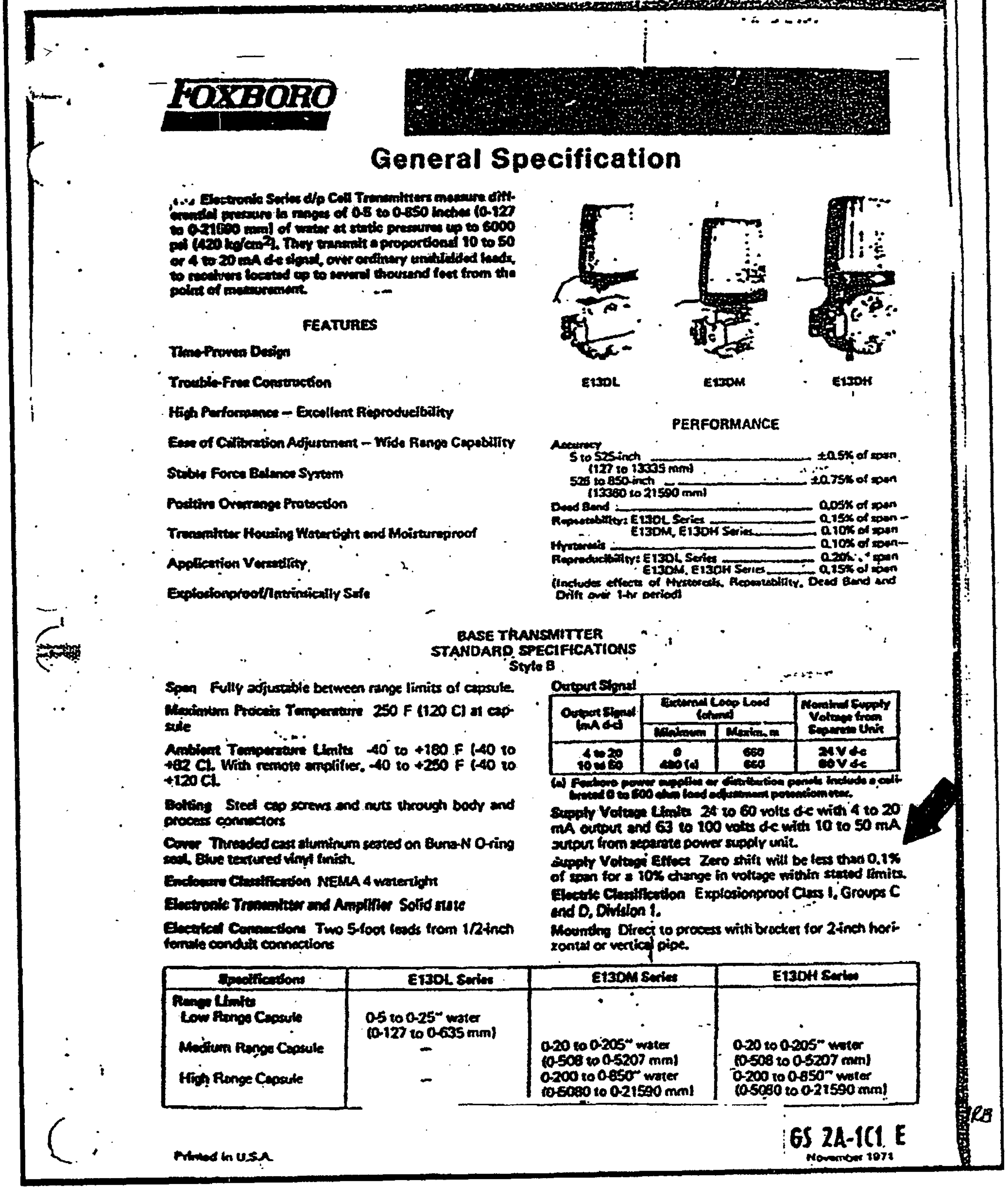
TEST POINT	REQUIRED (GPM)	AS FOUND LO LIMIT	AS FOUND AS FOUND	AS FOUND HI LIMIT	AS LEFT LO LIMIT	AS LEFT AS LEFT	AS LEFT HI LIMIT
1	28.30	23.18	25.63	32.38	23.18	LEFT AS FOUND	32.38
2	50.00	47.34	48.88	52.26	47.34		52.26
3	100.00	98.66	99.67	101.14	98.66		101.14
4	150.00	149.08	150.01	150.68	149.08		150.68
5	195.00	194.32	194.72	195.60	194.32		195.60
6	150.00	149.08	149.94	150.68	149.08		150.68
7	100.00	98.66	99.52	101.14	98.66		101.14
8	50.00	47.34	48.64	52.26	47.34		52.26
9	28.30	23.18	25.63	32.38	23.18		32.38

Remarks: None

CREW NO 5	OOT ( ) YES [✓ NO]	PC ( ) YES [✓ NO]	
PERFORMED BY/DATE 7-9-94 McKinney, Hunt, Stone	REVIEWED BY/DATE (SIMF) D.E. McClanton 7-9-94	INSTRUCTION NO. N/R	REV. NO. N/R

Function: Letdown Heat Exch Flow

Reviewed by: Gary L. Hyden Approved by: Ed Hall EH Date: 03/10/94



FOXBORO

General Specification

... Electronic Series d/p Cell Transmitters measure differential pressure in ranges of 0-5 to 0-850 inches (0-127 to 0-21590 mm) of water at static pressures up to 6000 psi (420 kg/cm²). They transmit a proportional 10 to 50 or 4 to 20 mA d-c signal, over ordinary unshielded leads, to receivers located up to several thousand feet from the point of measurement.

FEATURES

Time-Proven Design

Trouble-Free Construction

High Performance — Excellent Reproducibility

Ease of Calibration Adjustment — Wide Range Capability

Stable Force Balance System

Positive Overrange Protection

Transmitter Housing Watertight and Moistureproof

Application Versatility

Explosionproof/Intrinsically Safe

E13DL E13DM E13DH

PERFORMANCE

Accuracy	
5 to 525-inch (127 to 13335 mm)	±0.5% of span
526 to 850-inch (13360 to 21590 mm)	±0.75% of span
Dead Band	0.05% of span
Repeatability: E13DL Series	0.15% of span
E13DM, E13DH Series	0.10% of span
Hysteresis	0.10% of span
Reproducibility: E13DL Series	0.20% of span
E13DM, E13DH Series	0.15% of span

(Includes effects of Hysteresis, Repeatability, Dead Band and Drift over 1-hr period)

BASE TRANSMITTER STANDARD SPECIFICATIONS
Style B

Span Fully adjustable between range limits of capsule.

Maximum Process Temperature 250 F (120 C) at capsule

Ambient Temperature Limits -40 to +180 F (-40 to +82 C). With remote amplifier, -40 to +250 F (-40 to +120 C).

Bolting Steel cap screws and nuts through body and process connectors

Cover Threaded cast aluminum seated on Buna-N O-ring seal. Blue textured vinyl finish.

Enclosure Classification NEMA 4 watertight

Electronic Transmitter and Amplifier Solid state

Electrical Connections Two 5-foot leads from 1/2-inch female conduit connections

Output Signal

Output Signal (mA d-c)	External Loop Load (ohms)		Nominal Supply Voltage from Separate Unit
	Minimum	Maximum	
4 to 20	0	660	24 V d-c
10 to 50	480 (a)	650	80 V d-c

(a) Foxboro power supplies or distribution panels include a calibrated 0 to 600 ohm load adjustment potentiometer.

Supply Voltage Limits 24 to 60 volts d-c with 4 to 20 mA output and 63 to 100 volts d-c with 10 to 50 mA output from separate power supply unit.

Supply Voltage Effect Zero shift will be less than 0.1% of span for a 10% change in voltage within stated limits.

Electric Classification Explosionproof Class I, Groups C and D, Division 1.

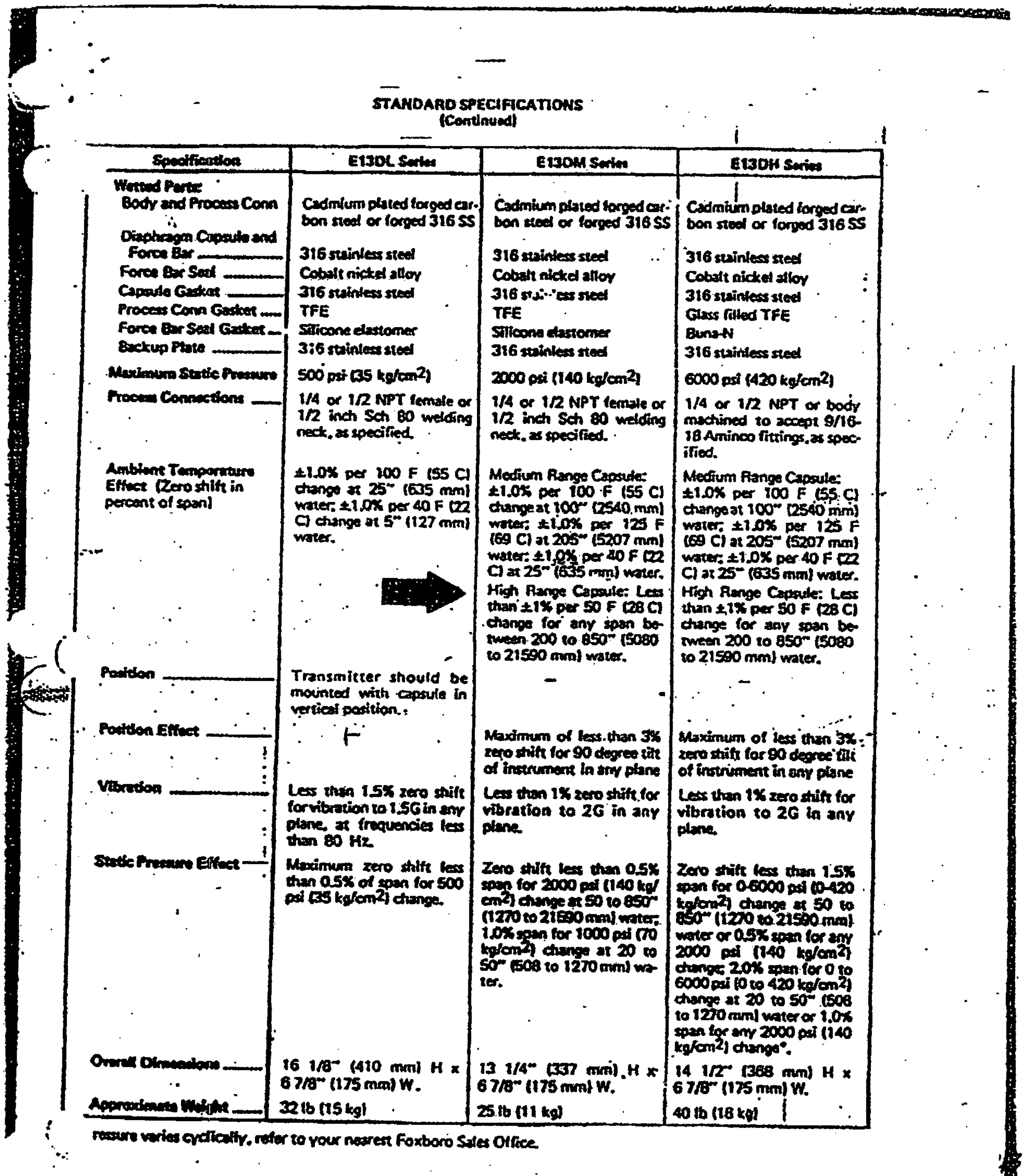
Mounting Direct to process with bracket for 2-inch horizontal or vertical pipe.

Specifications	E13DL Series	E13DM Series	E13DH Series
Range Limits			
Low Range Capsule	0-5 to 0-25" water (0-127 to 0-635 mm)		
Medium Range Capsule	—	0-20 to 0-205" water (0-508 to 0-5207 mm)	0-20 to 0-205" water (0-508 to 0-5207 mm)
High Range Capsule	—	0-200 to 0-850" water (0-5080 to 0-21590 mm)	0-200 to 0-850" water (0-5080 to 0-21590 mm)

RB

Printed in U.S.A.

GS 2A-1C1 E
November 1971



STANDARD SPECIFICATIONS
(Continued)

Specification	E13DL Series	E13DM Series	E13DH Series
Wetted Parts:			
Body and Process Conn	Cadmium plated forged carbon steel or forged 316 SS	Cadmium plated forged carbon steel or forged 316 SS	Cadmium plated forged carbon steel or forged 316 SS
Diaphragm Capsule and Force Bar	316 stainless steel	316 stainless steel	316 stainless steel
Force Bar Seal	Cobalt nickel alloy	Cobalt nickel alloy	Cobalt nickel alloy
Capsule Gasket	316 stainless steel	316 stainless steel	316 stainless steel
Process Conn Gasket	TFE	TFE	Glass filled TFE
Force Bar Seal Gasket	Silicone elastomer	Silicone elastomer	Buna-N
Backup Plate	316 stainless steel	316 stainless steel	316 stainless steel
Maximum Static Pressure	500 psi (35 kg/cm2)	2000 psi (140 kg/cm2)	6000 psi (420 kg/cm2)
Process Connections	1/4 or 1/2 NPT female or 1/2 inch Sch 80 welding neck, as specified.	1/4 or 1/2 NPT female or 1/2 inch Sch 80 welding neck, as specified.	1/4 or 1/2 NPT or body machined to accept 9/16-18 Aminco fittings, as specified.
Ambient Temperature Effect (Zero shift in percent of span)	±1.0% per 100 F (55 C) change at 25" (635 mm) water; ±1.0% per 40 F (22 C) change at 5" (127 mm) water.	Medium Range Capsule: ±1.0% per 100 F (55 C) change at 100" (2540 mm) water; ±1.0% per 125 F (69 C) at 205" (5207 mm) water; ±1.0% per 40 F (22 C) at 25" (635 mm) water. High Range Capsule: Less than ±1% per 50 F (28 C) change for any span between 200 to 850" (5080 to 21590 mm) water.	Medium Range Capsule: ±1.0% per 100 F (55 C) change at 100" (2540 mm) water; ±1.0% per 125 F (69 C) at 205" (5207 mm) water; ±1.0% per 40 F (22 C) at 25" (635 mm) water. High Range Capsule: Less than ±1% per 50 F (28 C) change for any span between 200 to 850" (5080 to 21590 mm) water.
Position	Transmitter should be mounted with capsule in vertical position.	—	—
Position Effect		Maximum of less than 3% zero shift for 90 degree tilt of instrument in any plane	Maximum of less than 3% zero shift for 90 degree tilt of instrument in any plane
Vibration	Less than 1.5% zero shift for vibration to 1.5G in any plane, at frequencies less than 80 Hz.	Less than 1% zero shift for vibration to 2G in any plane.	Less than 1% zero shift for vibration to 2G in any plane.
Static Pressure Effect	Maximum zero shift less than 0.5% of span for 500 psi (35 kg/cm2) change.	Zero shift less than 0.5% span for 2000 psi (140 kg/cm2) change at 50 to 850" (1270 to 21590 mm) water; 1.0% span for 1000 psi (70 kg/cm2) change at 20 to 50" (508 to 1270 mm) water.	Zero shift less than 1.5% span for 0-6000 psi (0-420 kg/cm2) change at 50 to 850" (1270 to 21590 mm) water or 0.5% span for any 2000 psi (140 kg/cm2) change; 2.0% span for 0 to 6000 psi (0 to 420 kg/cm2) change at 20 to 50" (508 to 1270 mm) water or 1.0% span for any 2000 psi (140 kg/cm2) change*.
Overall Dimensions	16 1/8" (410 mm) H x 6 7/8" (175 mm) W.	13 1/4" (337 mm) H x 6 7/8" (175 mm) W.	14 1/2" (368 mm) H x 6 7/8" (175 mm) W.
Approximate Weight	32 lb (15 kg)	25 lb (11 kg)	40 lb (18 kg)

ressure varies cyclically, refer to your nearest Foxboro Sales Office.

oS 2A-1C1 E

Appendix C: Example of Pre-Accident Iodine Spike STP Model

```
//APS77S9A JOB 264318,9MBERG.LP4T-C,MSGLEVEL=1,MSGCLASS=T
//*MAIN ORG=KNXLCL01,CLASS=LB
//JCL JCLLIB ORDER=(APB.NEN.PS264460.PROCLIB)
//    EXEC STP,SOUT='*'
//GO.FT07F001 DD DSN=$KBI988.APS77S9A.OUT,UNIT=ALLOC,
//    DCB=(RECFM=FB,LRECL=80,BLKSIZE=6160),SPACE=(TRK,(5,2),RLSE),
//    DISP=(NEW,CATLG,DELETE)
//GO.FT01F001 DD *
NV= 4  MS= 2
//GO.FT11F001 DD *
$     CLASS         DESCRIPTION
$       1               NOBLE GASES
$       2               IODINE
$       3               TRITIUM
NI= 23  NK= 7  NG= 0  NL= 3
   1KRM  83 1 1,0352E-04   10.0          10.0          10.0
   2KRM  85 1 4,2978E-05   10.0          10.0          10.0
   3KR   85 1 2,0470E-09   29.8849E-06   10.0          10.0
   4KR   87 1 1,5141E-04   10.0          10.0          10.0
   5KR   88 1 6,8765E-05   10.0          10.0          10.0
   6KR   89 1 3,6328E-03   10.0          10.0          10.0
   7XEM 131 1 6,7414E-07  131.3039E-08  181.3039E-08   10.0
   8XEM 133 1 3,5656E-06  152.0365E-07  202.0365E-07   10.0
   9XE  133 1 1,5165E-06   83.5656E-06  159.0531E-06  209.0531E-06
  10XEM 135 1 7,3818E-04  174.8062E-06  224.8062E-06   10.0
  11XE  135 1 2,1043E-05  107.3818E-04  172.4322E-05  222.4322E-05
  12XE  138 1 8,1528E-04   10.0          10.0          10.0
  13I   131 2 9,9536E-07   10.0          10.0          10.0
  14I   132 3 8,4448E-05   10.0          10.0          10.0
  15I   133 4 9,2568E-06   10.0          10.0          10.0
  16I   134 5 2,1963E-04   10.0          10.0          10.0
  17I   135 6 2,9129E-05   10.0          10.0          10.0
  18I*  131 2 9,9536E-07   10.0          10.0          10.0
  19I*  132 3 8,4448E-05   10.0          10.0          10.0
  20I*  133 4 9,2568E-06   10.0          10.0          10.0
  21I*  134 5 2,1963E-04   10.0          10.0          10.0
  22I*  135 6 2,9129E-05   10.0          10.0          10.0
  23H     3 7 1,7785E-09   10.0000E+00   10.0000E+00   10.0000E+00
//GO.SYSIN3 DD *
1  'REACTOR COOLANT ANS/ANSI-18.1-1984 UCI/GM, WBNAPS3-003 R3'
 1 0.0 2 1.71E-1 3 2.66E-1 4 1.61E-1 5 3.00E-1 6 0.0
 7 6.54E-1 8 7.17E-2 9 2.53E0  10 1.39E-1 11 9.04E-1 12 1.29E-1
 13 4.77E-2 14 2.25E-1 15 1.49E-1 16 3.64E-1 17 2.78E-1
 18 0.0  19 0.0  20 0.0  21 0.0  22 0.0  23 9.84E1
0
2  'SECONDARY COOL  ANS/ANSI-18.1-1984 UCI/GM, WBNAPS3-003 R3'
 1 0.0 2 3.63E-8 3 5.51E-8 4 3.22E-8 5 6.31E-8 6 0.0
 7 1.34E-7 8 1.54E-8 9 5.25E-7 10 2.90E-8 11 1.91E-7 12 2.68E-8
 13 1.41E-6 14 3.37E-6 15 4.03E-6 16 2.93E-6 17 6.19E-6
 18 0.0  19 0.0  20 0.0  21 0.0  22 0.0  23 9.84E-2
0
T
WBN MSLB, 21 UCI/CC INITIAL CONC, 10+1GPM LK SS,1.0 GPM LEAK IN SG
NJ= 4  KCONC= 1
1 'REACTOR COOLANT'
2 'STEAM GENERATOR W/LEAK'
3 'STEAM GENERATORS/NO LEAK'
4 'ENVIRONMENT'
-1
INITIALIZATION
V 1 2.622E8 GM
V 2 5.31E7 GM
V 3 1.593E8 GM
V 4 1.0 GM
S 1 1 0 4.386E4
S 1 1 1 7.6195E3
S 2 3 0 4.996E6
S 1 1 7 2.622E2
S 2 3 7 1.593E2
S 2 4 1 1.667E6 2 4 2 1.667E6 2 4 3 1.667E6
S 2 4 4 1.667E6 2 4 5 1.667E6 2 4 6 1.667E6
S 2 4 7 5.316E1
A 4
```

```
F 1 3 0 7.098E4 GM/HR
F 3 4 0 1.0026E6 GM/HR
F 3 4 1 1.0026E8 GM/HR
F 3 4 7 1.0026E8 GM/HR
F 1 4 0 2.271E5 GM/HR
20.6 SEC
TIME TO 20.6 SEC
N 4 0
P 1 0 4
2.0 HR
TIME TO 2.0 HR
N 4 0
P 1 0 4
8.0 HR
TIME TO 8.0 HR
F 3 4 0 6.977E5 GM/HR
F 3 4 1 6.977E7 GM/HR
F 3 4 7 6.977E7 GM/HR
P 1 0 4
T
T
/*
//
```

Appendix D: Example of Accident Initiated Iodine Spike (factor of 500 increase) STP Model

```
//APS77S9B JOB 264318,9MBERG.LP4T-C,MSGLEVEL=1,MSGCLASS=T
//*MAIN ORG=KNXLCL01,CLASS=LB
//JCL JCLLIB ORDER=(APB.NEN.PS264460.PROCLIB)
//    EXEC STP,SOUT='*'
//GO.FT07F001 DD DSN=$KBI988.APS77S9B.OUT,UNIT=ALLOC,
//    DCB=(RECFM=FB,LRECL=80,BLKSIZE=6160),SPACE=(TRK,(5,2),RLSE),
//    DISP=(NEW,CATLG,DELETE)
//GO.FT01F001 DD *
NV= 4  MS= 2
//GO.FT11F001 DD *
$     CLASS         DESCRIPTION
$       1                NOBLE GASES
$       2                IODINE
$       3                TRITIUM
NI= 23  NK= 7  NG= 0  NL= 3
   1KRM  83 1 1.0352E-04   10.0           10.0           10.0
   2KRM  85 1 4.2978E-05   10.0           10.0           10.0
   3KR   85 1 2.0470E-09   29.8849E-06    10.0           10.0
   4KR   87 1 1.5141E-04   10.0           10.0           10.0
   5KR   88 1 6.8765E-05   10.0           10.0           10.0
   6KR   89 1 3.6328E-03   10.0           10.0           10.0
   7XEM 131 1 6.7414E-07  131.3039E-08  181.3039E-08   10.0
   8XEM 133 1 3.5656E-06  152.0365E-07  202.0365E-07   10.0
   9XE  133 1 1.5165E-06   83.5656E-06  159.0531E-06  209.0531E-06
  10XEM 135 1 7.3818E-04  174.8062E-06  224.8062E-06   10.0
  11XE  135 1 2.1043E-05  107.3818E-04  172.4322E-05  222.4322E-05
  12XE  138 1 8.1528E-04   10.0           10.0           10.0
  13I   131 2 9.9536E-07   10.0           10.0           10.0
  14I   132 3 8.4448E-05   10.0           10.0           10.0
  15I   133 4 9.2568E-06   10.0           10.0           10.0
  16I   134 5 2.1963E-04   10.0           10.0           10.0
  17I   135 6 2.9129E-05   10.0           10.0           10.0
  18I*  131 2 9.9536E-07   10.0           10.0           10.0
  19I*  132 3 8.4448E-05   10.0           10.0           10.0
  20I*  133 4 9.2568E-06   10.0           10.0           10.0
  21I*  134 5 2.1963E-04   10.0           10.0           10.0
  22I*  135 6 2.9129E-05   10.0           10.0           10.0
  23H     3 7 1.7785E-09   10.0000E+00    10.0000E+00    10.0000E+00
//GO.SYSIN3 DD *
1  'REACTOR COOLANT ANS/ANSI-18.1-1984 UCI/GM, WBNAPS3-003 R3'
 1 0.0 2 1.71E-1 3 2.66E-1 4 1.61E-1 5 3.00E-1 6 0.0
 7 6.54E-1 8 7.17E-2 9 2.53E0  10 1.39E-1 11 9.04E-1 12 1.29E-1
 13 4.77E-2 14 2.25E-1 15 1.49E-1 16 3.64E-1 17 2.78E-1
 18 0.0  19 0.0  20 0.0  21 0.0  22 0.0  23 9.84E1
0
2  'SECONDARY COOL  ANS/ANSI-18.1-1984 UCI/GM, WBNAPS3-003 R3'
 1 0.0 2 3.63E-8 3 5.51E-8 4 3.22E-8 5 6.31E-8 6 0.0
 7 1.34E-7 8 1.54E-8 9 5.25E-7 10 2.90E-8 11 1.91E-7 12 2.68E-8
 13 1.41E-6 14 3.37E-6 15 4.03E-6 16 2.93E-6 17 6.19E-6
 18 0.0  19 0.0  20 0.0  21 0.0  22 0.0  23 9.84E-2
0
T
WBN MSLB,.265 UCI/CC INIT CONC,10+1GPM LK,500 IODINE SPIKE,1.0 GPM SG LK
NJ= 4  KCONC= 1
1 'REACTOR COOLANT'
2 'STEAM GENERATOR W/LEAK'
3 'STEAM GENERATORS/NO LEAK'
4 'ENVIRONMENT'
-1
INITIALIZATION
V 1 2.622E8 GM
V 2 5.31E7 GM
V 3 1.593E8 GM
V 4 1.0 GM
S 1 1 0 5.534E2
S 1 1 1 7.6195E3
S 2 3 0 4.996E6
S 1 1 7 2.622E2
S 2 3 7 1.593E2
S 2 4 1 1.667E6 2 4 2 1.667E6 2 4 3 1.667E6
S 2 4 4 1.667E6 2 4 5 1.667E6 2 4 6 1.667E6
S 2 4 7 5.316E1
C 1 1 2 3.345E4
```

```
C 1 1 3 1.166E5
C 1 1 4 4.163E4
C 1 1 5 2.512E5
C 1 1 6 6.147E4
A 4
F 1 3 0 7.098E4 GM/HR
F 3 4 0 1.0026E6 GM/HR
F 3 4 1 1.0026E8 GM/HR
F 3 4 7 1.0026E8 GM/HR
F 1 4 0 2.271E5 GM/HR
20.6 SEC
TIME TO 20.6 SEC
N 4 0
P 1 0 4
2.0 HR
TIME TO 2.0 HR
N 4 0
P 1 0 4
8.0 HR
TIME TO 8.0 HR
F 3 4 0 6.977E5 GM/HR
F 3 4 1 6.977E7 GM/HR
F 3 4 7 6.977E7 GM/HR
P 1 0 4
T
T
/*
//
```

Appendix E: Example of COROD Input (ARCON96 X/Q)

```
//APS77C9A JOB 264318,9MBERG.LP4T-C,MSGLEVEL=1,MSGCLASS=T
//*MAIN ORG=KNXLCL01,CLASS=SB
//JCL JCLLIB ORDER=(APB.NEN.EX262358.PROCLIB)
//STEP1 EXEC CORODV6,COND=(4,LT)
//COROD1.FT05F001 DD *
NIT= 23   NR= 1   ITP= 6   FACT= 1.0
COROD-WBN MSLB                                                        S
KRM 83  KRM 85  KR 85  KR 87  KR 88  KR 89
XEM 131  XEM 133  XE 133  XEM 135  XE 135  XE 138
I 131  I 132  I 133  I 134  I 135
I* 131  I* 132  I* 133  I* 134  I* 135  H 3
   4  'ENVIRONMENT                ' $ TN=  0.5722E-02
      1 0.0          2 6.762E-02    3 1.029E-01    4 6.033E-02    5 1.176E-01
      6 0.0          7 2.505E-01    8 2.866E-02    9 9.802E-01   10 5.429E-02
     11 3.560E-01   12 4.999E-02   13 2.361E+00   14 5.667E+00   15 6.751E+00
     16 4.964E+00   17 1.038E+01   18 0.0         19 0.0         20 0.0
     21 0.0         22 0.0         23 5.415E+00
   4  'ENVIRONMENT                ' $ TN=  0.2000E+01
      1 0.0          2 2.298E+00    3 4.166E+00    4 1.513E+00    5 3.687E+00
      6 0.0          7 1.021E+01    8 1.119E+00    9 3.957E+01   10 7.468E+00
     11 1.647E+01   12 3.232E-01   13 3.691E+00   14 1.293E+01   15 1.117E+01
     16 1.391E+01   17 1.936E+01   18 0.0         19 0.0         20 0.0
     21 0.0         22 0.0         23 6.170E+01
   4  'ENVIRONMENT                ' $ TN=  0.8000E+01
      1 0.0          2 4.043E+00    3 1.324E+01    4 7.744E-01    5 4.691E+00
      6 0.0          7 3.216E+01    8 3.429E+00    9 1.242E+02   10 1.706E+01
     11 5.754E+01   12 9.744E-04   13 1.087E+01   14 1.296E+01   15 2.926E+01
     16 3.585E+00   17 3.865E+01   18 0.0         19 0.0         20 0.0
     21 0.0         22 0.0         23 1.718E+02
  -6  'ENVIRONMENT     CURIES     ' $ TN=  0.2400E+02
      1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
      6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
     11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
     16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
     21 0.000E+00   22 0.000E+00   23 0.000E+00
  -6  'ENVIRONMENT     CURIES     ' $ TN=  0.9600E+02
      1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
      6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
     11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
     16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
     21 0.000E+00   22 0.000E+00   23 0.000E+00
  -6  'ENVIRONMENT     CURIES     ' $ TN=  0.7200E+03
      1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
      6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
     11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
     16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
     21 0.000E+00   22 0.000E+00   23 0.000E+00
4.03E-03  4.03E-03  3.35E-03  2.27E-03  1.81E-03  1.45E-04
20.6  7179.4  21600.0  57600.0  259200.0  2246400.0
3200.0  51.0
711.0  51.0
711.0  51.0
711.0  51.0
711.0  51.0
711.0  51.0
0.0  0.0  0.0  0.0  0.0  0.0  3200.0
0.95  0.70  0.95  0.70  0.99  0.0  2889.0
0.95  0.70  0.95  0.70  0.99  0.0  2889.0
0.95  0.70  0.95  0.70  0.99  0.0  2889.0
0.95  0.70  0.95  0.70  0.99  0.0  2889.0
0.95  0.70  0.95  0.70  0.99  0.0  2889.0
100.0  60.0  40.0  1440.0  5760.0 257198.0
1.2492 0.63  0.8352
322.0 45.0 17.75 46.0 9.0 4.0 161.0 22.5 4.0 0.0
ROOFFLUX DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE THROUGH ROOF
1000.0 1000.0 1000.0  20.0  20.0 20.0  500.0  500.0  -16.0  2.25
ADJACENT DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE FROM AUX BUILDING
270.0 150.0 148.0 27.0 15.0 14.0 135.0 75.0 -25.5  3.0
ADJACENT DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE FROM TURBINE BLDG
322.0  112.0  341.0  32.0 11.0 34.0  161.0  56.0  -25.5  3.0
ADJACENT DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE FROM SPREADING ROOM
322.0  45.0  26.0 32.0 9.0 5.0  22.5  161.0  -4.67  0.67
```

```
ADJACENT DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE FROM CR BLDG END
18.0 45.0 460.0 10.0 10.0 100.0 4.0 22.5 -25.5 3.0
ADJACENT DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE FROM CR BLDG END
18.0 45.0 460.0 10.0 10.0 100.0 4.0 22.5 -25.5 3.0
/*
//
```

Appendix F: Example of FENCDOSE Model

```
//APS77F9A JOB 264360,'9MBERG.LP4T-C',MSGLEVEL=1,MSGCLASS=T
//*MAIN ORG=KNXLCL01,CLASS=SB
//JCL JCLLIB ORDER=(APB.NEN.EX262358.PROCLIB)
//STEP1 EXEC FNCDOSV4,COND=(4,LT)
//FNCDOS1.FT05F001 DD *
1
KRM-83  KRM-85  KR-85
KR-87   KR-88   KR-89
XEM-131 XEM-133 XE-133 XEM-135 XE-135 XE-138
I-131   I-132   I-133 I-134   I-135
I*-131  I*-132  I*-133 I*-134  I*-135  H-3
T
.141E-3  .668E-4  .459E-4  .204E-4  .635E-5  6.07E-4
WBN MSLB, 21 UCI/CC INITIAL CONC, 10+1GPM LK SS,1.0 GPM LEAK IN SG
TIME TO 20.6 SEC
    4  'ENVIRONMENT                     ' $ TN=  0.5722E-02
         1 0.0          2 6.762E-02    3 1.029E-01    4 6.033E-02    5 1.176E-01
         6 0.0          7 2.505E-01    8 2.866E-02    9 9.802E-01   10 5.429E-02
        11 3.560E-01   12 4.999E-02   13 2.361E+00   14 5.667E+00   15 6.751E+00
        16 4.964E+00   17 1.038E+01   18 0.0         19 0.0         20 0.0
        21 0.0         22 0.0         23 5.415E+00
WBN MSLB, 21 UCI/CC INITIAL CONC, 10+1GPM LK SS,1.0 GPM LEAK IN SG
TIME TO 2.0 HR
    4  'ENVIRONMENT                     ' $ TN=  0.2000E+01
         1 0.0          2 2.298E+00    3 4.166E+00    4 1.513E+00    5 3.687E+00
         6 0.0          7 1.021E+01    8 1.119E+00    9 3.957E+01   10 7.468E+00
        11 1.647E+01   12 3.232E-01   13 3.691E+00   14 1.293E+01   15 1.117E+01
        16 1.391E+01   17 1.936E+01   18 0.0         19 0.0         20 0.0
        21 0.0         22 0.0         23 6.170E+01
WBN MSLB, 21 UCI/CC INITIAL CONC, 10+1GPM LK SS,1.0 GPM LEAK IN SG
TIME TO 8.0 HR
    4  'ENVIRONMENT                     ' $ TN=  0.8000E+01
         1 0.0          2 4.043E+00    3 1.324E+01    4 7.744E-01    5 4.691E+00
         6 0.0          7 3.216E+01    8 3.429E+00    9 1.242E+02   10 1.706E+01
        11 5.754E+01   12 9.744E-04   13 1.087E+01   14 1.296E+01   15 2.926E+01
        16 3.585E+00   17 3.865E+01   18 0.0         19 0.0         20 0.0
        21 0.0         22 0.0         23 1.718E+02
WBN MSLB
TIME TO 1 DAY
   -6  'ENVIRONMENT        CURIES       ' $ TN=  0.2400E+02
         1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
         6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
        11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
        16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
        21 0.000E+00   22 0.000E+00   23 0.000E+00
WBN MSLB
TIME TO 4 DAYS
   -6  'ENVIRONMENT        CURIES       ' $ TN=  0.9600E+02
         1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
         6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
        11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
        16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
        21 0.000E+00   22 0.000E+00   23 0.000E+00
WBN MSLB
TIME TO 30 DAYS
   -6  'ENVIRONMENT        CURIES       ' $ TN=  0.7200E+03
         1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
         6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
        11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
        16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
        21 0.000E+00   22 0.000E+00   23 0.000E+00
```

Appendix G: Additional Cases

This appendix documents the original steam generator MSLB results used as input to the FSAR (0.265 μCi/gm I-131 equivalent or 21 μCi/gm I-131 equivalent, with a 10 gpm known primary to secondary side leakage and 1 gpm unknown leakage and 150 gpd per steam generator with the 3 gpm post accident leakage). The control room operator dose COROD model recirculation and time increments were corrected. All other cases (with different concentrations and/or leak rates) can be found in revision 8 of this calculation (these were not corrected, as they were not used in the FSAR). Note that all other cases are historical and utilize original steam generator data. Details of these results (excluding the COROD corrections) may be found in revision 8.

Unit 1 MSLB Control Room Doses (rem) Using ARCON96 X/Q values **with ORIGINAL STEAM GENERATOR DATA**:
10 gpm known + 1 gpm unknown + 3 gpm post accident leakage

	Pre-accident Iodine Spiking	Accident Initiated Iodine Spiking	limit
Gamma	1.340E-02	2.475E-02	5
Beta	1.339E-01	2.052E-01	30
Thyroid (ICRP-2)	2.851E+01	4.730E+01	30
Thyroid (ICRP-30)	1.570E+01	2.426E+01	30
TEDE	5.856E-01	9.425E-01	5

Unit 1 MSLB Offsite Doses (rem) with ORIGINAL STEAM GENERATOR DATA :
10 gpm known + 1 gpm unknown + 3 gpm post accident leakage

Pre-accident Iodine spiking case
I-131 equivalent: 21 uCi/cc

	2-hr EAB	30-day LPZ	limit
gamma	6.381E-02	2.233E-02	25
beta	2.058E-02	8.335E-03	300
Inhalation (ICRP-2)	1.046E+01	4.695E+00	300
Inhalation (ICRP-30)	5.282E+00	2.469E+00	300
TEDE	3.957E-01	1.698E-01	25

Accident Initiated Iodine Spiking (500) case
I-131 equivalent: 0.265 uCi/cc

	2-hr EAB	30-day LPZ	limit
gamma	2.006E-01	1.981E-01	2.5
beta	4.981E-02	4.809E-02	30
Inhalation (ICRP-2)	1.296E+01	1.709E+01	30
Inhalation (ICRP-30)	5.251E+00	7.394E+00	30
TEDE	6.212E-01	7.551E-01	2.5

Appendix H: Unit 2 MSLB

Unit 2 utilizes the original steam generators, however the mass releases were revised by Westinghouse (ref.26). The main text models apply except for the following changes:

Volumes:
#1: Reactor Coolant: 5.4E5 lb (ref.2) = 2.4494E8 gm
#2: Steam Generator w/Leak: 4.735E7 gm (ref.2)
#3: Steam Generators w/out Leak: 1.421E8 gm (ref.2).

Step Sources:

The step sources (Ci-gm/μCi) to initialize the reactor coolant and the secondary side activities are:
<u>All cases</u>:
S=2.4494E8 gm*1E-6 Ci/μCi * 29.06 =7.118E3 (noble gasses)
S=2.4494E8 gm*1E-6 Ci/μCi = 2.4494E2 (tritium)
Pre-accident iodine spike case (initial concentration = 21 μCi/gm):
S=2.4494E8 gm*1E-6 Ci/μCi * 7.965[μCi/gm I-131]$^{-1}$ *21μCi/gm I-131 = 4.097E4 (iodines)
Accident initiated iodine spike case (initial concentration = 0.265 μCi/gm):
S=2.4494E8 gm*1E-6 Ci/μCi * 7.965 [μCi/gm I-131]$^{-1}$*0.265 μCi/gm I-131= 5.170E2
Secondary side, all cases, steam generator w/ leak, release to environment. (concentration = 0.1μCi/gm) which is due to dryout (4.74E7 gm rounded up from 4.735E7 gm mass in steam generator with leak):
S = 4.74E7 gm * 1E-6 Ci/μCi * 3.136E5 [μCi/gm I-131]$^{-1}$* 0.1μCi/gm I-131 =1.49E6
S = 4.74E7 gm * 1E-6 Ci/μCi = 4.74E1 (tritium)
Secondary side, all cases, steam generators without leak (initial concentration = 0.1 μCi/gm):
S = 1.421E8 gm * 1E-6 Ci/μCi * 3.136E5 [μCi/gm I-131]$^{-1}$* 0.1μCi/gm I-131 = 4.46E6
S = 1.421E8 gm*1E-6 Ci/μCi = 1.421E2 (tritium)

Continuous Sources:

For the accident initiated iodine spike case, the iodine spike is 500 times the iodine release rate from the fuel. At steady state, the iodine release (production) rate is equal to the removal rate. The iodine removal is due to a) radioactive decay, b) removal by the letdown system, and c) removal through reactor coolant leakage. These terms are expressed as:

$P = \Sigma$removal rates = decay + letdown + leakage
or $P = \lambda + f_L\varepsilon/V + p_s/V$
where P = production rate [hr^{-1}]
λ = decay constant for the isotope in question [hr^{-1}] = ln(2)/$T_{1/2}$
f_L = letdown flow rate = 120 gpm + 4.39 gpm = 124.39 gpm
ε = letdown demineralizer efficiency = 1 (assumed so as to maximize removal/production rate)
V = volume of primary coolant = 5.4E5 lb
p_s = removal rate of iodine from the primary side due to preaccident primary side leakage
= 11 gpm (10 gpm identified + 1 gpm unidentified)
$T_{1/2}$ = halflife taken from ref.15

Note: all the above flow rates are converted to mass flow rates at STP:

Production Rates for a Reactor Coolant Leak of 11 gpm (10 gpm identified + 1 gpm unidentified)

	Half Life	λ [1/hr]	$f_L\varepsilon/V$ [1/hr]	p_s/V [1/hr]	prod rate P [1/hr]
I-131	8.04 d	3.59E-03	1.15E-01	1.02E-02	0.1291
I-132	2.28 h	3.04E-01	1.15E-01	1.02E-02	0.4296
I-133	20.9 h	3.32E-02	1.15E-01	1.02E-02	0.1587
I-134	52.6 m	7.91E-01	1.15E-01	1.02E-02	0.9162
I-135	6.61 h	1.05E-01	1.15E-01	1.02E-02	0.2304

The accident initiated iodine spike of 500 times the increase in the iodine release (production) rate from the fuel is modeled as a continuous source:

C = Volume * 1E-6 Ci/μCi * Prod. Rate * 500 * 1 μCi/gm I-131 equiv. conversion factor*I-131 equiv.

where Volume = 2.4494E8 gm

Prod Rate = see table above

1 μCi/gm I-131 equivalent conversion factor = 7.965 (value determined above, this is to get the ANSI/ANS-18.1-1984 source into 1 μCi/gm I-131 equivalent

I-131 equiv. = 0.265 μCi/gm I-131

Continuous Source [gm-Ci/μCi-hr] for Accident Initiated Iodine Spike:

Reactor Coolant Leak of 11 gpm (10 gpm identified + 1 gpm unidentified)

case:	0.265 μCi/gm I-131
I-131	3.338E+04
I-132	1.110E+05
I-133	4.103E+04
I-134	2.368E+05
I-135	5.956E+04

Flow Rates:

The following flow rates/leakage rates for each component are (determined by trial and error with the ultimate goal being to find the flow/leak which would lead to the offsite/control room doses reaching the regulatory limits):

Flow from Reactor Coolant #1 to Environment #4 all classes which consists of 1 gpm and is for leak in the steam generators, the production rate of iodines is based on a total RCS leakage of 11 gpm (=10gpm identified +1gpm unidentified):

F = 1.0 gpm * 60 min/hr * 3785.48 cc/gal * 1g/cc = 2.271E5 g/hr

Flow from Reactor Coolant #1 to Steam Generator w/ no Leak #3 all classes:

F = 3 steam generators * 150 gpd * 3785.48 cc/gal / 24 hr/day * 1g/cc = 7.098E4 g/hr

The initial steam released from the defective steam generator is 4.74E7 g (entire mass of SG rounded up). From reference 26, the non-defective steam generators (= "steam generators without leak" in this model) the mass release is 433,079 lb (0-2 hr), and 870,754 lb (2-8 hr). The accident releases end at eight hours. To take into account uncovery of the faulted steam generator, there is no iodine partitioning in the release to the environment (iodine partition coefficient = 1). The mass release representing 1 gpm primary to secondary side leak is a flow directly to the environment. This is reflected in the flows listed above. For other leak rates, the flow cards will correctly take into account the mass released.

The reactor coolant release to the unfaulted steam generator is small relative to the secondary side mass, therefore partitioning is allowed per the SRP. The iodine partition coefficient due to steaming for the unfaulted steam generators to the environment is 100. These mass releases translate into the following flows:

Flow from Steam Generators w/out Leak #3 to Environment #4:

F = (433,079 lb)(453.59 g/lb)/(2 hr) = 9.822E7 g/hr (0-2 hr, noble gasses, tritium)

F = (433,079 lb)(453.59 g/lb)/(100*2 hr) = 9.822E5 g/hr (0-2 hr, iodines)

F = (870,754 lb)(453.59 g/lb)/(6 hr) = 6.583E7 g/hr (2-8 hr) (noble gasses, tritium)

F = (870,754 lb)(453.59 g/lb)/(100*6 hr) = 6.583E5 g/hr (2-8 hr) (iodines)

The STP output is used as input to COROD (which determines control room operator dose) and FENCDOSE (which determines 30-day and 2-hour LPZ offsite dose).

Unit 2 ARCON96 X/Q values (worst case) for Unit 2 (ref.20): 2.87E-3 sec/cum 0-2 hr, 2.46E-3 sec/cum

Results

The results were (rem):

Unit 2 MSLB Offsite:

Pre-Accident Iodine Spike
21 uCi/g I-131 Equivalent

	2-hr EAB	30-day LPZ	limit
gamma	2.527E-02	8.554E-03	25
beta	8.118E-03	3.221E-03	300
Thyroid (ICRP-30)	2.190E+00	9.325E-01	300
TEDE	1.617E-01	6.422E-02	25

Accident Initiated Iodine Spike
0.265 uCi/g I-131 Equivalent

	2-hr EAB	30-day LPZ	limit
gamma	7.091E-02	6.747E-02	2.5
beta	1.787E-02	1.659E-02	30
Thyroid (ICRP-30)	2.177E+00	2.583E+00	30
TEDE	2.369E-01	2.603E-01	2.5

Unit 2 MSLB Control Room

Pre-Accident Iodine Spike
21 uCi/g I-131 Equivalent

	Airborne	Shine	Total	Limit
Gamma	4.448E-03	4.488E-03	8.936E-03	5
Beta	4.241E-02	0.000E+00	4.241E-02	30
Thyroid (ICRP-30)	6.912E+00	0.000E+00	6.912E+00	30
TEDE	2.469E-01	4.488E-03	2.514E-01	5

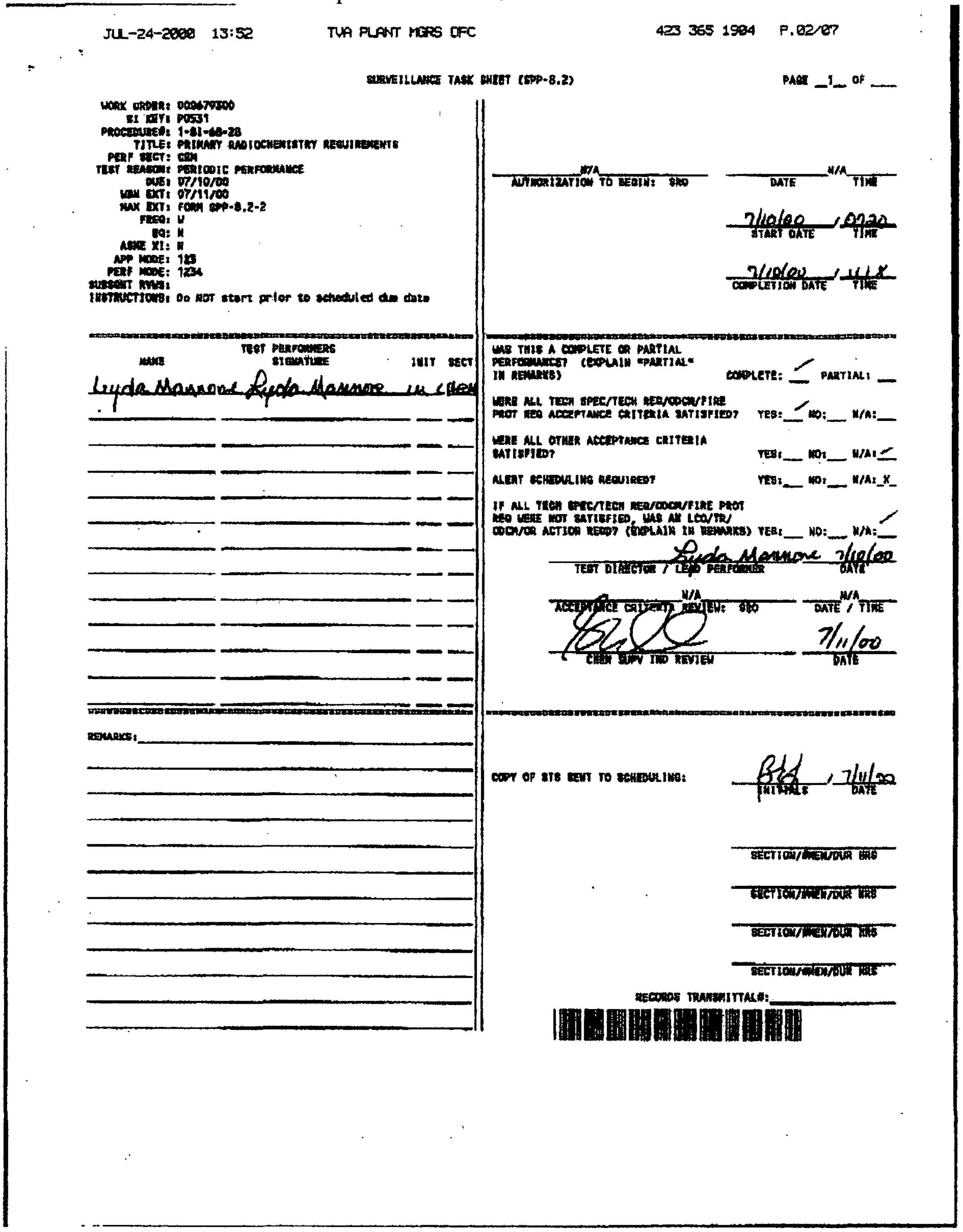
Accident Initiated Iodine Spike
0.265 uCi/g I-131 Equivalent

	Airborne	Shine	Total	Limit
Gamma	7.059E-03	7.344E-03	1.440E-02	5
Beta	6.126E-02	0.000E+00	6.126E-02	30
Thyroid (ICRP-30)	9.018E+00	0.000E+00	9.018E+00	30
TEDE	3.346E-01	7.344E-03	3.419E-01	5

Discussion:

The Unit 2 MSLB doses are less than the 10CFR100 and 10CFR50 GDC 19 limits. Most of the Unit 1 doses bound the Unit 2 doses, except for the gamma, beta and TEDE offsite doses for the accident initiated iodine spike, and the gamma control room for the accident initiated iodine spike.

Attachment 1: Surveillance test 1-SI-68-28 performed on 7/10/00



JUL-24-2000 13:52 TVA PLANT MGRS OFC 423 365 1904 P.02/07

SURVEILLANCE TASK SHEET (SPP-8.2) PAGE 1 OF ___

WORK ORDER: 000679300
SI KEY: P0531
PROCEDURE#: 1-SI-68-28
TITLE: PRIMARY RADIOCHEMISTRY REQUIREMENTS
PERF SECT: CEM
TEST REASON: PERIODIC PERFORMANCE
DUE: 07/10/00
WBN EXT: 07/11/00
MAX EXT: FORM SPP-8.2-2
FREQ: W
EQ: N
ASME XI: N
APP MODE: 123
PERF MODE: 1234
SUBSQNT RVWS:
INSTRUCTIONS: Do NOT start prior to scheduled due date

N/A AUTHORIZATION TO BEGIN: SRO
N/A DATE / TIME

7/10/00 START DATE / 0920 TIME

7/10/00 COMPLETION DATE / 1118 TIME

TEST PERFORMERS

NAME	SIGNATURE	INIT	SECT
Lyda Mansone	Lyda Mansone	LM	CHEM

REMARKS:___

WAS THIS A COMPLETE OR PARTIAL PERFORMANCE? (EXPLAIN "PARTIAL" IN REMARKS) COMPLETE: ✓ PARTIAL: ___

WERE ALL TECH SPEC/TECH REQ/ODCM/FIRE PROT REQ ACCEPTANCE CRITERIA SATISFIED? YES: ✓ NO: ___ N/A: ___

WERE ALL OTHER ACCEPTANCE CRITERIA SATISFIED? YES: ___ NO: ___ N/A: ✓

ALERT SCHEDULING REQUIRED? YES: ___ NO: ___ N/A: X

IF ALL TECH SPEC/TECH REQ/ODCM/FIRE PROT REQ WERE NOT SATISFIED, WAS AN LCO/TR/ODCM/OR ACTION REQD? (EXPLAIN IN REMARKS) YES: ___ NO: ___ N/A: ✓

Lyda Mansone TEST DIRECTOR / LEAD PERFORMER 7/10/00 DATE

N/A ACCEPTANCE CRITERIA REVIEW: SRO N/A DATE / TIME

CHEM SUPV IND REVIEW 7/11/00 DATE

COPY OF STS SENT TO SCHEDULING: BH INITIALS / 7/11/00 DATE

___ SECTION/MEN/DUR HRS
___ SECTION/MEN/DUR HRS
___ SECTION/MEN/DUR HRS
___ SECTION/MEN/DUR HRS

RECORDS TRANSMITTAL#:___

```
JUL-24-2000  13:52          TVA PLANT MGRS OFC                      423 365 1904    P.03/07
                                  10-JUL-2000 09:23:05.19
                                TENNESSEE VALLEY AUTHORITY
                                 WATTS BAR NUCLEAR PLANT
                         ******************************************

SAMPLE TITLE   : U1 - RCS - GASEOUS ACTIVTY
FILE IDENT     : DKB600:[TVA.SAMPLE.CHEM.NEW]W0007108796_C401.CNF;1

SAMPLE ID      : W0007108796_C401          * OPERATOR          : LLMANNONE
SAMPLE TIME    : 10-JUL-2000 08:53         * SAMPLE GEOMETRY   : GM1K
                                           * SHELF HEIGHT      : 0
                                           * EFFICIENCY FILE   : GM1K0
SAMPLE TYPE    : 1240 CC GAS MARI          * SAMPLE QUANTITY   : 1.00000E+00 CC
********************************************************************************

ACQ DATE & TIME    : 10-JUL-2000 09:12     * DEADTIME (%)      : 0.3%
PRESET  LIVE TIME  : 0 00:10:00            * SENSITIVITY       : 4.00000
ELASPED REAL TIME  : 0 00:10:01            * GAUSSIAN SEN      : 10.00000
ELAPSED LIVE TIME  : 0 00:10:00            * NBR ITERATIONS    : 10
********************************************************************************

DETECTOR           : DET #3, GSS-3286      * LIBRARY             : NOBLEGAS
EFFIC CAL DATE     : 29-JUL-1994 13:47     * EFFIC CERT DATE     : 29-JUL-1994 13:47
DCAL DATE & TIME   : 9-JUL-2000 15:52:     * ENERGY TOLER        : 1.25
KEV/CHAN           : 4.99928E-01           * HALF LIFE RATIO     : 8.00000
OFFSET             : -1.48334E-01 keV      * ABUNDANCE LIMIT     : 80.0%
Q COEFFICIENT      : 3.22120E-08           * CORRECTION FACTOR   : 1.00000E+00
PEAK START CHAN    : 140                   * PEAK END CHAN       : 4096
********************************************************************************
ANALYSES : PEAK V16.9 NID V3.3 MINACT V2.8 WTMEAN/KEY V1.8
********************************************************************************

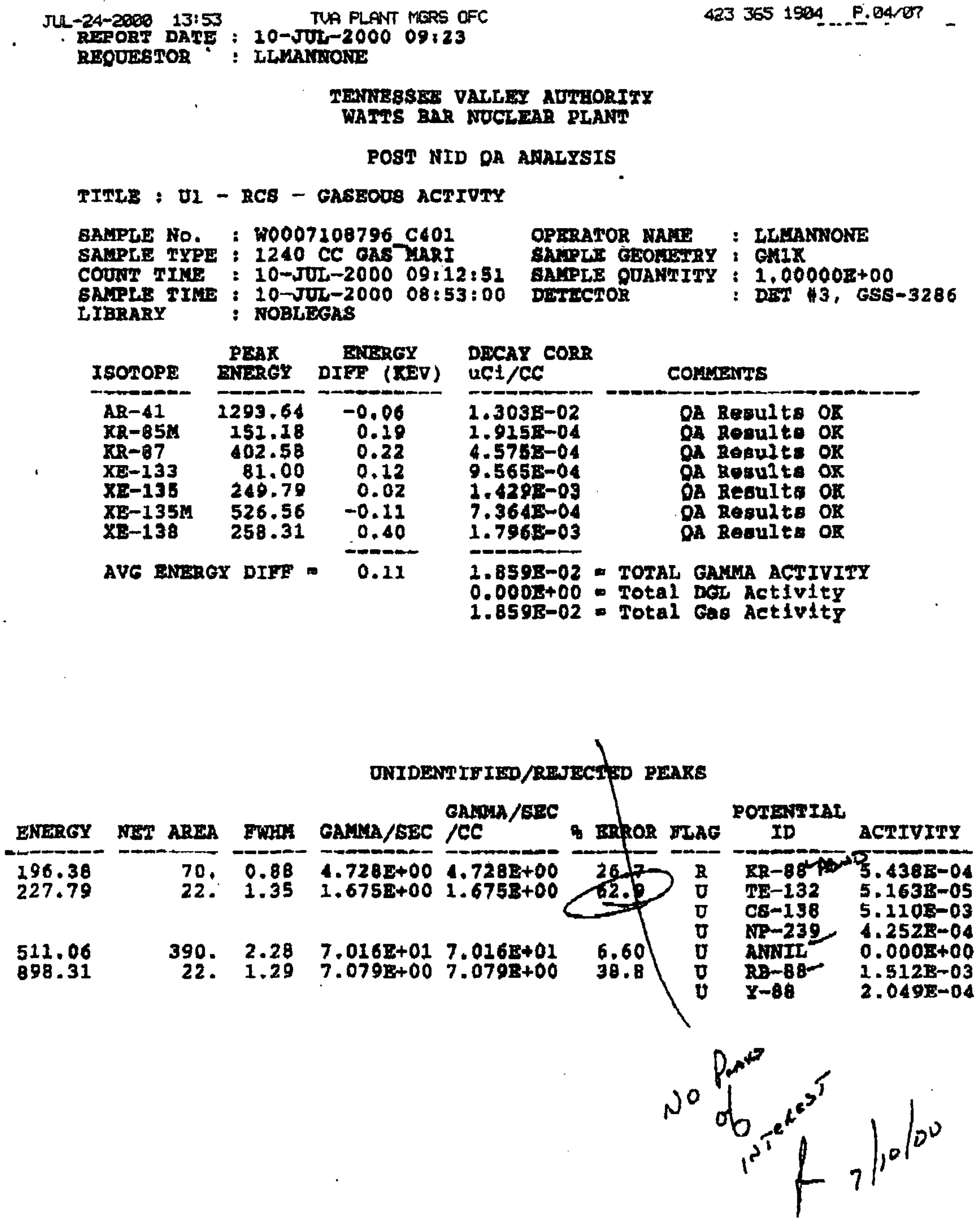
COUNTED ON     : LION
COLLECTED BY   :
COUNTED BY     : LLMANNONE
REVIEWED BY    :
COMMENTS       :

********************************************************************************

Post-NID Peak Search Report

It    Energy       Area    Bkgnd  FWHM Channel   Left  Pw %Err      Fit     Nuclides

 0     81.12        230       92  1.01  162.55    157  12 10.8              XE-133
 0    151.37         88       53  0.97  303.07    299   8 17.7              KR-85M
 0    196.38         70       80  0.88  393.10    388  10 26.7
 0    227.79         22       47  1.35  455.92    448  10 62.9
 0    249.81        549       83  0.94  499.98    494  12  5.4              XE-135
 0    258.71         72       40  0.89  517.78    514  10 20.2              XE-138
 0    305.21         19       34  0.76  610.77    607   8 57.2              KR-85M
 0    402.80         48       34  2.39  805.96    801  12 29.3              KR-87
 0    435.19         26       16  1.31  870.75    866  11 35.3              XE-138
 0    511.06        390       49  2.28 1022.51   1014  18  6.6
 0    526.45         39       24  1.21 1053.28   1048  12 29.8              XE-135M
 0    898.31         22       16  1.29 1796.96   1791   9 38.8
 0   1293.58        904        9  1.60 2587.40   2578  16  3.4              AR-41
```



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JUL-24-2000  13:53          TVA PLANT MGRS OFC                      423 365 1904   P.04/07
  REPORT DATE : 10-JUL-2000 09:23
  REQUESTOR   : LLMANNONE

                           TENNESSEE VALLEY AUTHORITY
                            WATTS BAR NUCLEAR PLANT

                               POST NID QA ANALYSIS

  TITLE : U1 - RCS - GASEOUS ACTIVTY

  SAMPLE No.   : W0007108796 C401      OPERATOR NAME    : LLMANNONE
  SAMPLE TYPE  : 1240 CC GAS MARI      SAMPLE GEOMETRY  : GM1K
  COUNT TIME   : 10-JUL-2000 09:12:51  SAMPLE QUANTITY  : 1.00000E+00
  SAMPLE TIME  : 10-JUL-2000 08:53:00  DETECTOR         : DET #3, GSS-3286
  LIBRARY      : NOBLEGAS

               PEAK     ENERGY      DECAY CORR
   ISOTOPE    ENERGY  DIFF (KEV)    uCi/CC            COMMENTS
   --------   ------  ----------   ----------  ---------------------------
    AR-41     1293.64    -0.06     1.303E-02       QA Results OK
    KR-85M     151.18     0.19     1.915E-04       QA Results OK
    KR-87      402.58     0.22     4.578E-04       QA Results OK
    XE-133      81.00     0.12     9.565E-04       QA Results OK
    XE-135     249.79     0.02     1.429E-03       QA Results OK
    XE-135M    526.56    -0.11     7.364E-04       QA Results OK
    XE-138     258.31     0.40     1.796E-03       QA Results OK
                         -----     ---------
    AVG ENERGY DIFF =     0.11     1.859E-02 = TOTAL GAMMA ACTIVITY
                                   0.000E+00 = Total DGL Activity
                                   1.859E-02 = Total Gas Activity



                        UNIDENTIFIED/REJECTED PEAKS

                                       GAMMA/SEC                 POTENTIAL
 ENERGY   NET AREA   FWHM   GAMMA/SEC  /CC        % ERROR  FLAG     ID       ACTIVITY
 -------  --------  -----  ---------  ---------  -------  ----  --------  ----------
 196.38       70.    0.88  4.728E+00  4.728E+00    26.7     R    KR-88     5.438E-04
 227.79       22.    1.35  1.675E+00  1.675E+00    62.9     U    TE-132    5.163E-05
                                                            U    CS-138    5.110E-03
                                                            U    NP-239    4.252E-04
 511.06      390.    2.28  7.016E+01  7.016E+01    6.60     U    ANNIL     0.000E+00
 898.31       22.    1.29  7.079E+00  7.079E+00    38.8     U    RB-88     1.512E-03
                                                            U    Y-88      2.049E-04
```

No Peaks of interest
7/10/00

```
     JUL-24-2000  13:53          TVA PLANT MGRS OFC                 423 365 1904    P.05/07
                                 10-JUL-2000 09:37:45.71
                              TENNESSEE VALLEY AUTHORITY
                                WATTS BAR NUCLEAR PLANT
                       ****************************************

SAMPLE TITLE   : U1 - RCS - DEGASSED LIQUID ACTIVITY
FILE IDENT     : DKB600:[TVA.SAMPLE.CHEM.NEW]W0007108795_C402.CNF;1

SAMPLE ID     : W0007108795_C402      * OPERATOR           : LLMANNONE
SAMPLE TIME   : 10-JUL-2000 07:25     * SAMPLE GEOMETRY    : LSV20
                                      * SHELF HEIGHT       : 1
                                      * EFFICIENCY FILE    : LSV201
SAMPLE TYPE   : RCS 20ML LSV          * SAMPLE QUANTITY    : 5.00000E+00 GRAMS
*******************************************************************************

ACQ DATE & TIME    : 10-JUL-2000 08:36  * DEADTIME (%)       : 2.2%
PRESET  LIVE TIME  : 0 01:00:00         * SENSITIVITY        : 4.00000
ELASPED REAL TIME  : 0 01:01:20         * GAUSSIAN SEN       : 10.00000
ELAPSED LIVE TIME  : 0 01:00:00         * NBR ITERATIONS     : 10
*******************************************************************************

DETECTOR          : DET #4, GSS-3310    * LIBRARY             : RCSLIQUID
EFFIC CAL DATE    : 5-AUG-1994 11:11:   * EFFIC CERT DATE     : 5-AUG-1994 11:11:
DCAL DATE & TIME  : 9-JUL-2000 15:52:   * ENERGY TOLER        : 1.25
KEV/CHAN          : 5.00474E-01         * HALF LIFE RATIO     : 8.00000
OFFSET            : -3.73924E-01 keV    * ABUNDANCE LIMIT     : 80.0%
Q COEFFICIENT     : -1.14092E-07        * CORRECTION FACTOR   : 1.00000E+00
PEAK START CHAN   : 140                 * PEAK END CHAN       : 4096
*******************************************************************************
ANALYSES : PEAK V16.9 NID V3.3 MINACT V2.8 WTMEAN/KEY V1.8
*******************************************************************************

COUNTED ON    : LION
COLLECTED BY  :
COUNTED BY    : LLMANNONE
REVIEWED BY   :
COMMENTS      :

*******************************************************************************

Post-NID Peak Search Report

It   Energy      Area    Bkgnd  FWHM Channel   Left  Pw %Err      Fit   Nuclides

 0   135.60       697    25268  0.92  271.70    269   7 38.0            I-134
 0   249.64       887    20225  0.79  499.61    498   6 25.6            XE-135
 0   287.87       540    22521  0.98  576.01    574   7 46.3            I-135
                                                                        I-135
 0   364.21       455    13323  1.06  728.61    726   8 44.3            I-131
 0   405.43       310     6932  1.05  810.99    808   8 46.9            I-134
 0   417.67       485     6009  1.20  835.46    832   8 28.1            I-135
 0   462.73       545     5368  1.28  925.53    922   8 23.7            CS-138
 0   511.00    838084    22601  2.65 1022.01   1014  19  0.1            F-18
 0   522.65       824      999  1.38 1045.31   1043   7  7.3            I-132
 1   526.58      1048      823  1.29 1053.15   1050  18  5.2 1.06E+00 I-135
                                                                        XE-135M
 1   529.88      4510     1009  1.34 1059.77   1050  18  1.9            I-133
```

```
JUL-24-2000  13:53          TVA PLANT MGRS OFC                 423 365 1904   P.06/07
   REPORT DATE : 10-JUL-2000 09:37
   REQUESTOR   : LLMANNONE

                          TENNESSEE VALLEY AUTHORITY
                           WATTS BAR NUCLEAR PLANT

                             POST NID QA ANALYSIS

   TITLE : U1 - RCS - DEGASSED LIQUID ACTIVITY

   SAMPLE No.  : W0007108795_C402       OPERATOR NAME     : LLMANNONE
   SAMPLE TYPE : RCS 20ML LSV           SAMPLE GEOMETRY   : LSV20
   COUNT TIME  : 10-JUL-2000 08:36:15   SAMPLE QUANTITY   : 5.00000E+00
   SAMPLE TIME : 10-JUL-2000 07:25:00   DETECTOR          : DET #4, GSS-3310
   LIBRARY     : RCSLIQUID

                PEAK     ENERGY     DECAY CORR
    ISOTOPE    ENERGY  DIFF (KEV)   uCi/GRAM          COMMENTS
    -------    ------  ----------   ----------   --------------------
     F-18      511.00     0.00      1.179E-01        QA Results OK
     NA-24    1368.53     0.07      9.169E-04        QA Results OK
     MN-56    1810.69    -0.63      9.313E-05        QA Results OK
     CO-58     810.76    -0.01      5.019E-04        QA Results OK
     NB-95     765.79     0.89      3.132E-05        QA Results OK
     I-131     364.48    -0.27      6.070E-05        QA Results OK
     I-132     667.69     0.03      1.459E-03        QA Results OK
     I-133     529.87     0.01      8.208E-04        QA Results OK
     I-134     847.03    -0.05      2.694E-03        QA Results OK
     I-135    1260.41     0.03      1.608E-03        QA Results OK
     XE-135    249.79    -0.16      8.914E-05        QA Results OK
     XE-135M   526.56     0.02      1.406E-02        QA Results OK
     CS-138   1435.86    -0.11      2.395E-03        QA Results OK
                        -------     ----------
     AVG ENERGY DIFF =   -0.01      1.426E-01 = TOTAL GAMMA ACTIVITY
                                    1.218E-01 = Total DGL Activity
                                    2.427E-03 = Total FP Activity
                                    1.512E-03 = Total AP Activity
                                    1.415E-02 = Total Gas Activity
                                    6.643E-03 = Total HFP Activity

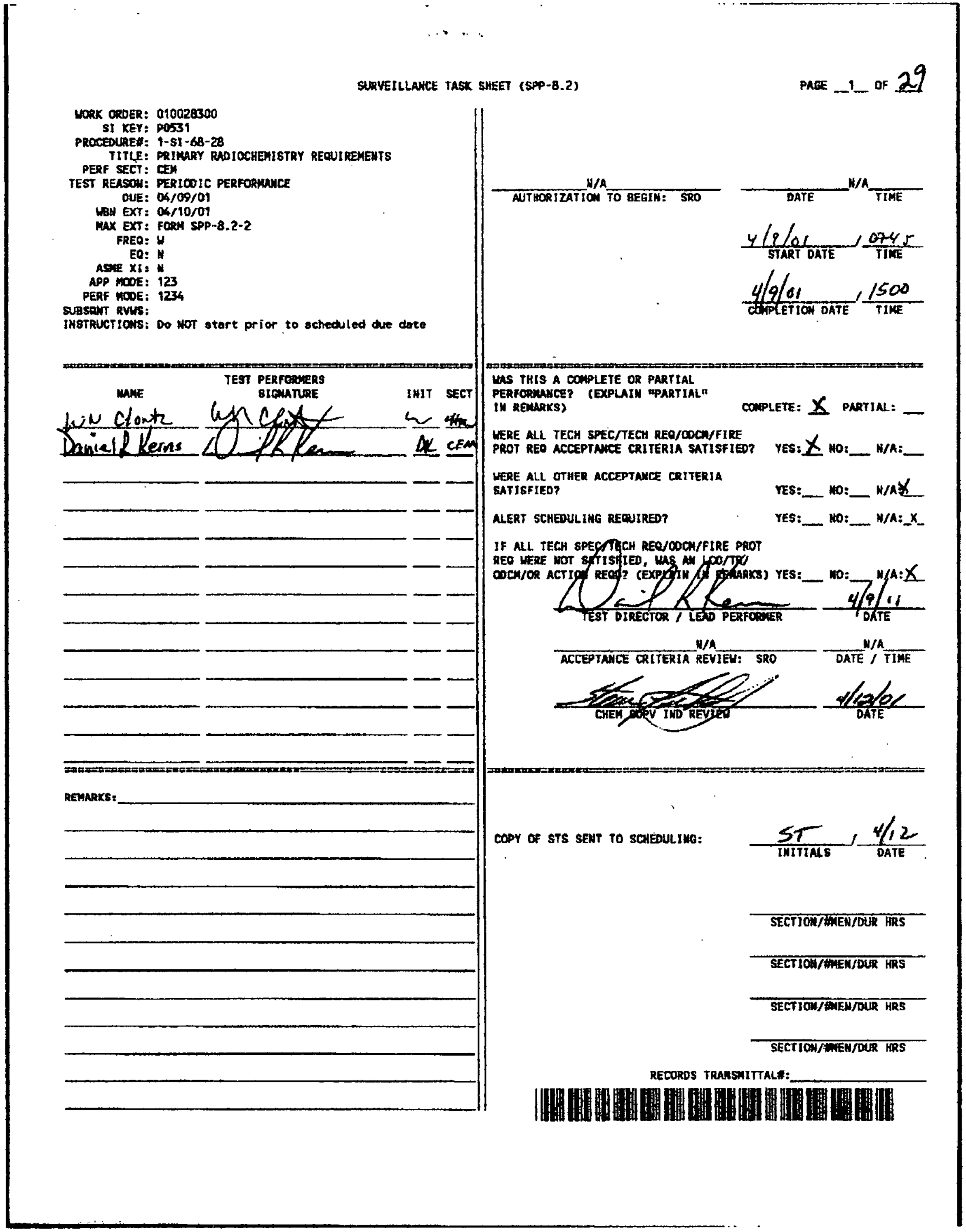
    Dose Equivalent Iodine-131 =  2.905E-04
    Iodine 131/133 Ratio =  7.395E-02
    Iodine 133/135 Ratio =  5.105E-01

    287.87 KeV Peak was used in identifying  2 isotopes
    526.58 KeV Peak was used in identifying  2 isotopes
    546.88 KeV Peak was used in identifying  2 isotopes
    766.68 KeV Peak was used in identifying  2 isotopes
    810.75 KeV Peak was used in identifying  2 isotopes
    846.97 KeV Peak was used in identifying  2 isotopes
    857.15 KeV Peak was used in identifying  2 isotopes
   1136.29 KeV Peak was used in identifying  2 isotopes
```

3.94E-3

DGA= [illegible]

Surveillance test 1-SI-68-28 performed on 4/9/01



SURVEILLANCE TASK SHEET (SPP-8.2)

PAGE 1 OF 29

WORK ORDER: 010028300
SI KEY: P0531
PROCEDURE#: 1-SI-68-28
TITLE: PRIMARY RADIOCHEMISTRY REQUIREMENTS
PERF SECT: CEM
TEST REASON: PERIODIC PERFORMANCE
DUE: 04/09/01
WBN EXT: 04/10/01
MAX EXT: FORM SPP-8.2-2
FREQ: W
EQ: N
ASME XI: N
APP MODE: 123
PERF MODE: 1234
SUBSQNT RVWS:
INSTRUCTIONS: Do NOT start prior to scheduled due date

N/A AUTHORIZATION TO BEGIN: SRO
DATE N/A TIME

4/9/01 START DATE / 0745 TIME

4/9/01 COMPLETION DATE / 1500 TIME

TEST PERFORMERS

NAME	SIGNATURE	INIT	SECT
W N Clontz			
Daniel K Kerns		DK	CEM

WAS THIS A COMPLETE OR PARTIAL PERFORMANCE? (EXPLAIN "PARTIAL" IN REMARKS) COMPLETE: X PARTIAL: ___

WERE ALL TECH SPEC/TECH REQ/ODCM/FIRE PROT REQ ACCEPTANCE CRITERIA SATISFIED? YES: X NO: ___ N/A: ___

WERE ALL OTHER ACCEPTANCE CRITERIA SATISFIED? YES: ___ NO: ___ N/A: X

ALERT SCHEDULING REQUIRED? YES: ___ NO: ___ N/A: X

IF ALL TECH SPEC/TECH REQ/ODCM/FIRE PROT REQ WERE NOT SATISFIED, WAS AN LCO/TR/ODCM/OR ACTION REQD? (EXPLAIN IN REMARKS) YES: ___ NO: ___ N/A: X

TEST DIRECTOR / LEAD PERFORMER — 4/9/01 DATE

N/A ACCEPTANCE CRITERIA REVIEW: SRO — N/A DATE / TIME

CHEM SUPV IND REVIEW — 4/12/01 DATE

REMARKS:

COPY OF STS SENT TO SCHEDULING: ST INITIALS / 4/12 DATE

SECTION/#MEN/DUR HRS

SECTION/#MEN/DUR HRS

SECTION/#MEN/DUR HRS

SECTION/#MEN/DUR HRS

RECORDS TRANSMITTAL#: ______

```
                    *********************************************
                             9-APR-2001 14:25:02.67
                          TENNESSEE VALLEY AUTHORITY
                           WATTS BAR NUCLEAR PLANT
                    *********************************************

SAMPLE TITLE   : U1 - RCS - GASEOUS ACTIVTY
FILE IDENT     : DKB600:[TVA.SAMPLE.CHEM.NEW]W0104095767_C401.CNF;1

SAMPLE ID     : W0104095767_C401        * OPERATOR          : DRKERNS
SAMPLE TIME   : 9-APR-2001 13:25:       * SAMPLE GEOMETRY : GM1K
                                        * SHELF HEIGHT      : 0
                                        * EFFICIENCY FILE : GM1K0
SAMPLE TYPE   : 1240 CC GAS MARI        * SAMPLE QUANTITY : 2.51000E+00 CC
******************************************************************************

ACQ DATE & TIME    : 9-APR-2001 14:14:  * DEADTIME (%)      : 0.1%
PRESET  LIVE TIME : 0 00:10:00          * SENSITIVITY       : 4.00000
ELASPED REAL TIME : 0 00:10:00          * GAUSSIAN SEN      : 10.00000
ELAPSED LIVE TIME : 0 00:10:00          * NBR ITERATIONS    : 10
******************************************************************************

DETECTOR           : DET #4, GSS-3310   * LIBRARY              : NOBLEGAS
EFFIC CAL DATE     : 2-AUG-1994 11:26:  * EFFIC CERT DATE      : 2-AUG-1994 11:26:
DCAL DATE & TIME   : 9-APR-2001 02:40:  * ENERGY TOLER         : 1.25
KEV/CHAN           : 5.00516E-01        * HALF LIFE RATIO      : 8.00000
OFFSET             : 1.44837E-01 keV    * ABUNDANCE LIMIT      : 80.0%
Q COEFFICIENT      : -1.10914E-07       * CORRECTION FACTOR    : 1.00000E+00
PEAK START CHAN    : 140                * PEAK END CHAN        : 4096
******************************************************************************
ANALYSES : PEAK V16.9 NID V3.3 MINACT V2.8 WTMEAN/KEY V1.8
******************************************************************************

COUNTED ON     : LION
COLLECTED BY   :
COUNTED BY     : DRKERNS
REVIEWED BY    :
COMMENTS       :

******************************************************************************

Post-NID Peak Search Report

It    Energy      Area    Bkgnd  FWHM Channel   Left  Pw %Err      Fit     Nuclides

 0     80.94       902      374  1.03  161.44    157  10  5.2              XE-133
 0    151.17       294      315  1.07  301.75    297  10 12.8              KR-85M
 0    166.01        57      226  1.10  331.42    328   8 47.7              KR-88
 0    196.08       202      345  1.03  391.51    387  10 18.5              KR-88
 0    249.77      2313      340  1.12  498.78    494  12  2.6              XE-135
 0    258.57        59      201  1.04  516.37    513   8 43.2
 0    402.62       160       50  1.21  804.27    800   8 11.0              KR-87
 0    510.99      7378      174  2.34 1020.88   1013  19  1.2
 0    526.86        66       31  1.08 1052.60   1048  11 20.7              XE-135M
 0    609.00        34       35  0.87 1216.79   1209  16 43.6              XE-135
 0    677.82        14       17  1.85 1354.36   1348   9 61.5
 0    834.68        38       12  1.75 1667.96   1662  12 24.5              KR-88
 0    897.59        24       13  2.20 1793.76   1789   9 34.3
```

```
REPORT NAME : QA_CHECK (V10.4)                                    PAGE :     1
REPORT DATE :  9-APR-2001 14:25
REQUESTOR   : DRKERNS

                       TENNESSEE VALLEY AUTHORITY
                        WATTS BAR NUCLEAR PLANT

                          POST NID QA ANALYSIS

TITLE : U1 - RCS - GASEOUS ACTIVTY

SAMPLE No.   : W0104095767_C401       OPERATOR NAME    : DRKERNS
SAMPLE TYPE  : 1240 CC GAS MARI       SAMPLE GEOMETRY  : GM1K
COUNT TIME   : 9-APR-2001 14:14:53.   SAMPLE QUANTITY  : 2.51000E+00
SAMPLE TIME  : 9-APR-2001 13:25:00.   DETECTOR         : DET #4, GSS-3310
LIBRARY      : NOBLEGAS

             PEAK    ENERGY      DECAY CORR
 ISOTOPE    ENERGY  DIFF (KEV)   uCi/CC            COMMENTS
 -------    ------  ----------   ---------   -------------------------
  AR-41     1293.64   -0.10      2.696E-03       QA Results OK
  KR-85M     151.18   -0.01      2.013E-04       QA Results OK
  KR-87      402.58    0.04      4.809E-04       QA Results OK
  KR-88      196.32   -0.24      4.982E-04       QA Results OK
  XE-133      81.00   -0.05      1.202E-03       QA Results OK
  XE-135     249.79   -0.03      1.676E-03       QA Results OK
  XE-135M    526.56    0.30      1.105E-03       QA Results OK
                      ------     ---------
  AVG ENERGY DIFF =   -0.01      7.859E-03 = TOTAL GAMMA ACTIVITY
                                 0.000E+00 = Total DGL Activity
                                 7.859E-03 = Total Gas Activity




                      UNIDENTIFIED/REJECTED PEAKS

                                     GAMMA/SEC                 POTENTIAL
 ENERGY   NET AREA  FWHM  GAMMA/SEC  /CC        % ERROR FLAG      ID      ACTIVITY
 -------  --------  ----  ---------  ---------  ------- ----  ---------  ---------
  258.57       59.  1.04  3.448E+00  1.374E+00    43.2     R    XE-138   1.724E-03
  510.99     7378.  2.34  7.643E+02  3.045E+02    1.25     U    F-18     6.016E-03
                                                           U    ANNIL    0.000E+00
  677.82       14.  1.85  1.829E+00  7.289E-01    61.5     U    AG-110M  1.845E-04
                                                           U    I-134    4.949E-04
  897.59       24.  2.20  4.089E+00  1.629E+00    34.3     U    RB-88    3.932E-04
                                                           U    Y-88     4.716E-05
 1835.84       17.  2.13  5.418E+00  2.159E+00    24.3     U    RB-88    3.408E-04
                                                           U    Y-88     5.872E-05
```

DK 4/9/01

```
                   *****************************************
                          9-APR-2001 10:48:39.98
                        TENNESSEE VALLEY AUTHORITY
                         WATTS BAR NUCLEAR PLANT
                   *****************************************

SAMPLE TITLE  : U1 - RCS - DEGASSED LIQUID ACTIVITY
FILE IDENT    : DKB600:[TVA.SAMPLE.CHEM.NEW]W0104095766_C402.CNF;1

SAMPLE ID     : W0104095766_C402        * OPERATOR          : WNCLONTZ
SAMPLE TIME   : 9-APR-2001 08:20:       * SAMPLE GEOMETRY : 65ML
                                        * SHELF HEIGHT      : 1
                                        * EFFICIENCY FILE : 65ML1
SAMPLE TYPE   : RCS 65ML BOTTLE         * SAMPLE QUANTITY : 1.58100E+01 GRAMS
*******************************************************************************

ACQ DATE & TIME    : 9-APR-2001 09:45:  * DEADTIME (%)      : 4.6%
PRESET  LIVE TIME : 0 01:00:00          * SENSITIVITY       : 4.00000
ELASPED REAL TIME : 0 01:02:52          * GAUSSIAN SEN      : 10.00000
ELAPSED LIVE TIME : 0 01:00:00          * NBR ITERATIONS   : 10
*******************************************************************************

DETECTOR           : DET #4, GSS-3310   * LIBRARY              : RCSLIQUID
EFFIC CAL DATE     : 19-JUL-2000 20:26  * EFFIC CERT DATE      : 19-JUL-2000 20:26
DCAL DATE & TIME   : 9-APR-2001 02:40:  * ENERGY TOLER         : 1.25
KEV/CHAN           : 5.00516E-01        * HALF LIFE RATIO      : 8.00000
OFFSET             : 1.44837E-01 keV    * ABUNDANCE LIMIT      : 80.0%
Q COEFFICIENT      : -1.10914E-07       * CORRECTION FACTOR    : 1.00000E+00
PEAK START CHAN    : 140                * PEAK END CHAN        : 4096
*******************************************************************************
ANALYSES : PEAK V16.9 NID V3.3 MINACT V2.8 WTMEAN/KEY V1.8
*******************************************************************************

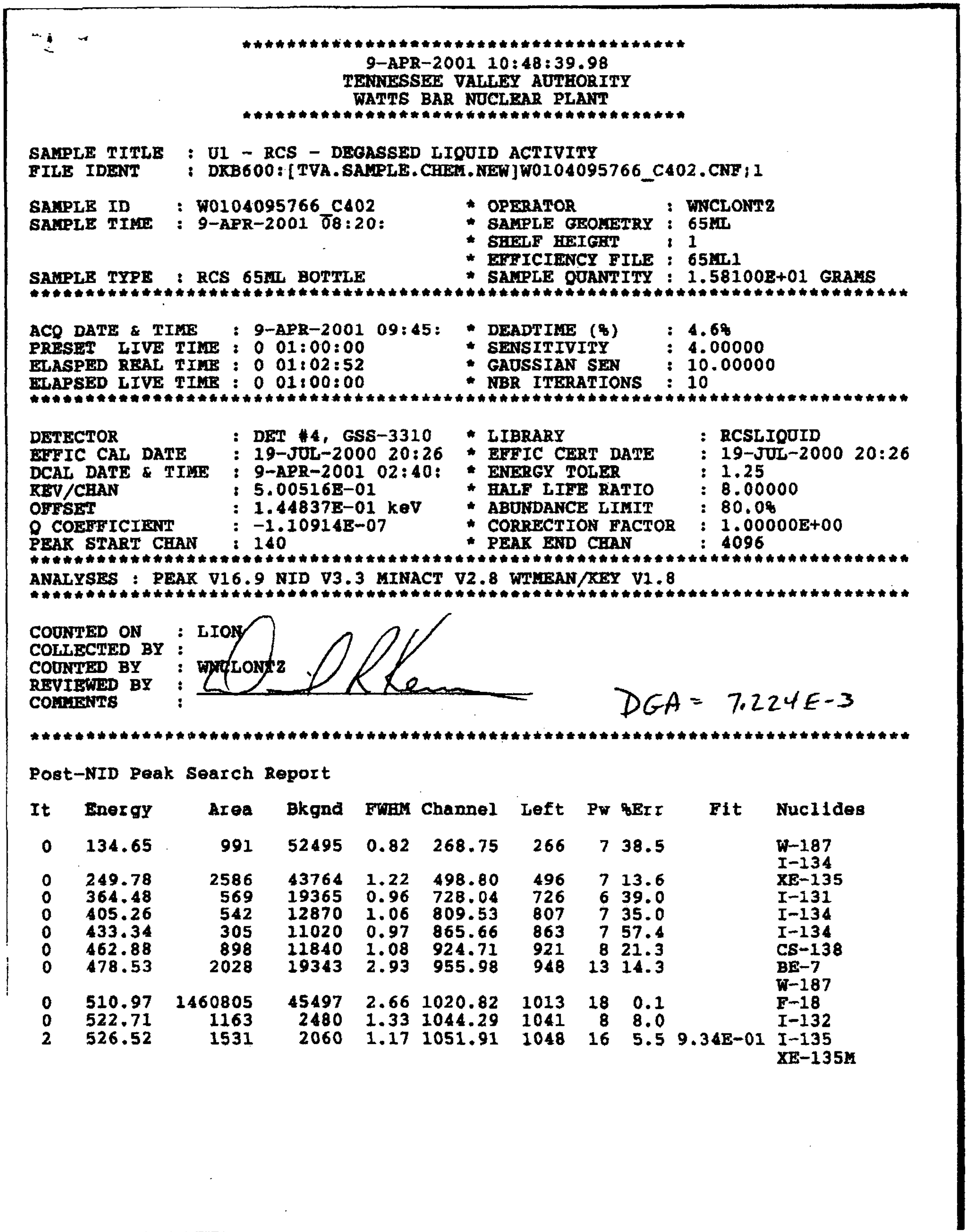
COUNTED ON    : LION
COLLECTED BY  :
COUNTED BY    : WNCLONTZ
REVIEWED BY   :
COMMENTS      :
*******************************************************************************

Post-NID Peak Search Report

It   Energy     Area   Bkgnd  FWHM Channel   Left   Pw %Err     Fit     Nuclides

 0   134.65      991   52495  0.82  268.75    266    7 38.5              W-187
                                                                         I-134
 0   249.78     2586   43764  1.22  498.80    496    7 13.6              XE-135
 0   364.48      569   19365  0.96  728.04    726    6 39.0              I-131
 0   405.26      542   12870  1.06  809.53    807    7 35.0              I-134
 0   433.34      305   11020  0.97  865.66    863    7 57.4              I-134
 0   462.88      898   11840  1.08  924.71    921    8 21.3              CS-138
 0   478.53     2028   19343  2.93  955.98    948   13 14.3              BE-7
                                                                         W-187
 0   510.97  1460805   45497  2.66 1020.82   1013   18  0.1              F-18
 0   522.71     1163    2480  1.33 1044.29   1041    8  8.0              I-132
 2   526.52     1531    2060  1.17 1051.91   1048   16  5.5 9.34E-01 I-135
                                                                         XE-135M
```

DGA = 7.224E-3



```
                   ******************************************
                          9-APR-2001 10:48:39.98
                        TENNESSEE VALLEY AUTHORITY
                         WATTS BAR NUCLEAR PLANT
                   ******************************************

SAMPLE TITLE  : U1 - RCS - DEGASSED LIQUID ACTIVITY
FILE IDENT    : DKB600:[TVA.SAMPLE.CHEM.NEW]W0104095766_C402.CNF;1

SAMPLE ID     : W0104095766_C402        * OPERATOR          : WNCLONTZ
SAMPLE TIME   : 9-APR-2001 08:20:       * SAMPLE GEOMETRY : 65ML
                                        * SHELF HEIGHT      : 1
                                        * EFFICIENCY FILE : 65ML1
SAMPLE TYPE   : RCS 65ML BOTTLE         * SAMPLE QUANTITY : 1.58100E+01 GRAMS
*****************************************************************************

ACQ DATE & TIME     : 9-APR-2001 09:45: * DEADTIME (%)      : 4.6%
PRESET  LIVE TIME : 0 01:00:00          * SENSITIVITY       : 4.00000
ELASPED REAL TIME : 0 01:02:52          * GAUSSIAN SEN      : 10.00000
ELAPSED LIVE TIME : 0 01:00:00          * NBR ITERATIONS    : 10
*****************************************************************************

DETECTOR            : DET #4, GSS-3310  * LIBRARY              : RCSLIQUID
EFFIC CAL DATE      : 19-JUL-2000 20:26 * EFFIC CERT DATE      : 19-JUL-2000 20:26
DCAL DATE & TIME    : 9-APR-2001 02:40: * ENERGY TOLER         : 1.25
KEV/CHAN            : 5.00516E-01       * HALF LIFE RATIO      : 8.00000
OFFSET              : 1.44837E-01 keV   * ABUNDANCE LIMIT      : 80.0%
Q COEFFICIENT       : -1.10914E-07      * CORRECTION FACTOR    : 1.00000E+00
PEAK START CHAN     : 140               * PEAK END CHAN        : 4096
*****************************************************************************
ANALYSES : PEAK V16.9 NID V3.3 MINACT V2.8 WTMEAN/KEY V1.8
*****************************************************************************

COUNTED ON    : LION
COLLECTED BY  :
COUNTED BY    : WNCLONTZ
REVIEWED BY   :
COMMENTS      :
*****************************************************************************

Post-NID Peak Search Report

It   Energy      Area    Bkgnd   FWHM  Channel   Left   Pw  %Err      Fit     Nuclides

 0   134.65       991    52495   0.82   268.75    266    7  38.5              W-187
                                                                              I-134
 0   249.78      2586    43764   1.22   498.80    496    7  13.6              XE-135
 0   364.48       569    19365   0.96   728.04    726    6  39.0              I-131
 0   405.26       542    12870   1.06   809.53    807    7  35.0              I-134
 0   433.34       305    11020   0.97   865.66    863    7  57.4              I-134
 0   462.88       898    11840   1.08   924.71    921    8  21.3              CS-138
 0   478.53      2028    19343   2.93   955.98    948   13  14.3              BE-7
                                                                              W-187
 0   510.97   1460805    45497   2.66  1020.82   1013   18   0.1              F-18
 0   522.71      1163     2480   1.33  1044.29   1041    8   8.0              I-132
 2   526.52      1531     2060   1.17  1051.91   1048   16   5.5  9.34E-01    I-135
                                                                              XE-135M
```

DGA = 7.224E-3

```
REPORT NAME : QA_CHECK (V10.4)                              PAGE :     1
REPORT DATE :  9-APR-2001 10:48
REQUESTOR   : WNCLONTZ

                      TENNESSEE VALLEY AUTHORITY
                       WATTS BAR NUCLEAR PLANT

                          POST NID QA ANALYSIS

TITLE : U1 - RCS - DEGASSED LIQUID ACTIVITY

SAMPLE No.   : W0104095766_C402       OPERATOR NAME    : WNCLONTZ
SAMPLE TYPE  : RCS 65ML BOTTLE        SAMPLE GEOMETRY  : 65ML
COUNT TIME   : 9-APR-2001 09:45:36.   SAMPLE QUANTITY  : 1.58100E+01
SAMPLE TIME  : 9-APR-2001 08:20:00.   DETECTOR         : DET #4, GSS-3310
LIBRARY      : RCSLIQUID

              PEAK    ENERGY      DECAY CORR
 ISOTOPE     ENERGY  DIFF (KEV)   uCi/GRAM          COMMENTS
 --------    ------  ---------    ---------   -------------------------

  F-18       511.00   -0.03       1.116E-01        QA Results OK
  NA-24     1368.53    0.05       2.060E-03        QA Results OK
  MN-56     1810.69    0.33       2.088E-04        QA Results OK
  CO-58      810.76    0.00       6.218E-04        QA Results OK
  CO-60     1173.22    0.28       2.776E-05        QA Results OK
  NB-95      765.79    0.46       2.794E-05        QA Results OK
  I-131      364.48    0.00       3.881E-05        QA Results OK
  I-132      667.69    0.00       1.165E-03        QA Results OK
  I-133      529.87    0.01       6.105E-04        QA Results OK
  I-134      847.03   -0.04       2.334E-03        QA Results OK
  I-135     1260.41   -0.03       1.158E-03        QA Results OK
  XE-135     249.79   -0.02       1.380E-04        QA Results OK
  XE-135M    526.56   -0.04       1.972E-02        QA Results OK
  CS-138    1435.86   -0.20       2.195E-03        QA Results OK
                     -------
  AVG ENERGY DIFF =    0.06       1.419E-01 = TOTAL GAMMA ACTIVITY
                                  1.168E-01 = Total DGL Activity
                                  2.223E-03 = Total FP Activity
                                  2.918E-03 = Total AP Activity
                                  1.986E-02 = Total Gas Activity
                                  5.307E-03 = Total HFP Activity


 Dose Equivalent Iodine-131 =  2.098E-04
 Iodine 131/133 Ratio =  6.357E-02
 Iodine 133/135 Ratio =  5.274E-01


 134.65 KeV Peak was used in identifying  2 isotopes
 478.53 KeV Peak was used in identifying  2 isotopes
 526.52 KeV Peak was used in identifying  2 isotopes
 546.50 KeV Peak was used in identifying  2 isotopes
 766.25 KeV Peak was used in identifying  2 isotopes
 772.62 KeV Peak was used in identifying  2 isotopes
 810.76 KeV Peak was used in identifying  2 isotopes
 835.61 KeV Peak was used in identifying  2 isotopes
 846.98 KeV Peak was used in identifying  2 isotopes
```

Attachment 11

FENCDOSE Run

APS77F10A.txt

Time Dependent Releases preaccident 21 uCi/gm I-131 equivalent case

```
1
          FFFFFFFFFF  EEEEEEEEEE  NN       NN     CCCCCC     DDDDDDDD        OOOOOO
SSSSSS    EEEEEEEEEE
          FFFFFFFFFF  EEEEEEEEEE  NNN      NN    CCCCCCCC    DDDDDDDDD      OOOOOOOO
SSSSSSSS   EEEEEEEEEE
          FF          EE          NNNN     NN   CC       CC  DD       DD  OO       OO  SS
     SS  EE
          FF          EE          NN NN    NN   CC           DD       DD  OO       OO  SS
         EE
          FFFFFFFF    EEEEEEEE    NN   NN  NN   CC           DD       DD  OO       OO
SSSSSSSSS   EEEEEEEE
          FFFFFFFF    EEEEEEEE    NN    NN NN   CC           DD       DD  OO       OO
SSSSSSSSS  EEEEEEEE
          FF          EE          NN     NNNN   CC           DD       DD  OO       OO
     SS  EE
          FF          EE          NN      NNN   CC       CC  DD       DD  OO       OO  SS
     SS  EE
          FF          EEEEEEEEEE  NN       NN    CCCCCCCC    DDDDDDDDD      OOOOOOOO
SSSSSSSS   EEEEEEEEEE
          FF          EEEEEEEEEE  NN       NN     CCCCCC     DDDDDDDD        OOOOOO
SSSSSS    EEEEEEEEEE


          RRRRRRRR    EEEEEEEEEE  VV       VV                5555555555

          RRRRRRRRR   EEEEEEEEEE  VV       VV                5555555555

          RR      RR  EE           VV     VV                 55

          RR      RR  EE           VV     VV                 55

          RRRRRRRRR   EEEEEEEE      VV   VV                   5555555

          RRRRRRRR    EEEEEEEE      VV   VV                    5555555

          RR    RR    EE             VVVV                            55

          RR     RR   EE             VVVV                    55      55

          RR      RR  EEEEEEEEEE      VV                      55555555

          RR      RR  EEEEEEEEEE      VV                       555555


          WW      WW    IIIIII    NN       NN     999999     5555555555  NN       NN
QQQQQQ      AAAAAA
          WW      WW    IIIIII    NNN      NN    99999999    5555555555  NNN      NN
QQQQQQQQ    AAAAAAAA
          WW      WW      II      NNNN     NN   99      99   55          NNNN     NN  QQ
     QQ  AA      AA
          WW      WW      II      NN NN    NN   99      99   55          NN NN    NN  QQ
     QQ  AA      AA
          WW      WW      II      NN   NN  NN    999999999    5555555    NN   NN  NN  QQ
     QQ  AA      AA
          WW  WW  WW      II      NN    NN NN     99999999     5555555   NN    NN NN  QQ
  Q  QQ  AAAAAAAAAA
          WW WWWW WW      II      NN     NNNN           99           55  NN     NNNN  QQ
   Q QQ  AAAAAAAAAA
          WWWW  WWWW      II      NN      NNN   99      99   55      55  NN      NNN  QQ
    QQQ  AA      AA
          WWW     WWW   IIIIII    NN       NN    99999999     55555555   NN       NN
QQQQQQQQ   AA      AA
```

```
          WW      WW    IIIIII    NN      NN    999999      555555    NN      NN
QQQQQQ Q  AA      AA


            00000         11              //    222222      888888            //
 11        00000
           0000000       111             //    22222222    88888888          //
111       0000000
          00     00     1111            //    22      22  88      88        //
1111      00     00
          00     00       11           //              22  88      88       //
 11      00     00
          00     00       11          //        2222222    88888888       //
 11      00     00
          00     00       11         //        2222222     88888888      //
 11      00     00
          00     00       11        //        22          88      88    //
 11      00     00
          00     00       11       //         22          88      88   //
 11      00     00
           0000000      111111    //          2222222222   88888888   //
111111     0000000
            00000       111111    /           2222222222    888888    /
111111      00000


              11        666666                5555555555  7777777777
333333    5555555555
             111       66666666               5555555555  7777777777
33333333   5555555555
            1111      66      66      ::      55                 77       ::      33
     33  55
              11      66              ::      55                77        ::
     33  55
              11      66666666                 5555555         77
 33333    5555555
              11      666666666                 5555555       77
 33333     5555555
              11      66      66      ::              55     77           ::
     33          55
              11      66      66      ::      55      55    77            ::      33
     33  55      55
            111111     66666666                5555555555    77
33333333    55555555
            111111      666666                  555555    77
333333      555555


1



1
 REPRODUCTION OF INPUT DATA DECK


 +         +         +         +         +         +         +         +

 1
 KRM-83   KRM-85   KR-85
 KR-87    KR-88    KR-89
 XEM-131 XEM-133 XE-133 XEM-135 XE-135 XE-138
 I-131    I-132    I-133  I-134    I-135
```

```
I*-131  I*-132  I*-133 I*-134  I*-135  H-3
T
.141E-3  .668E-4  .459E-4  .204E-4  .635E-5  6.07E-4
WBN MSLB, 21 UCI/CC INITIAL CONC, 10+1GPM LK SS,1.0 GPM LEAK IN SG
TIME TO 20.6 SEC
    4  'ENVIRONMENT                    ' $ TN=  0.5722E-02
          1 0.000E+00    2 6.118E-02    3 9.312E-02    4 5.462E-02    5 1.065E-01
          6 0.000E+00    7 2.267E-01    8 2.593E-02    9 8.871E-01   10 4.914E-02
         11 3.221E-01   12 4.523E-02   13 2.112E+00   14 5.071E+00   15 6.038E+00
         16 4.445E+00   17 9.285E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
         21 0.000E+00   22 0.000E+00   23 4.847E+00
WBN MSLB, 21 UCI/CC INITIAL CONC, 10+1GPM LK SS,1.0 GPM LEAK IN SG
TIME TO 2.0 HR
    4  'ENVIRONMENT                    ' $ TN=  0.2000E+01
          1 0.000E+00    2 2.306E+00    3 4.182E+00    4 1.518E+00    5 3.700E+00
          6 0.000E+00    7 1.025E+01    8 1.123E+00    9 3.972E+01   10 7.368E+00
         11 1.645E+01   12 3.237E-01   13 3.690E+00   14 1.292E+01   15 1.117E+01
         16 1.391E+01   17 1.935E+01   18 0.000E+00   19 0.000E+00   20 0.000E+00
         21 0.000E+00   22 0.000E+00   23 6.132E+01
WBN MSLB, 21 UCI/CC INITIAL CONC, 10+1GPM LK SS,1.0 GPM LEAK IN SG
TIME TO 8.0 HR
    4  'ENVIRONMENT                    ' $ TN=  0.8000E+01
          1 0.000E+00    2 4.046E+00    3 1.325E+01    4 7.748E-01    5 4.693E+00
          6 0.000E+00    7 3.219E+01    8 3.429E+00    9 1.243E+02   10 1.677E+01
         11 5.700E+01   12 9.735E-04   13 1.086E+01   14 1.295E+01   15 2.924E+01
         16 3.584E+00   17 3.862E+01   18 0.000E+00   19 0.000E+00   20 0.000E+00
         21 0.000E+00   22 0.000E+00   23 1.713E+02
WBN MSLB
TIME TO 1 DAY
   -6  'ENVIRONMENT       CURIES       ' $ TN=  0.2400E+02
          1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
          6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
         11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
         16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
         21 0.000E+00   22 0.000E+00   23 0.000E+00
WBN MSLB
TIME TO 4 DAYS
   -6  'ENVIRONMENT       CURIES       ' $ TN=  0.9600E+02
          1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
          6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
         11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
         16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
         21 0.000E+00   22 0.000E+00   23 0.000E+00
WBN MSLB
TIME TO 30 DAYS
   -6  'ENVIRONMENT       CURIES       ' $ TN=  0.7200E+03
          1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
          6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
         11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
         16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
         21 0.000E+00   22 0.000E+00   23 0.000E+00

 +         +         +         +         +         +         +         +


1                                                         PROGRAM FENCDOSE
0                                                       REVISION NUMBER:5
0                                                 REVISION DATE: 31 JUL 2009
0                                                      TODAY IS: 01/28/10
0                                                  STARTING TIME IS: 16:57:35
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1ISOTOPE        GAMMA ENERGY    BETA ENERGY
                 (MEV/DIS)       (MEV/DIS)
 KRM-83           0.0025          0.0371
 KRM-85           0.1586          0.2529
 KR-85            0.0022          0.2506
 KR-87            0.7928          1.3237
 KR-88            1.9629          0.3750
 KR-89            2.0837          1.2310
 XEM-131          0.0201          0.1428
 XEM-133          0.0416          0.1898
 XE-133           0.0454          0.1354
 XEM-135          0.4318          0.0950
 XE-135           0.2470          0.3168
 XE-138           1.1830          0.6058
 I-131            0.3810          0.1943
 I-132            2.3332          0.5143
 I-133            0.6100          0.4080
 I-134            2.5928          0.6102
 I-135            1.5802          0.3680
 I*~131           0.3810          0.1943
 I*~132           2.3332          0.5143
 I*~133           0.6100          0.4080
 I*~134           2.5928          0.6102
 I*~135           1.5802          0.3680
 H-3              0.0000          0.0057


0CHI/Q
   1.410E-04   6.680E-05   4.590E-05   2.040E-05   6.350E-06
   6.070E-04


1
0WBN MSLB, 21 UCI/CC INITIAL CONC, 10+1GPM LK SS,1.0 GPM LEAK IN SG
 TIME TO 20.6 SEC
 COMPONENT  4 ENVIRONMENT                           , TIME =   0.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.6118E-01
 KR~85          0.9312E-01
 KR~87          0.5462E-01
 KR~88          0.1065E+00
 KR~89          0.0000E+00
 XEM-131        0.2267E+00
 XEM-133        0.2593E-01
 XE~133         0.8871E+00
 XEM-135        0.4914E-01
 XE~135         0.3221E+00
 XE~138         0.4523E-01
 I-131          0.2112E+01
 I-132          0.5071E+01
 I-133          0.6038E+01
 I-134          0.4445E+01
 I-135          0.9285E+01
 I*~131         0.0000E+00
 I*~132         0.0000E+00
 I*~133         0.0000E+00
 I*~134         0.0000E+00
 I*~135         0.0000E+00
 H-3            0.4847E+01
0WBN MSLB, 21 UCI/CC INITIAL CONC, 10+1GPM LK SS,1.0 GPM LEAK IN SG
 TIME TO 2.0 HR
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 COMPONENT  4 ENVIRONMENT                    , TIME =  2.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.2306E+01
 KR-85          0.4182E+01
 KR-87          0.1518E+01
 KR-88          0.3700E+01
 KR-89          0.0000E+00
 XEM-131        0.1025E+02
 XEM-133        0.1123E+01
 XE-133         0.3972E+02
 XEM-135        0.7368E+01
 XE-135         0.1645E+02
 XE-138         0.3237E+00
 I-131          0.3690E+01
 I-132          0.1292E+02
 I-133          0.1117E+02
 I-134          0.1391E+02
 I-135          0.1935E+02
 I*-131         0.0000E+00
 I*-132         0.0000E+00
 I*-133         0.0000E+00
 I*-134         0.0000E+00
 I*-135         0.0000E+00
 H-3            0.6132E+02
0WBN MSLB, 21 UCI/CC INITIAL CONC, 10+1GPM LK SS,1.0 GPM LEAK IN SG
 TIME TO 8.0 HR
 COMPONENT  4 ENVIRONMENT                    , TIME =  8.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.4046E+01
 KR-85          0.1325E+02
 KR-87          0.7748E+00
 KR-88          0.4693E+01
 KR-89          0.0000E+00
 XEM-131        0.3219E+02
 XEM-133        0.3429E+01
 XE-133         0.1243E+03
 XEM-135        0.1677E+02
 XE-135         0.5700E+02
 XE-138         0.9735E-03
 I-131          0.1086E+02
 I-132          0.1295E+02
 I-133          0.2924E+02
 I-134          0.3584E+01
 I-135          0.3862E+02
 I*-131         0.0000E+00
 I*-132         0.0000E+00
 I*-133         0.0000E+00
 I*-134         0.0000E+00
 I*-135         0.0000E+00
 H-3            0.1713E+03
0WBN MSLB
 TIME TO 1 DAY
 COMPONENT  6 ENVIRONMENT       CURIES       , TIME = 24.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.0000E+00
 KR-85          0.0000E+00
 KR-87          0.0000E+00
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 KR-88          0.0000E+00
 KR-89          0.0000E+00
 XEM-131        0.0000E+00
 XEM-133        0.0000E+00
 XE-133         0.0000E+00
 XEM-135        0.0000E+00
 XE-135         0.0000E+00
 XE-138         0.0000E+00
 I-131          0.0000E+00
 I-132          0.0000E+00
 I-133          0.0000E+00
 I-134          0.0000E+00
 I-135          0.0000E+00
 I*-131         0.0000E+00
 I*-132         0.0000E+00
 I*-133         0.0000E+00
 I*-134         0.0000E+00
 I*-135         0.0000E+00
 H-3            0.0000E+00
0WBN MSLB
 TIME TO 4 DAYS
 COMPONENT  6 ENVIRONMENT        CURIES       , TIME = 96.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.0000E+00
 KR-85          0.0000E+00
 KR-87          0.0000E+00
 KR-88          0.0000E+00
 KR-89          0.0000E+00
 XEM-131        0.0000E+00
 XEM-133        0.0000E+00
 XE-133         0.0000E+00
 XEM-135        0.0000E+00
 XE-135         0.0000E+00
 XE-138         0.0000E+00
 I-131          0.0000E+00
 I-132          0.0000E+00
 I-133          0.0000E+00
 I-134          0.0000E+00
 I-135          0.0000E+00
 I*-131         0.0000E+00
 I*-132         0.0000E+00
 I*-133         0.0000E+00
 I*-134         0.0000E+00
 I*-135         0.0000E+00
 H-3            0.0000E+00
0WBN MSLB
 TIME TO 30 DAYS
 COMPONENT  6 ENVIRONMENT        CURIES       , TIME =720.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.0000E+00
 KR-85          0.0000E+00
 KR-87          0.0000E+00
 KR-88          0.0000E+00
 KR-89          0.0000E+00
 XEM-131        0.0000E+00
 XEM-133        0.0000E+00
 XE-133         0.0000E+00
 XEM-135        0.0000E+00
 XE-135         0.0000E+00
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 XE-138          0.0000E+00
 I-131           0.0000E+00
 I-132           0.0000E+00
 I-133           0.0000E+00
 I-134           0.0000E+00
 I-135           0.0000E+00
 I*-131          0.0000E+00
 I*-132          0.0000E+00
 I*-133          0.0000E+00
 I*-134          0.0000E+00
 I*-135          0.0000E+00
 H-3             0.0000E+00

1INPUT CONCENTRATION
 KRM-83        0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00
 KRM-85        2.3672E+00     4.0460E+00     0.0000E+00     0.0000E+00     0.0000E+00
 KR-85         4.2751E+00     1.3250E+01     0.0000E+00     0.0000E+00     0.0000E+00
 KR-87         1.5726E+00     7.7480E-01     0.0000E+00     0.0000E+00     0.0000E+00
 KR-88         3.8065E+00     4.6930E+00     0.0000E+00     0.0000E+00     0.0000E+00
 KR-89         0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00
 XEM-131       1.0477E+01     3.2190E+01     0.0000E+00     0.0000E+00     0.0000E+00
 XEM-133       1.1489E+00     3.4290E+00     0.0000E+00     0.0000E+00     0.0000E+00
 XE-133        4.0607E+01     1.2430E+02     0.0000E+00     0.0000E+00     0.0000E+00
 XEM-135       7.4171E+00     1.6770E+01     0.0000E+00     0.0000E+00     0.0000E+00
 XE-135        1.6772E+01     5.7000E+01     0.0000E+00     0.0000E+00     0.0000E+00
 XE-138        3.6893E-01     9.7350E-04     0.0000E+00     0.0000E+00     0.0000E+00
 I-131         5.8020E+00     1.0860E+01     0.0000E+00     0.0000E+00     0.0000E+00
 I-132         1.7991E+01     1.2950E+01     0.0000E+00     0.0000E+00     0.0000E+00
 I-133         1.7208E+01     2.9240E+01     0.0000E+00     0.0000E+00     0.0000E+00
 I-134         1.8355E+01     3.5840E+00     0.0000E+00     0.0000E+00     0.0000E+00
 I-135         2.8635E+01     3.8620E+01     0.0000E+00     0.0000E+00     0.0000E+00
 I*-131        0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00
 I*-132        0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00
 I*-133        0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00
 I*-134        0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00
 I*-135        0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00     0.0000E+00
 H-3           6.6167E+01     1.7130E+02     0.0000E+00     0.0000E+00     0.0000E+00

1WBN MSLB

0GAMMA DOSE FOR EACH ISOTOPE AND TIME PERIOD (REM)

   ID    ISOTOPE        0-2 HRS      2-8 HRS     8-24 HRS     1-4 DAYS     4-30 DAYS
2-HR EAB

    1    KRM-83       0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
    2    KRM-85       1.324E-05    1.072E-05    0.000E+00    0.000E+00    0.000E+00
5.698E-05
    3    KR-85        3.331E-07    4.891E-07    0.000E+00    0.000E+00    0.000E+00
1.434E-06
    4    KR-87        4.395E-05    1.026E-05    0.000E+00    0.000E+00    0.000E+00
1.892E-04
    5    KR-88        2.634E-04    1.538E-04    0.000E+00    0.000E+00    0.000E+00
1.134E-03
    6    KR-89        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
    7    XEM-131      7.407E-06    1.078E-05    0.000E+00    0.000E+00    0.000E+00
3.189E-05
    8    XEM-133      1.683E-06    2.380E-06    0.000E+00    0.000E+00    0.000E+00
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7.246E-06
  9    XE-133        6.496E-05   9.421E-05   0.000E+00   0.000E+00   0.000E+00
2.797E-04
 10    XEM-135       1.129E-04   1.209E-04   0.000E+00   0.000E+00   0.000E+00
4.860E-04
 11    XE-135        1.460E-04   2.351E-04   0.000E+00   0.000E+00   0.000E+00
6.286E-04
 12    XE-138        1.538E-05   1.923E-08   0.000E+00   0.000E+00   0.000E+00
6.623E-05
 13    I-131         7.792E-05   6.909E-05   0.000E+00   0.000E+00   0.000E+00
3.354E-04
 14    I-132         1.480E-03   5.046E-04   0.000E+00   0.000E+00   0.000E+00
6.370E-03
 15    I-133         3.700E-04   2.979E-04   0.000E+00   0.000E+00   0.000E+00
1.593E-03
 16    I-134         1.678E-03   1.552E-04   0.000E+00   0.000E+00   0.000E+00
7.222E-03
 17    I-135         1.595E-03   1.019E-03   0.000E+00   0.000E+00   0.000E+00
6.867E-03
 18    I*-131        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
 19    I*-132        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
 20    I*-133        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
 21    I*-134        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
 22    I*-135        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
 23    H-3           0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
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 TOTAL               5.869E-03   2.685E-03   0.000E+00   0.000E+00   0.000E+00
2.527E-02
0BETA DOSE FOR EACH ISOTOPE AND TIME PERIOD (REM)

   ID   ISOTOPE        0-2 HRS     2-8 HRS    8-24 HRS    1-4 DAYS    4-30 DAYS
2-HR EAB

   1    KRM-83       0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   2    KRM-85       1.941E-05   1.572E-05   0.000E+00   0.000E+00   0.000E+00
8.358E-05
   3    KR-85        3.474E-05   5.102E-05   0.000E+00   0.000E+00   0.000E+00
1.496E-04
   4    KR-87        6.751E-05   1.576E-05   0.000E+00   0.000E+00   0.000E+00
2.906E-04
   5    KR-88        4.629E-05   2.704E-05   0.000E+00   0.000E+00   0.000E+00
1.993E-04
   6    KR-89        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   7    XEM-131      4.852E-05   7.062E-05   0.000E+00   0.000E+00   0.000E+00
2.089E-04
   8    XEM-133      7.072E-06   9.999E-06   0.000E+00   0.000E+00   0.000E+00
3.044E-05
   9    XE-133       1.783E-04   2.586E-04   0.000E+00   0.000E+00   0.000E+00
7.676E-04
  10    XEM-135      2.285E-05   2.448E-05   0.000E+00   0.000E+00   0.000E+00
9.837E-05
  11    XE-135       1.723E-04   2.774E-04   0.000E+00   0.000E+00   0.000E+00
7.418E-04
  12    XE-138       7.248E-06   9.061E-09   0.000E+00   0.000E+00   0.000E+00
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3.120E-05
  13    I-131        3.656E-05   3.242E-05   0.000E+00   0.000E+00   0.000E+00
1.574E-04
  14    I-132        3.001E-04   1.023E-04   0.000E+00   0.000E+00   0.000E+00
1.292E-03
  15    I-133        2.277E-04   1.833E-04   0.000E+00   0.000E+00   0.000E+00
9.802E-04
  16    I-134        3.632E-04   3.360E-05   0.000E+00   0.000E+00   0.000E+00
1.564E-03
  17    I-135        3.417E-04   2.184E-04   0.000E+00   0.000E+00   0.000E+00
1.471E-03
  18    I*-131       0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  19    I*-132       0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  20    I*-133       0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  21    I*-134       0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  22    I*-135       0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  23    H-3          1.219E-05   1.495E-05   0.000E+00   0.000E+00   0.000E+00
5.247E-05
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 TOTAL               1.886E-03   1.336E-03   0.000E+00   0.000E+00   0.000E+00
8.118E-03
0INHALATION DOSE FOR EACH IODINE AND TIME PERIOD (REM) (ICRP 2 DATA

   ID   ISOTOPE        0-2 HRS     2-8 HRS    8-24 HRS    1-4 DAYS    4-30 DAYS
2-HR EAB

   1    I-131        4.201E-01   3.726E-01   0.000E+00   0.000E+00   0.000E+00
1.809E+00
   2    I-132        4.709E-02   1.606E-02   0.000E+00   0.000E+00   0.000E+00
2.027E-01
   3    I-133        3.368E-01   2.711E-01   0.000E+00   0.000E+00   0.000E+00
1.450E+00
   4    I-134        2.245E-02   2.077E-03   0.000E+00   0.000E+00   0.000E+00
9.665E-02
   5    I-135        1.737E-01   1.110E-01   0.000E+00   0.000E+00   0.000E+00
7.479E-01
   6    I*-131       0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   7    I*-132       0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   8    I*-133       0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   9    I*-134       0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  10    I*-135       0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
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 TOTAL               1.000E+00   7.728E-01   0.000E+00   0.000E+00   0.000E+00
4.306E+00
0INHALATION DOSE FOR EACH IODINE AND TIME PERIOD (REM) (ICRP 30 DATA)

   ID   ISOTOPE        0-2 HRS     2-8 HRS    8-24 HRS    1-4 DAYS    4-30 DAYS
2-HR EAB

   1    I-131        3.066E-01   2.719E-01   0.000E+00   0.000E+00   0.000E+00
1.320E+00
```

```
  2    I-132         5.669E-03   1.933E-03   0.000E+00   0.000E+00   0.000E+00
2.440E-02
  3    I-133         1.515E-01   1.220E-01   0.000E+00   0.000E+00   0.000E+00
6.524E-01
  4    I-134         9.609E-04   8.889E-05   0.000E+00   0.000E+00   0.000E+00
4.137E-03
  5    I-135         4.385E-02   2.802E-02   0.000E+00   0.000E+00   0.000E+00
1.888E-01
  6    I*-131        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  7    I*-132        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  8    I*-133        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  9    I*-134        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
 10    I*-135        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
                     ---------   ---------   ---------   ---------   ---------
---------
 TOTAL               5.086E-01   4.239E-01   0.000E+00   0.000E+00   0.000E+00
2.190E+00
0AT 2 HOUR EXCLUSION AREA BOUNDARY (EAB)


 TOTAL GAMMA DOSE =  2.527E-02 REM
 TOTAL BETA DOSE =  8.118E-03 REM
 TOTAL INHALATION DOSE (ICRP-2) =  4.306E+00 REM
 TOTAL INHALATION DOSE (ICRP-30) =  2.190E+00 REM

0AT 30 DAY LPZ BOUNDARY


 TOTAL GAMMA DOSE =  8.554E-03 REM
 TOTAL BETA DOSE =  3.221E-03 REM
 TOTAL INHALATION DOSE (ICRP-2) =  1.773E+00 REM
 TOTAL INHALATION DOSE (ICRP-30) =  9.325E-01 REM

 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.


1WBN MSLB


0TEDE FOR EACH ISOTOPE AND TIME PERIOD (REM)

   ID   ISOTOPE       0-2 HRS     2-8 HRS     8-24 HRS    1-4 DAYS    4-30 DAYS
2-HR EAB

  1    KRM-83        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  2    KRM-85        8.622E-06   6.982E-06   0.000E+00   0.000E+00   0.000E+00
3.712E-05
  3    KR-85         2.177E-07   3.196E-07   0.000E+00   0.000E+00   0.000E+00
9.371E-07
  4    KR-87         3.141E-05   7.332E-06   0.000E+00   0.000E+00   0.000E+00
1.352E-04
  5    KR-88         1.938E-04   1.132E-04   0.000E+00   0.000E+00   0.000E+00
```

```
8.344E-04
   6    KR-89          0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   7    XEM-131        2.011E-06   2.927E-06   0.000E+00   0.000E+00   0.000E+00
8.656E-06
   8    XEM-133        7.650E-07   1.082E-06   0.000E+00   0.000E+00   0.000E+00
3.293E-06
   9    XE-133         3.181E-05   4.613E-05   0.000E+00   0.000E+00   0.000E+00
1.369E-04
  10    XEM-135        7.263E-05   7.779E-05   0.000E+00   0.000E+00   0.000E+00
3.127E-04
  11    XE-135         9.197E-05   1.481E-04   0.000E+00   0.000E+00   0.000E+00
3.959E-04
  12    XE-138         1.040E-05   1.301E-08   0.000E+00   0.000E+00   0.000E+00
4.479E-05
  13    I-131          1.204E-02   1.068E-02   0.000E+00   0.000E+00   0.000E+00
5.185E-02
  14    I-132          3.453E-03   1.177E-03   0.000E+00   0.000E+00   0.000E+00
1.486E-02
  15    I-133          1.011E-02   8.138E-03   0.000E+00   0.000E+00   0.000E+00
4.352E-02
  16    I-134          2.229E-03   2.062E-04   0.000E+00   0.000E+00   0.000E+00
9.594E-03
  17    I-135          9.084E-03   5.805E-03   0.000E+00   0.000E+00   0.000E+00
3.911E-02
  18    I*-131         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  19    I*-132         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  20    I*-133         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  21    I*-134         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  22    I*-135         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  23    H-3            1.995E-04   2.447E-04   0.000E+00   0.000E+00   0.000E+00
8.590E-04
                       ---------   ---------   ---------   ---------   ---------
---------
 TOTAL                 3.756E-02   2.666E-02   0.000E+00   0.000E+00   0.000E+00
1.617E-01
 TOTAL TEDE =  6.422E-02
0THIS RUN IS DATED 01/28/10. THE TOTAL ELAPSED TIME IS  0.0 MINUTES.  0.0 SECONDS.
```

Attachment 12

FENCDOSE Run

APS77F10B.txt

Time Dependent Releases 0.265 uCi/gm I-131 accident initiated Iodine spike

```
1
          FFFFFFFFFF  EEEEEEEEEE  NN      NN    CCCCCC    DDDDDDDD      OOOOOO
SSSSSS    EEEEEEEEEE
          FFFFFFFFFF  EEEEEEEEEE  NNN     NN   CCCCCCCC   DDDDDDDDD    OOOOOOOO
SSSSSSSS   EEEEEEEEEE
          FF          EE          NNNN    NN  CC      CC  DD      DD  OO      OO  SS
     SS  EE
          FF          EE          NN NN   NN  CC          DD      DD  OO      OO  SS
         EE
          FFFFFFFF    EEEEEEEE    NN  NN  NN  CC          DD      DD  OO      OO
SSSSSSSSS   EEEEEEEE
          FFFFFFFF    EEEEEEEE    NN   NN NN  CC          DD      DD  OO      OO
SSSSSSSSS  EEEEEEEE
          FF          EE          NN    NNNN  CC          DD      DD  OO      OO
     SS  EE
          FF          EE          NN     NNN  CC      CC  DD      DD  OO      OO  SS
     SS  EE
          FF          EEEEEEEEEE  NN      NN   CCCCCCCC   DDDDDDDDD    OOOOOOOO
SSSSSSSS   EEEEEEEEEE
          FF          EEEEEEEEEE  NN      NN    CCCCCC    DDDDDDDD      OOOOOO
SSSSSS    EEEEEEEEEE

          RRRRRRRR    EEEEEEEEEE  VV      VV              5555555555

          RRRRRRRRR   EEEEEEEEEE  VV      VV              5555555555

          RR      RR  EE           VV    VV               55

          RR      RR  EE           VV    VV               55

          RRRRRRRRR   EEEEEEEE      VV  VV                 5555555

          RRRRRRRR    EEEEEEEE      VV  VV                  5555555

          RR   RR     EE             VVVV                         55

          RR    RR    EE             VVVV                 55      55

          RR     RR   EEEEEEEEEE      VV                   55555555

          RR      RR  EEEEEEEEEE      VV                    555555


          WW      WW    IIIIII    NN      NN    999999    5555555555  NN      NN
QQQQQQ      AAAAAA
          WW      WW    IIIIII    NNN     NN   99999999   5555555555  NNN     NN
QQQQQQQQ    AAAAAAAA
          WW      WW      II      NNNN    NN  99      99  55          NNNN    NN  QQ
     QQ  AA      AA
          WW      WW      II      NN NN   NN  99      99  55          NN NN   NN  QQ
     QQ  AA      AA
          WW      WW      II      NN  NN  NN   99999999    5555555    NN  NN  NN  QQ
     QQ  AA      AA
          WW WW   WW      II      NN   NN NN    99999999    5555555   NN   NN NN  QQ
  Q  QQ  AAAAAAAAAA
          WW WWWW WW      II      NN    NNNN          99          55  NN    NNNN  QQ
   Q QQ  AAAAAAAAAA
          WWWW  WWWW      II      NN     NNN  99      99  55      55  NN     NNN  QQ
    QQQ  AA      AA
          WWW    WWW    IIIIII    NN      NN   99999999    55555555   NN      NN
QQQQQQQQ   AA      AA
```

```
          WW      WW    IIIIII    NN      NN    999999      555555    NN      NN
QQQQQQ Q  AA      AA


            00000         11              //    222222      888888            //
 11        00000
           0000000       111             //    22222222    88888888          //
111       0000000
          00     00     1111            //    22        22  88      88      //
1111      00     00
          00     00       11           //             22  88      88     //
 11      00     00
          00     00       11          //      2222222    88888888       //
 11      00     00
          00     00       11         //      2222222    88888888       //
 11      00     00
          00     00       11        //      22          88      88    //
 11      00     00
          00     00       11       //      22          88      88   //
 11      00     00
           0000000      111111    //        2222222222  88888888   //
111111     0000000
            00000       111111    /         2222222222  888888     /
111111      00000


              11        666666                  5555555555  7777777777
5555555555      11
             111       66666666                 5555555555  7777777777
5555555555     111
            1111      66      66      ::        55                 77        ::        55
           1111
             11       66              ::        55                77         ::        55
             11
              11      66666666                   5555555         77
5555555        11
              11      666666666                   5555555       77
5555555       11
              11      66      66      ::                55     77            ::
     55      11
              11      66      66      ::        55      55    77             ::        55
     55      11
            111111     66666666                  55555555    77
55555555     111111
            111111      666666                    555555    77
555555      111111

1


1
 REPRODUCTION OF INPUT DATA DECK


 +         +         +         +         +         +         +         +

 1
 KRM-83  KRM-85  KR-85
 KR-87   KR-88   KR-89
 XEM-131 XEM-133 XE-133 XEM-135 XE-135 XE-138
 I-131   I-132   I-133  I-134   I-135
```

```
I*-131  I*-132  I*-133 I*-134  I*-135  H-3
T
.141E-3  .668E-4  .459E-4  .204E-4  .635E-5  6.07E-4
WBN MSLB,.265 UCI/CC INIT CONC,10+1GPM LK,500 IODINE SPIKE,1.0 GPM SG LK
TIME TO 20.6 SEC
    4  'ENVIRONMENT                         ' $ TN=  0.5722E-02
          1 0.000E+00    2 6.118E-02    3 9.312E-02    4 5.462E-02    5 1.065E-01
          6 0.000E+00    7 2.267E-01    8 2.593E-02    9 8.871E-01   10 4.907E-02
         11 3.221E-01   12 4.523E-02   13 2.101E+00   14 5.023E+00   15 6.006E+00
         16 4.369E+00   17 9.225E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
         21 0.000E+00   22 0.000E+00   23 4.847E+00
WBN MSLB,.265 UCI/CC INIT CONC,10+1GPM LK,500 IODINE SPIKE,1.0 GPM SG LK
TIME TO 2.0 HR
    4  'ENVIRONMENT                         ' $ TN=  0.2000E+01
          1 0.000E+00    2 2.306E+00    3 4.182E+00    4 1.518E+00    5 3.700E+00
          6 0.000E+00    7 1.025E+01    8 1.121E+00    9 3.970E+01   10 8.098E+00
         11 1.638E+01   12 3.237E-01   13 3.079E+00   14 3.853E+01   15 1.147E+01
         16 1.009E+02   17 2.926E+01   18 0.000E+00   19 0.000E+00   20 0.000E+00
         21 0.000E+00   22 0.000E+00   23 6.132E+01
WBN MSLB,.265 UCI/CC INIT CONC,10+1GPM LK,500 IODINE SPIKE,1.0 GPM SG LK
TIME TO 8.0 HR
    4  'ENVIRONMENT                         ' $ TN=  0.8000E+01
          1 0.000E+00    2 4.046E+00    3 1.325E+01    4 7.748E-01    5 4.693E+00
          6 0.000E+00    7 3.219E+01    8 3.533E+00    9 1.262E+02   10 7.861E+01
         11 1.250E+02   12 9.735E-04   13 4.417E+01   14 3.430E+02   15 1.561E+02
         16 5.806E+02   17 3.509E+02   18 0.000E+00   19 0.000E+00   20 0.000E+00
         21 0.000E+00   22 0.000E+00   23 1.713E+02
WBN MSLB
TIME TO 1 DAY
   -6  'ENVIRONMENT           CURIES        ' $ TN=  0.2400E+02
          1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
          6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
         11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
         16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
         21 0.000E+00   22 0.000E+00   23 0.000E+00
WBN MSLB
TIME TO 4 DAYS
   -6  'ENVIRONMENT           CURIES        ' $ TN=  0.9600E+02
          1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
          6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
         11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
         16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
         21 0.000E+00   22 0.000E+00   23 0.000E+00
WBN MSLB
TIME TO 30 DAYS
   -6  'ENVIRONMENT           CURIES        ' $ TN=  0.7200E+03
          1 0.000E+00    2 0.000E+00    3 0.000E+00    4 0.000E+00    5 0.000E+00
          6 0.000E+00    7 0.000E+00    8 0.000E+00    9 0.000E+00   10 0.000E+00
         11 0.000E+00   12 0.000E+00   13 0.000E+00   14 0.000E+00   15 0.000E+00
         16 0.000E+00   17 0.000E+00   18 0.000E+00   19 0.000E+00   20 0.000E+00
         21 0.000E+00   22 0.000E+00   23 0.000E+00

 +         +         +         +         +         +         +         +


1                                                             PROGRAM FENCDOSE
0                                                           REVISION NUMBER:5
0                                                     REVISION DATE: 31 JUL 2009
0                                                           TODAY IS: 01/28/10
0                                                      STARTING TIME IS: 16:57:51
```

```
1ISOTOPE        GAMMA ENERGY    BETA ENERGY
                 (MEV/DIS)       (MEV/DIS)
 KRM-83           0.0025          0.0371
 KRM-85           0.1586          0.2529
 KR-85            0.0022          0.2506
 KR-87            0.7928          1.3237
 KR-88            1.9629          0.3750
 KR-89            2.0837          1.2310
 XEM-131          0.0201          0.1428
 XEM-133          0.0416          0.1898
 XE-133           0.0454          0.1354
 XEM-135          0.4318          0.0950
 XE-135           0.2470          0.3168
 XE-138           1.1830          0.6058
 I-131            0.3810          0.1943
 I-132            2.3332          0.5143
 I-133            0.6100          0.4080
 I-134            2.5928          0.6102
 I-135            1.5802          0.3680
 I*-131           0.3810          0.1943
 I*-132           2.3332          0.5143
 I*-133           0.6100          0.4080
 I*-134           2.5928          0.6102
 I*-135           1.5802          0.3680
 H-3              0.0000          0.0057


0CHI/Q
   1.410E-04   6.680E-05   4.590E-05   2.040E-05   6.350E-06
   6.070E-04


1
0WBN MSLB,.265 UCI/CC INIT CONC,10+1GPM LK,500 IODINE SPIKE,1.0 GPM SG LK
 TIME TO 20.6 SEC
 COMPONENT  4 ENVIRONMENT                          , TIME =   0.
 1ISOTOPE

 KRM-83        0.0000E+00
 KRM-85        0.6118E-01
 KR-85         0.9312E-01
 KR-87         0.5462E-01
 KR-88         0.1065E+00
 KR-89         0.0000E+00
 XEM-131       0.2267E+00
 XEM-133       0.2593E-01
 XE-133        0.8871E+00
 XEM-135       0.4907E-01
 XE-135        0.3221E+00
 XE-138        0.4523E-01
 I-131         0.2101E+01
 I-132         0.5023E+01
 I-133         0.6006E+01
 I-134         0.4369E+01
 I-135         0.9225E+01
 I*-131        0.0000E+00
 I*-132        0.0000E+00
 I*-133        0.0000E+00
 I*-134        0.0000E+00
 I*-135        0.0000E+00
 H-3           0.4847E+01
0WBN MSLB,.265 UCI/CC INIT CONC,10+1GPM LK,500 IODINE SPIKE,1.0 GPM SG LK
 TIME TO 2.0 HR
```

```
 COMPONENT  4 ENVIRONMENT                     , TIME =  2.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.2306E+01
 KR-85          0.4182E+01
 KR-87          0.1518E+01
 KR-88          0.3700E+01
 KR-89          0.0000E+00
 XEM-131        0.1025E+02
 XEM-133        0.1121E+01
 XE-133         0.3970E+02
 XEM-135        0.8098E+01
 XE-135         0.1638E+02
 XE-138         0.3237E+00
 I-131          0.3079E+01
 I-132          0.3853E+02
 I-133          0.1147E+02
 I-134          0.1009E+03
 I-135          0.2926E+02
 I*-131         0.0000E+00
 I*-132         0.0000E+00
 I*-133         0.0000E+00
 I*-134         0.0000E+00
 I*-135         0.0000E+00
 H-3            0.6132E+02
0WBN MSLB,.265 UCI/CC INIT CONC,10+1GPM LK,500 IODINE SPIKE,1.0 GPM SG LK
 TIME TO 8.0 HR
 COMPONENT  4 ENVIRONMENT                     , TIME =  8.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.4046E+01
 KR-85          0.1325E+02
 KR-87          0.7748E+00
 KR-88          0.4693E+01
 KR-89          0.0000E+00
 XEM-131        0.3219E+02
 XEM-133        0.3533E+01
 XE-133         0.1262E+03
 XEM-135        0.7861E+02
 XE-135         0.1250E+03
 XE-138         0.9735E-03
 I-131          0.4417E+02
 I-132          0.3430E+03
 I-133          0.1561E+03
 I-134          0.5806E+03
 I-135          0.3509E+03
 I*-131         0.0000E+00
 I*-132         0.0000E+00
 I*-133         0.0000E+00
 I*-134         0.0000E+00
 I*-135         0.0000E+00
 H-3            0.1713E+03
0WBN MSLB
 TIME TO 1 DAY
 COMPONENT  6 ENVIRONMENT        CURIES       , TIME = 24.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.0000E+00
 KR-85          0.0000E+00
 KR-87          0.0000E+00
```

```
 KR-88          0.0000E+00
 KR-89          0.0000E+00
 XEM-131        0.0000E+00
 XEM-133        0.0000E+00
 XE-133         0.0000E+00
 XEM-135        0.0000E+00
 XE-135         0.0000E+00
 XE-138         0.0000E+00
 I-131          0.0000E+00
 I-132          0.0000E+00
 I-133          0.0000E+00
 I-134          0.0000E+00
 I-135          0.0000E+00
 I*-131         0.0000E+00
 I*-132         0.0000E+00
 I*-133         0.0000E+00
 I*-134         0.0000E+00
 I*-135         0.0000E+00
 H-3            0.0000E+00
0WBN MSLB
 TIME TO 4 DAYS
 COMPONENT  6 ENVIRONMENT        CURIES       , TIME = 96.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.0000E+00
 KR-85          0.0000E+00
 KR-87          0.0000E+00
 KR-88          0.0000E+00
 KR-89          0.0000E+00
 XEM-131        0.0000E+00
 XEM-133        0.0000E+00
 XE-133         0.0000E+00
 XEM-135        0.0000E+00
 XE-135         0.0000E+00
 XE-138         0.0000E+00
 I-131          0.0000E+00
 I-132          0.0000E+00
 I-133          0.0000E+00
 I-134          0.0000E+00
 I-135          0.0000E+00
 I*-131         0.0000E+00
 I*-132         0.0000E+00
 I*-133         0.0000E+00
 I*-134         0.0000E+00
 I*-135         0.0000E+00
 H-3            0.0000E+00
0WBN MSLB
 TIME TO 30 DAYS
 COMPONENT  6 ENVIRONMENT        CURIES       , TIME =720.
 1ISOTOPE

 KRM-83         0.0000E+00
 KRM-85         0.0000E+00
 KR-85          0.0000E+00
 KR-87          0.0000E+00
 KR-88          0.0000E+00
 KR-89          0.0000E+00
 XEM-131        0.0000E+00
 XEM-133        0.0000E+00
 XE-133         0.0000E+00
 XEM-135        0.0000E+00
 XE-135         0.0000E+00
```

```
 XE-138        0.0000E+00
 I-131         0.0000E+00
 I-132         0.0000E+00
 I-133         0.0000E+00
 I-134         0.0000E+00
 I-135         0.0000E+00
 I*-131        0.0000E+00
 I*-132        0.0000E+00
 I*-133        0.0000E+00
 I*-134        0.0000E+00
 I*-135        0.0000E+00
 H-3           0.0000E+00


1INPUT CONCENTRATION
 KRM-83      0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 KRM-85      2.3672E+00    4.0460E+00    0.0000E+00    0.0000E+00    0.0000E+00
 KR-85       4.2751E+00    1.3250E+01    0.0000E+00    0.0000E+00    0.0000E+00
 KR-87       1.5726E+00    7.7480E-01    0.0000E+00    0.0000E+00    0.0000E+00
 KR-88       3.8065E+00    4.6930E+00    0.0000E+00    0.0000E+00    0.0000E+00
 KR-89       0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 XEM-131     1.0477E+01    3.2190E+01    0.0000E+00    0.0000E+00    0.0000E+00
 XEM-133     1.1469E+00    3.5330E+00    0.0000E+00    0.0000E+00    0.0000E+00
 XE-133      4.0587E+01    1.2620E+02    0.0000E+00    0.0000E+00    0.0000E+00
 XEM-135     8.1471E+00    7.8610E+01    0.0000E+00    0.0000E+00    0.0000E+00
 XE-135      1.6702E+01    1.2500E+02    0.0000E+00    0.0000E+00    0.0000E+00
 XE-138      3.6893E-01    9.7350E-04    0.0000E+00    0.0000E+00    0.0000E+00
 I-131       5.1800E+00    4.4170E+01    0.0000E+00    0.0000E+00    0.0000E+00
 I-132       4.3553E+01    3.4300E+02    0.0000E+00    0.0000E+00    0.0000E+00
 I-133       1.7476E+01    1.5610E+02    0.0000E+00    0.0000E+00    0.0000E+00
 I-134       1.0527E+02    5.8060E+02    0.0000E+00    0.0000E+00    0.0000E+00
 I-135       3.8485E+01    3.5090E+02    0.0000E+00    0.0000E+00    0.0000E+00
 I*-131      0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 I*-132      0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 I*-133      0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 I*-134      0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 I*-135      0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00    0.0000E+00
 H-3         6.6167E+01    1.7130E+02    0.0000E+00    0.0000E+00    0.0000E+00

1WBN MSLB


0GAMMA DOSE FOR EACH ISOTOPE AND TIME PERIOD (REM)

   ID   ISOTOPE       0-2 HRS      2-8 HRS     8-24 HRS     1-4 DAYS     4-30 DAYS
2-HR EAB

   1    KRM-83       0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   2    KRM-85       1.324E-05    1.072E-05    0.000E+00    0.000E+00    0.000E+00
5.698E-05
   3    KR-85        3.331E-07    4.891E-07    0.000E+00    0.000E+00    0.000E+00
1.434E-06
   4    KR-87        4.395E-05    1.026E-05    0.000E+00    0.000E+00    0.000E+00
1.892E-04
   5    KR-88        2.634E-04    1.538E-04    0.000E+00    0.000E+00    0.000E+00
1.134E-03
   6    KR-89        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   7    XEM-131      7.407E-06    1.078E-05    0.000E+00    0.000E+00    0.000E+00
3.189E-05
   8    XEM-133      1.680E-06    2.452E-06    0.000E+00    0.000E+00    0.000E+00
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7.233E-06
   9    XE-133        6.493E-05   9.565E-05   0.000E+00   0.000E+00   0.000E+00
2.795E-04
  10    XEM-135       1.240E-04   5.668E-04   0.000E+00   0.000E+00   0.000E+00
5.338E-04
  11    XE-135        1.454E-04   5.155E-04   0.000E+00   0.000E+00   0.000E+00
6.259E-04
  12    XE-138        1.538E-05   1.923E-08   0.000E+00   0.000E+00   0.000E+00
6.623E-05
  13    I-131         6.956E-05   2.810E-04   0.000E+00   0.000E+00   0.000E+00
2.995E-04
  14    I-132         3.582E-03   1.336E-02   0.000E+00   0.000E+00   0.000E+00
1.542E-02
  15    I-133         3.758E-04   1.590E-03   0.000E+00   0.000E+00   0.000E+00
1.618E-03
  16    I-134         9.621E-03   2.514E-02   0.000E+00   0.000E+00   0.000E+00
4.142E-02
  17    I-135         2.144E-03   9.260E-03   0.000E+00   0.000E+00   0.000E+00
9.229E-03
  18    I*-131        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  19    I*-132        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  20    I*-133        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  21    I*-134        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  22    I*-135        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  23    H-3           0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
                      ---------   ---------   ---------   ---------   ---------
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 TOTAL                1.647E-02   5.100E-02   0.000E+00   0.000E+00   0.000E+00
7.091E-02
0BETA DOSE FOR EACH ISOTOPE AND TIME PERIOD (REM)

   ID   ISOTOPE        0-2 HRS     2-8 HRS    8-24 HRS    1-4 DAYS    4-30 DAYS
2-HR EAB

   1    KRM-83        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   2    KRM-85        1.941E-05   1.572E-05   0.000E+00   0.000E+00   0.000E+00
8.358E-05
   3    KR-85         3.474E-05   5.102E-05   0.000E+00   0.000E+00   0.000E+00
1.496E-04
   4    KR-87         6.751E-05   1.576E-05   0.000E+00   0.000E+00   0.000E+00
2.906E-04
   5    KR-88         4.629E-05   2.704E-05   0.000E+00   0.000E+00   0.000E+00
1.993E-04
   6    KR-89         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   7    XEM-131       4.852E-05   7.062E-05   0.000E+00   0.000E+00   0.000E+00
2.089E-04
   8    XEM-133       7.060E-06   1.030E-05   0.000E+00   0.000E+00   0.000E+00
3.039E-05
   9    XE-133        1.782E-04   2.625E-04   0.000E+00   0.000E+00   0.000E+00
7.672E-04
  10    XEM-135       2.510E-05   1.147E-04   0.000E+00   0.000E+00   0.000E+00
1.081E-04
  11    XE-135        1.716E-04   6.084E-04   0.000E+00   0.000E+00   0.000E+00
7.387E-04
  12    XE-138        7.248E-06   9.061E-09   0.000E+00   0.000E+00   0.000E+00
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3.120E-05
  13    I-131         3.264E-05    1.319E-04    0.000E+00    0.000E+00    0.000E+00
1.405E-04
  14    I-132         7.264E-04    2.710E-03    0.000E+00    0.000E+00    0.000E+00
3.127E-03
  15    I-133         2.312E-04    9.785E-04    0.000E+00    0.000E+00    0.000E+00
9.954E-04
  16    I-134         2.083E-03    5.443E-03    0.000E+00    0.000E+00    0.000E+00
8.968E-03
  17    I-135         4.593E-04    1.984E-03    0.000E+00    0.000E+00    0.000E+00
1.977E-03
  18    I*-131        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
  19    I*-132        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
  20    I*-133        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
  21    I*-134        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
  22    I*-135        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
  23     H-3          1.219E-05    1.495E-05    0.000E+00    0.000E+00    0.000E+00
5.247E-05
                      ---------    ---------    ---------    ---------    ---------

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 TOTAL                4.151E-03    1.244E-02    0.000E+00    0.000E+00    0.000E+00
1.787E-02
0INHALATION DOSE FOR EACH IODINE AND TIME PERIOD (REM) (ICRP 2 DATA

   ID   ISOTOPE        0-2 HRS      2-8 HRS     8-24 HRS     1-4 DAYS     4-30 DAYS
2-HR EAB

    1   I-131         3.751E-01    1.515E+00    0.000E+00    0.000E+00    0.000E+00
1.615E+00
    2   I-132         1.140E-01    4.254E-01    0.000E+00    0.000E+00    0.000E+00
4.908E-01
    3   I-133         3.420E-01    1.447E+00    0.000E+00    0.000E+00    0.000E+00
1.472E+00
    4   I-134         1.288E-01    3.365E-01    0.000E+00    0.000E+00    0.000E+00
5.543E-01
    5   I-135         2.335E-01    1.009E+00    0.000E+00    0.000E+00    0.000E+00
1.005E+00
    6   I*-131        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
    7   I*-132        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
    8   I*-133        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
    9   I*-134        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
   10   I*-135        0.000E+00    0.000E+00    0.000E+00    0.000E+00    0.000E+00
0.000E+00
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 TOTAL                1.193E+00    4.733E+00    0.000E+00    0.000E+00    0.000E+00
5.137E+00
0INHALATION DOSE FOR EACH IODINE AND TIME PERIOD (REM) (ICRP 30 DATA)

   ID   ISOTOPE        0-2 HRS      2-8 HRS     8-24 HRS     1-4 DAYS     4-30 DAYS
2-HR EAB

    1   I-131         2.737E-01    1.106E+00    0.000E+00    0.000E+00    0.000E+00
1.178E+00
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  2    I-132          1.372E-02   5.120E-02   0.000E+00   0.000E+00   0.000E+00
5.908E-02
  3    I-133          1.539E-01   6.513E-01   0.000E+00   0.000E+00   0.000E+00
6.626E-01
  4    I-134          5.511E-03   1.440E-02   0.000E+00   0.000E+00   0.000E+00
2.372E-02
  5    I-135          5.894E-02   2.546E-01   0.000E+00   0.000E+00   0.000E+00
2.537E-01
  6    I*-131         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  7    I*-132         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  8    I*-133         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  9    I*-134         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
 10    I*-135         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
                      ---------   ---------   ---------   ---------   ---------
---------
 TOTAL                5.058E-01   2.077E+00   0.000E+00   0.000E+00   0.000E+00
2.177E+00
0AT 2 HOUR EXCLUSION AREA BOUNDARY (EAB)


 TOTAL GAMMA DOSE =  7.091E-02 REM
 TOTAL BETA DOSE =  1.787E-02 REM
 TOTAL INHALATION DOSE (ICRP-2) =  5.137E+00 REM
 TOTAL INHALATION DOSE (ICRP-30) =  2.177E+00 REM

0AT 30 DAY LPZ BOUNDARY


 TOTAL GAMMA DOSE =  6.747E-02 REM
 TOTAL BETA DOSE =  1.659E-02 REM
 TOTAL INHALATION DOSE (ICRP-2) =  5.926E+00 REM
 TOTAL INHALATION DOSE (ICRP-30) =  2.583E+00 REM

 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.
 KRM   83 IS NOT IN EPA LIBRARY. ISOTOPE IGNORED.


1WBN MSLB


0TEDE FOR EACH ISOTOPE AND TIME PERIOD (REM)

  ID   ISOTOPE        0-2 HRS     2-8 HRS     8-24 HRS    1-4 DAYS    4-30 DAYS
2-HR EAB

  1    KRM-83         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  2    KRM-85         8.622E-06   6.982E-06   0.000E+00   0.000E+00   0.000E+00
3.712E-05
  3    KR-85          2.177E-07   3.196E-07   0.000E+00   0.000E+00   0.000E+00
9.371E-07
  4    KR-87          3.141E-05   7.332E-06   0.000E+00   0.000E+00   0.000E+00
1.352E-04
  5    KR-88          1.938E-04   1.132E-04   0.000E+00   0.000E+00   0.000E+00
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8.344E-04
   6    KR-89         0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
   7    XEM-131       2.011E-06   2.927E-06   0.000E+00   0.000E+00   0.000E+00
8.656E-06
   8    XEM-133       7.637E-07   1.114E-06   0.000E+00   0.000E+00   0.000E+00
3.288E-06
   9    XE-133        3.179E-05   4.683E-05   0.000E+00   0.000E+00   0.000E+00
1.369E-04
  10    XEM-135       7.977E-05   3.647E-04   0.000E+00   0.000E+00   0.000E+00
3.434E-04
  11    XE-135        9.158E-05   3.247E-04   0.000E+00   0.000E+00   0.000E+00
3.943E-04
  12    XE-138        1.040E-05   1.301E-08   0.000E+00   0.000E+00   0.000E+00
4.479E-05
  13    I-131         1.075E-02   4.344E-02   0.000E+00   0.000E+00   0.000E+00
4.629E-02
  14    I-132         8.359E-03   3.119E-02   0.000E+00   0.000E+00   0.000E+00
3.598E-02
  15    I-133         1.027E-02   4.345E-02   0.000E+00   0.000E+00   0.000E+00
4.420E-02
  16    I-134         1.278E-02   3.340E-02   0.000E+00   0.000E+00   0.000E+00
5.502E-02
  17    I-135         1.221E-02   5.274E-02   0.000E+00   0.000E+00   0.000E+00
5.256E-02
  18    I*-131        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  19    I*-132        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  20    I*-133        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  21    I*-134        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  22    I*-135        0.000E+00   0.000E+00   0.000E+00   0.000E+00   0.000E+00
0.000E+00
  23    H-3           1.995E-04   2.447E-04   0.000E+00   0.000E+00   0.000E+00
8.590E-04
                      ---------   ---------   ---------   ---------   ---------
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 TOTAL                5.502E-02   2.053E-01   0.000E+00   0.000E+00   0.000E+00
2.369E-01
 TOTAL TEDE =  2.603E-01
0THIS RUN IS DATED 01/28/10. THE TOTAL ELAPSED TIME IS  0.0 MINUTES.  0.0 SECONDS.
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Attachment 13

TVA Nuclear Power Group Calculation

WBNTSR-064 R8

Offsite and Control Room Operator Doses Due to a Waste Gas Decay Tank Rupture

TVAN CALCULATION COVERSHEET/CCRIS UPDATE

Page 1

REV 0 EDMS/RIMS NO.	EDMS TYPE:	EDMS ACCESSION NO (N/A for REV. 0)
B26 910624 200	calculations(nuclear)	T71 060905 8[illegible]

Calc Title:
Offsite and Control Room Operator Doses Due to a Waste Gas Decay Tank Rupture

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISION APPLICABILITY
CURRENT	CN	NUC	WBN	NTB	WBNTSR-064	R7	R8	Entire calc ☒ Selected pages ☐
NEW	CN	NUC						

ACTION	NEW ☐ REVISION ☒	DELETE ☐ RENAME ☐	SUPERSEDE ☐ DUPLICATE ☐	CCRIS UPDATE ONLY ☐ (Verifier Approval Signatures Not Required)	No CCRIS Changes ☐ (For calc revision, CCRIS been reviewed and no CCRIS changes required)

UNITS	SYSTEMS	UNIDS
0	NA	NA

DCN,EDC,N/A	APPLICABLE DESIGN DOCUMENT(S)	CLASSIFICATION
NA	NA	E

QUALITY RELATED?	SAFETY RELATED? (If yes, QR = yes)	UNVERIFIED ASSUMPTION	SPECIAL REQUIREMENTS AND/OR LIMITING CONDITIONS?	DESIGN OUTPUT ATTACHMENT?	SAR/TS and/or ISFSI SAR/CoC AFFECTED
Yes ☒ No ☐	Yes ☒ No ☐	Yes ☐ No ☒	Yes ☐ No ☒	Yes ☐ No ☒	Yes ☒ No ☐

PREPARER ID	PREPARER PHONE NO	PREPARING ORG (BRANCH)	VERIFICATION METHOD	NEW METHOD OF ANALYSIS
DPPOLLOCK	751-4312	NTB	Design Review	☐ Yes ☒ No

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
Douglas P. Pollock Doug Pollock	4/14/06	Marc C. Berg Marc C. Berg	4-24-06
VERIFIER SIGNATURE	**DATE**	**APPROVAL SIGNATURE** JSR / DSP 8/3/06	**DATE**
Marc C. Berg Marc C. Berg	4-24-06	Charles Allen JS Robertson for C.R. Allen	9/1/06

STATEMENT OF PROBLEM/ABSTRACT

This calculation determined the offsite and control room operator doses due to a Waste gas Decay Tank (WGDT) rupture. The calculation supports FSAR section 15.5.2 and Table 15.5-5. Three cases were calculated. One case assumed realistic gas source terms (from WBNNAL3-006) were present in the WGDT, the other assumed design basis source terms (1% failed fuel) and the third determined source terms which results in an offsite gamma dose < 0.5 rem. Computer code STP was used to determine the inventory released to the environment. Decay was allowed only for the realistic case and only for the time to fill the tank (55.75 hrs to fill the 600 cuft tank). The tank was assumed to release everything instantaneously and nonmechanistically to the environment after it was filled. The STP results were used as input to computer code COROD. COROD was used to determine the control room operator doses. The model was the same as that found in TI-RPS-198, except for the χ/Q values and adding a 20.6 sec control room isolation delay. The χ/Q values were determined using ARCON96 in WBNAPS3-104. The STP results were also used as input to computer code FENCDOSE, which determined the offsite dose. The FENCDOSE model was the same found in TI-RPS-197. The results are provided in Tables 3 and 5 in the Results section.

The 30 day LPZ offsite doses for a realistic and Regulatory Guide 1.24 Waste Gas Decay Tank rupture accident were calculated to be substantially below the regulatory limits of 25 rem gamma, 300 rem beta, 300 rem thyroid, and 25 rem TEDE. The control room operator doses for a realistic and Regulatory Guide 1.24 WGDT rupture calculated to be below the regulatory limits of 5 rem gamma, 30 rem beta, 30 rem thyroid, and 5 rem TEDE. The Regulatory Guide1.24 control room beta dose is relatively high, but this is due to the very conservative (high) noble gas inventory for that case.

For the realistic case, the 2-hr EAB/Site Boundary offsite dose was less than the 500 mrem criterion set forth in NUREG0800 section 11.3. **The Reg. Guide 1.24 case exceeds the 500 mrem limit**. Thus a case was performed to determine the source term, based on Xe-133 equivalency which results in the Site Boundary dose being just less than 500 mrem. For this case the Xe-133 equivalent is 7.408E+04 Ci. **Maintaining the Xe-133 equivalency to less than 7.408E+04 Ci, a rupture of a single Waste Gas Decay Tank will meet the intent of Regulatory Guide 1.24.**

MICROFICHE/EFICHE Yes ☒ No ☐ FICHE NUMBER(S): TVA-F-W000574

☐ LOAD INTO EDMS AND DESTROY
☒ LOAD INTO EDMS AND RETURN CALCULATION TO CALCULATION LIBRARY. ADDRESS:EQB 1M-WBN
☐ LOAD INTO EDMS AND RETURN CALCULATION TO:

TVAN CALCULATION COVERSHEET/CCRIS UPDATE

Page 2

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	REV
	CN	NUC	WBN	NTB	WBNTSR-064	8

ALTERNATE CALCULATION IDENTIFICATION

BLDG	ROOM	ELEV	COORD/AZIM	FIRM	Print Report Yes ☒

CATEGORIES

KEY NOUNS (A-add, D-delete)

ACTION (A/D)	KEY NOUN	A/D	KEY NOUN

CROSS-REFERENCES (A-add, C-change, D-delete)

ACTION (A/C/D)	XREF CODE	XREF TYPE	XREF PLANT	XREF BRANCH	XREF NUMBER	XREF REV
D	S	CN	WBN	NTB	WBNAPS3104	
A	P	CN	WBN	NTB	WBNAPS3104	

CCRIS ONLY UPDATES:

Following are required only when making keyword/cross reference CCRIS updates and page 1 of form NEDP-2-1 is not included:

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
PREPARER PHONE NO.	EDMS ACCESSION NO.		

TVAN CALCULATION RECORD OF REVISION

CALCULATION IDENTIFIER **WBNTSR-064**

Title **Offsite and Control Room Operator Doses Due to a Waste Gas Decay Tank Rupture**

Revision No.	DESCRIPTION OF REVISION
0	Initial issue.
1	Revision 1 was performed to update references and validate/justify an FSAR reference. pages added: 5.5 pages deleted: none pages changed: 1-6, 9, 10, 15
2	Revision 2 was performed because the X/Q values changed and to update references. All pages were renumbered. Only text with actual changes will have revision bars. pages added: 7 paged deleted: none pages changed: all
3	Revision 3 was performed because of new control building makeup flow. pages added: none pages deleted: none pages changed: 1-7, 9, 15, 17
4	Revision 4 was performed because the Regulatory Guide 1.24 source terms as supplied by Westinghouse changed due to the extended fuel cycle (18 month, 1000 EFPD, 5% enrichment). **These source terms are an unverified assumption that need to be verified later.** pages changed: all (all pages replaced since original R3 lost. Actual text changes have revision bars). pages added: none pages deleted: none
5	Revision 5 was performed to eliminate the unverified assumption by using the latest Westinghouse information. pages changed: 1-7, 9-11, 15, 17 pages added: none pages deleted: none R5 total pages = 18
6	Revision 6 implements EDC E50629A, which implements the use of a Tritium Production Core. This revision also supports the corrective action for PER WBN 01-000395-000. The calculation was reformatted and renumbered. The revision added an evaluation to determine the source inventory using Xe-133 equivalency that results in a Site boundary dose of slightly less than 500 mrem. The evaluations in this revision utilize latest revision of COROD and FENCDOSE, which now calculate an ICRP-30 thyroid dose in addition to the ICRP-2, and a TEDE dose. The results for the Non-TPC core are not impacted. Further, the discussion related to the administrative limit in PAI-15.01 was deleted. An independent 3rd party was performed on this calculation by Wesdyne and the comments were incorporated into the calculation, with no technical impact. Pages changed: 1-11, 14-18 Pages added: All. Pages deleted: All R6 total Pages: 22
7	Revision 7 is performed to incorporate a control room 20.6 second isolation time. Also incorporated ARCON96 control room X/Q values. Fixed minor typographical errors. All pages were renumbered, only pages with actual text changes are marked with revision bars. This revision is part of corrective actions for WBN PERs 03-012566-000 and 03-014473-000. The Technical Specifications and FSAR section 15.5 were reviewed and are not affected by this revision. Pages changed: 1-9, 11-13, 15-17 Pages deleted: the following page numbers correspond to the R6 pagination: 2, 12, 13, 21 Pages added: all R7: 18 total pages
8	Revision 8 is performed as corrective action for PER 61493 and PER 94426. PER 61493 documents that the recirculation flow rate for the control room was incorrectly modeled. PER 94426 documents that the time increments do not accurately reflect the 20.6 second delay. This revision corrects both modeling errors. This calculation directly impacts FSAR Table 15.5-5. The Technical Specifications are not impacted. Successor calculation WBNAPS3-074 is impacted by this revision. WBNAPS3104 is listed as a successor calculation, but a review of this calculation determined it does not use any information from this calculation is being deleted as a successor. Successors WBNOSG4243 and WBNTSR040 do not use any information that was revised in this revision and are thus not impacted. Pages Revised/Replaced: 1-3, 6-9, 11, 12, 16, 17 Pages Added: none Pages Deleted: none R8: 18 total pages

TVAN CALCULATION TABLE OF CONTENTS

Calculation Identifier: **WBNTSR-064**	Revision: 8

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TVAN CALCULATION VERIFICATION FORM

Calculation Identifier **WBNTSR-064** Revision 8

Method of verification used:

1. Design Review ☒
2. Alternate Calculation ☐
3. Qualification Test ☐

Verifier Marc C. Berg Date 1-24-06

Comments:

This calculation revision corrects the COROD model and adds a 2CREVS case. The calculation is technically adequate.

TVAN COMPUTER INPUT FILE
STORAGE INFORMATION SHEET

Document **WBNTSR-064**	Rev. 8	Plant: WBN	

Subject:
Offsite and Control Room Operator Doses Due to a Waste Gas Decay Tank Rupture

☐ Electronic storage of the input files for this calculation is not required. Comments:

☒ Input files for this calculation have been stored electronically and sufficient identifying information is provided below for each input file. (Any retrieved file requires re-verification of its contents before use.)

The R2 input files are stored in FILEKEEPER file # 263465

The R3 input files are stored in FILEKEEPER file # 263714

The R4 input files are stored in FILEKEEPER file # 300426

The R5 input files are stored in FILEKEEPER file # 300588

The R6 input files are stored in FILEKEEPER file # 303398

The R7 input files are stored in FILEKEEPER file # 305736

The R8 input files are stored in FILEKEEPER file # 308013

☒ Microfiche/eFiche

See next page

TVAN COMPUTER OUTPUT
MICROFICHE INFORMATION SHEET

Document **WBNTSR-064** | Rev. 8 | Plant: WBN

Subject:
Offsite and Control Room Operator Doses Due to a Waste Gas Decay Tank Rupture

Microfiche Number	Description		
R0: WRAD-27 (ufilm)	TSR064S	STP	Activity in WGDT
	TSR064F1	FENCDOSE	Offsite Dose, Realistic Case
	TSR064F2	FENCDOSE	Offsite Dose, RG 1.24 case
	TSR064C1	COROD	Cont. Room Operator Dose, Realistic
	TSR064C2	COROD	Control Room Operator Dose, RG 1.24
R2: TVA-F-C000081	TSR64FA2	FENCDOSE	Offsite Dose, Realistic Case
	TSR64FB2	FENCDOSE	Offsite Dose, RG 1.24 case
	TSR64CA2	COROD	Cont. Room Operator Dose, Realistic
	TSR64CB2	COROD	Control Room Operator Dose, RG 1.24
R3: TVA-F-C000118	TSR64CA3	COROD	Cont. Room Operator Dose, Realistic
	TSR64CB3	COROD	Control Room Operator Dose, RG 1.24
R4: TVA-F-C000273	TSR64FB4	FENCDOSE	Offsite Dose, RG 1.24 case
	TSR64CB4	COROD	Control Room Operator Dose, RG 1.24
R5: TVA-F-C000282	TSR64FB5	FENCDOSE	Offsite Dose, RG 1.24 case
	TSR64CB5	COROD	Control Room Operator Dose, RG 1.24
R6: TVA-F-C000337	TSR64FA6	FENCDOSE	Offsite Dose, Realistic case -TPC
	TSR64FB6	FENCDOSE	Offsite Dose, RG 1.24 case -TPC
	TSR64CA6	COROD	Control Room Operator Dose, Realistic -TPC
	TSR64CB6	COROD	Control Room Operator Dose, RG 1.24 -TPC
	TSR64FC6	FENCDOSE	Offsite Dose, Reduced case -TPC
	TSR64FD6	FENCDOSE	Offsite Dose, Reduced case -Non-TPC
R7: TVA-F-W000351 (eFichc)	TSR64IS7	STPISOTP	set up STP isotopic input
	TSR64S7	STP	source terms releases
	TSR64CA7	COROD	RG 1.24, conventional core, control room dose
	TSR64CB7	COROD	realistic, conventional core, control room dose
	TSR64CC7	COROD	RG 1.24, TPC, control room dose
	TSR64CD7	COROD	realistic, TPC, control room dose
R8: TVA-F-W000574	TSR64C8A	COROD	RG 1.24, conventional core, control room dose
	TSR64C8B	COROD	realistic, conventional core, control room dose
	TSR64C8C	COROD	RG 1.24, TPC, control room dose
	TSR64C8D	COROD	realistic, TPC, control room dose
	TSR64C8E	COROD	RG 1.24, conventional core, control room dose – 2 CREV*
	TSR64C8F	COROD	realistic, conventional core, control room dose – 2 CREV*
	TSR64C8G	COROD	RG 1.24, TPC, control room dose – 2 CREV*
	TSR64C8H	COROD	realistic, TPC, control room dose – 2 CREV*

* note these are for information only and the results are not given, see assumptions #9

Purpose

The purpose of this calculation is to determine the offsite and control room operator doses due to a Waste Gas Decay Tank rupture. This calculation will support Watts Bar Safety Analysis Report (FSAR) section 15.5.2 and Table 15.5-5. Revision 2 was done due to revised χ/Q values. Revision 3 is performed because of new control building makeup flow (711 cfm). Revision 4 is performed due to new R.G. 1.24 source terms as provided by Westinghouse as part of the extended fuel cycle (18 months, 1000 EFPD, 5% enrichment). Revision 5 uses new final WGDT inventories to eliminate an UVA. Revision 6 implements EDC E50629A to allow the use of a Tritium Production Core (TPC) and provide source terms for just satisfying an offsite gamma dose of < 0.5 rem, and supports the corrective action for PER WBN 01-000395-000. Revision 7 is performed to change the control room analysis to include a 20.6 sec isolation delay and to incorporate ARCON96 X/Q values. Revision 8 corrects the control room recirculation flow rate and time increments in the COROD model.

Introduction

From reference 4, the gaseous waste disposal system (WDS) contains nine (9) gas decay tanks. These tanks receive gaseous waste from the Chemical Volume and Control System (CVCS) Holdup Tank, CVCS Volume Control Tank, WDS Spent Resin Tank, CVCS Boric Acid Evaporator, and WDS Reactor Drain Tank. "The probability of a gas decay tank rupturing is low. However, the probability of an accidental release resulting from such things as operator error or malfunction of a valve or the overpressure relief system is considered to be sufficiently high that the calculated offsite whole body exposure that might result from a single failure during normal operation should be substantially below the guidelines of 10CFR Part 100," (ref.5).

This calculation will determine the offsite and control room operator doses due to a Waste Gas Decay Tank rupture. The calculation will be done for both a Regulatory Guide 1.24 (1% failed fuel, ref.5) accident and for a realistic case (ANS/ANSI-18.1-1984, ref.6) and one which results in an EAB/Site Boundary dose of just less than 500 mrem gamma. The maximum content of the failed decay tank is assumed to be released non-mechanistically to the environment over a two hour time period (ref.5). Radioactive decay is only taken into account for the time required to transfer the gasses to the decay tank (ref.5). Computer code STP (ref.1) will be used to determine the inventory of the radioactive gasses in the tank for the realistic case. The R.G. 1.24 case uses the inventory provided by Westinghouse in reference 11. Computer code FENCDOSE (ref.3) will be used to determine offsite doses utilizing STP results as input. The FENCDOSE model parameters, other than the releases activity are taken from TI-RPS-197 (ref.8). Computer code COROD (ref.7) will be used to determine the control room operator dose utilizing the STP results as input. The COROD parameters, other than released activity, and χ/Q values, are taken from TI-RPS-198 (ref.9). The ARCON96 χ/Q values were determined in WBNAPS3-104 (ref.24). The model sections pertaining to the 20.6 sec isolation delay are taken from WBNTSR-009 (ref.31).

The main dose limit for this calculation is an offsite gamma dose of 500 mrem from NUREG-0800 section 11.3. The following are standard limits for accidents. The offsite gamma dose limit is 25 rem (10CFR100.11), the thyroid dose limit is 300 rem (10CFR100.11), and the TEDE dose limit is 25 rem (10CFR50.67). SRP 6.4 in NUREG 0800 (ref.32) shows that the thyroid dose and beta dose limits are equivalent for the control room, therefore the offsite beta dose limit can be assumed the same as the offsite thyroid dose limit, 300 rem. 10CFR20.1201 also states that the organ (thyroid) dose and skin (beta) dose are equivalent. The control room dose limits are 5 rem gamma (10CFR50 Appendix A GDC19),30 rem thyroid (SRP 6.4), 30 rem beta (SRP 6.4), and 5 rem TEDE (10CFR50.67).

Design Input

The Following are the Regulatory Guide 1.24 WGDT activities from WAT-D-10436.

Kr-83m	17 Ci	Kr-85	4200 Ci	Kr-85m	130 Ci
Kr-87	29 Ci	Kr-88	160 Ci	Kr-89	0.1 Ci
Xe-131m	890 Ci	Xe-133	68000 Ci	Xe-~~33m~~ 133m DDX 1/14/06	1000Ci
Xe-135	940 Ci	Xe-135m	48 Ci	Xe137	0.27 Ci
Xe-138	3.2 Ci				
I-131	0.048 Ci	I-133	0.033 Ci	I-135	0.012 Ci

Total = 7.54E4 Ci

ARCON96 X/Q values (ref.24): 0-2hr=2.52E-3 sec/m^3, 2-8hr=1.57E-3, 8-24hr=6.71E-4, 1-4day=4.99E-4, 4-30day=3.79E-4

WGDT Room volume = 11269 cuft (room 692-A5, ref.29, which is smaller volume than WGDT room A3=11503 cuft)

Flow out of WGDT room = 944 cfm (= largest measured value, ref.30).

Assumptions

1. The tank is assumed to be filled with the highest concentration for each isotope from all sources into the WGDT. This will ensure maximum concentration of all isotopes.
   a) The realistic source terms come from WBNNAL3-006 (ref.10). The WBNNAL3-006 concentrations correspond to the realistic inventory (ANSI/ANS 18.1-1980 4). The Regulatory Guide 1.24 (design basis, 1% failed fuel) source terms are provided by Westinghouse in WAT-D-10436 (ref.11).
   b) WBNNAL3-003 (ref. 6) provides the total inventory of tritium for a TPC and in accordance with NUREG-0017(ref. 25) 10% of the tritium is released as gas, thus the tritium source terms are:
   TPC - Normal Operation: 906.9 Ci (total) * 10% = 90.69 Ci
   1 TPBAR Failure: 12506.9 Ci * 10% = 1250.69 Ci
   2 TPBAR Failure: 24106.9 Ci * 10% = 2410.66 Ci
   Only the 2 TPBAR Failure case is run, as the tritium has only a small impact on the results and using the 2 TPBAR failure source term is conservative.

2. Radioactive decay is only taken into account for the time period required to transfer the gasses to the tank (ref.5), except for tritium. The maximum content of the failed decay tank is assumed to be released non-mechanistically to the environment over a two hour time period (ref.5). For tritium, due to its 12.3 year half life, it is considered that no decay occurs.

3. The tank failure is assumed to occur immediately upon completion of the waste gas transfer (ref.5).

4. Only one tank is assumed to fail, as all decay tanks are isolated from each other whenever they are in use (ref.4).

5. deleted in R5

6. The release path of the radioisotopes from the ruptured tank is through the Auxiliary Building vent (ref.12).

Technical Justification: A rupture of a Waste Gas Decay Tank will lead to release into the Auxiliary Building and hence into the normal ventilation. Planned releases of the WGDT inventory to the environment will be through the Shield Building Vent. The Shield Building Vent release path is monitored by radiation monitors such that if excessive releases occur, the vent will isolate (ref. 4). The Auxiliary Building Vent is monitored and alarmed (1-RE-90-101), but no automatic isolation occurs (ref. 27). Also, the χ/Q values from the Auxiliary Building Vent are worse for the control room than the Shield Building Vent (see calculation WBNAPS3-104). Therefore, this release path is the most likely path and the most conservative path.

7. deleted in revision 7

8. All assumptions from TI-RPS-198 (ref.9) regarding the COROD model hold, except as denoted above.

9. Only one train of CREVS is in operation.

Technical Justification: Normally, each CREVS train takes suction from separate intakes with no cross communication between trains. This leads to one contaminated train, and one uncontaminated train. The only way a 2 CREVS operation could result in higher doses would be for both trains to take suction from the same vent. For this to happen, one intake path would require a failed closed intake path AND a fail open of normally closed passive manual damper at the beginning of the accident. An active failure of a train plus a failure of a passive component in less than 24 hours is beyond design basis.

Special Requirements / Limiting Conditions

There are no special requirements or limiting conditions in this calculation.

Calculations

A waste gas decay tank has a volume of 600 cuft and is filled at 1.4 scfm (from 2 volume control tanks at 0.7 scfm each) until it reaches 100 psig (114.696 psia, ref.4). Once full, the flow is diverted to another tank. Therefore the volume of the gas at STP and the time to fill the tank is:

$$P_1V_1 = P_2V_2$$

or

$$V_2 = P_1V_1/P_2 = (114.696 \text{ psia}(600 \text{ cuft})/(14.696 \text{ psia})$$

$$= 4682.7 \text{ cuft at STP}$$

then

$$\text{time} = (4682.7 \text{ cuft})/ (1.4 \text{ cuft/min} * 60 \text{ min/hr})$$

$$= 55.75 \text{ hr}$$

The realistic case (ANSI/ANS 18.1-1984) isotope concentration is taken from WBNNAL3-006 (ref.10). The Regulatory Guide 1.24 case (1% failed fuel) isotope concentration is taken from WAT-D-10436 (ref.11). For each case the tritium concentration for a TPC is taken from WBNNAL3-003 (ref.6). Using computer code STP (ref.1), a continuous realistic source flows at 1.4 cfm for 55.75 hr into a component labeled " Realistic WGDT". Because a total inventory is given in reference 11, the Regulatory Guide 1.24 source is stepped into a component labeled "R.G. 1.24 WGDT". No decay is assumed for the R.G. 1.24 case and no decay is assumed for tritium. Since the STP realistic case input values are in μCi/cc, and the FENCDOSE/COROD codes require input values in Curies, the realistic continuous source flow rate in the " Realistic WGDT" is:

$$F = (x\ \mu\text{Ci/cc})(1.4 \text{ cuft/min})(60 \text{ min/hr})(28317 \text{ cc/cuft})(10\text{-}6 \text{ Ci}/\mu\text{Ci})$$

$$= (x\ \mu\text{Ci/cc})(2.3786 \text{ Ci-cc}/\ \mu\text{Ci-hr}) = x * 2.3786 \text{ Ci/hr}$$

At the end of the 55.75 hr time period, the inventory of the tank is assumed to be released into the atmosphere. The inventory as calculated by STP is used as input into computer code FENCDOSE (ref.3) to calculate the Low Population Zone (LPZ) and the site boundary (SB), which is the same as the Exclusion Area Boundary (EAB), offsite dose. The FENCDOSE model is taken from TI-RPS-197 (ref.8).

The inventory as calculated by STP is also used as input into computer code COROD to determine the control room operator dose. The COROD models (less the containment shine) are taken from TI-RPS-198 (ref. 9) with a 20.6 second delay in isolation. From WBNTSR-009: "During the vertical slice review of the control room, a concern was raised that when the control room is isolated by a signal from the main control room intake radiation monitors, some amount of unfiltered activity could enter the control room before the isolation dampers close. This could be the case for a fuel handling accident [or waste gas decay tank rupture] because there will be no safety injection signal to isolate the control room. The isolation dampers downstream from the radiation monitors are 0-FCV-31-3 and 0-FCV-31-4. It is required ... that the closure time of the dampers is 14 seconds, with a signal response time of 6.6 seconds, which gives a total closure time of 20.6 seconds." |

The X/Q values used are different than the TI-RPS-198 model because the release points are different. There are 2 cases of X/Q values for the control room with a release from the Auxiliary Building exhaust vent. Per TI-RPS-198, the worst case X/Q values for the first 8 hours are used, with the better X/Q values used after 8 hours due to operator action to select the better intake

Results

Table 3
Doses Due to Waste Gas Decay Tank Rupture (Rem)

Conventional Core	Offsite		
Realistic Case (rem)	30 day LPZ	2 hr EAB	Control Room
Gamma	6.40E-03	2.76E-02	3.48E-02
Beta	2.44E-02	1.05E-01	4.58E-01
Inhalation (ICRP-2)	4.16E-03	1.79E-02	6.68E-03
Inhalation (ICRP-30)	-	-	4.35E-03
TEDE	-	-	3.95E-02

Conventional Core	Offsite		
R.G. 1.24 (rem)	30 day LPZ	2 hr EAB	Control Room
Gamma	1.33E-01	5.72E-01	7.70E-01
Beta	3.57E-01	1.54E+00	6.65E+00
Inhalation (ICRP-2)	4.19E-03	1.81E-02	6.84E-03
Inhalation (ICRP-30)	-	-	4.68E-03
TEDE	-	-	8.36E-01

TPC (2 TPBAR Failure)	Offsite		
Realistic Case (rem)	30 day LPZ	2 hr EAB	Control Room
Gamma	6.40E-03	2.76E-02	3.48E-02
Beta	2.48E-02	1.07E-01	4.66E-01
Inhalation (ICRP-2)	4.16E-03	1.79E-02	6.68E-03
Inhalation (ICRP-30)	2.67E-03	1.15E-02	4.35E-03
TEDE	1.06E-02	4.56E-02	1.81E-01

TPC (2 TPBAR Failure)	Offsite		
R.G. 1.24 (rem)	30 day LPZ	2 hr EAB	Control Room
Gamma	1.33E-01	5.72E-01	7.70E-01
Beta	3.58E-01	1.54E+00	6.66E+00
Inhalation (ICRP-2)	4.19E-03	1.81E-02	6.84E-03
Inhalation (ICRP-30)	2.85E-03	1.23E-02	4.68E-03
TEDE	7.66E-02	3.30E-01	9.77E-01

Notes for Table 3

COROD R6 does not include in the TEDE the dose due to direct shine from outside the control room, the value is manually added to arrive at the TEDE.

$$\begin{aligned} TEDE_{total} &= TEDE_{Air} + gamma_{Shine} + TEDE_{In/Egress} \\ &= 4.442E\text{-}01 + \text{negligible} + 0.0 = 4.442E\text{-}01 \text{ (Realistic TPC)} \\ &= 2.406E{+}00 + \text{negligible} + 0.0 = 2.406E{+}00 \text{ (R.G. 1.24 TPC)} \end{aligned}$$

where gamma shine > 0 but is considered to be negligible

The R.G. 1.24 EAB gamma dose presented in Table 3 exceeds the limit of 500 mrem gamma. In order to define a limiting condition for the WGDT that would, if released, not exceed the limits, a case is developed to determine the source inventory of the WGDT that would result in the EAB being just less than 500 mrem. The limiting condition for the WGDT is addressed as a total Xe-133 equivalency. To determine the limiting source terms a Xe-133 equivalent was determined for the R.G. 1.24 source inventory using dose factors for γ-body in Table B-1 of R.G. 1.109 (ref.26). A reduction factor value was determined by trial and error (by using various reduced source inventories as input to FENCDOSE) to be 0.127 so that the resulting offsite dose is just below the limit of 500 mrem. The R.G. 1.24 Xe-133 equivalent values were reduced by this reduction factor using the following equation:

[Xe-133 Equivalency - (Reduction Factor*Xe-133 Equivalency)]

To determine reduced source inventory the reduced Xe-133 Equivalency for each isotope is multiplied by the same dose factors ratio as used to determine the Xe-133 equivalency for each R. G. 1.24 isotope. This calculation is provided in Table 4. The reduced isotopic values were entered into FENCDOSE to validate the reduced source inventory and yielded the results provided in Table 5 for both a Non-TPC core and TPC core.

Table 4 - R.G. 1.24 case

Dose factors based on R.G. 1.109 R1 Table B-1 (DFB_i) Reduction Factor (RF) = 0.127

Nuclide	DFB_i mrem-m^2/pCi-yr	Ratio DFB_i/DFB_{Xe-133}	RG-1.24 (Ci)	Xe-133 Eqv (Ci)	Eqv-RF	Reduced Ci *
Kr-83m	7.56E-08	2.571E-04	1.700E+01	4.371E-03	3.816E-03	1.484E+01
Kr-85m	1.17E-03	3.980E+00	1.300E+02	5.173E+02	4.516E+02	1.135E+02
Kr-85	1.61E-05	5.476E-02	4.200E+03	2.300E+02	2.008E+02	3.667E+03
Kr-87	5.92E-03	2.014E+01	2.900E+01	5.839E+02	5.098E+02	2.532E+01
Kr-88	1.47E-02	5.000E+01	1.600E+02	8.00E+03	6.984E+03	1.397E+02
Kr-89	1.66E-02	5.646E+01	1.000E-01	5.646E+00	4.929E+00	8.730E-02
Xe-131m	9.15E-05	3.112E-01	8.900E+02	2.770E+02	2.418E+02	7.770E+02
Xe-133m	2.51E-04	8.537E-01	1.000E+03	8.537E+02	7.453E+02	8.730E+02
Xe-133	2.94E-04	1.0	6.800E+04	6.800E+04	5.936E+04	5.936E+04
Xe-135m	3.12E-03	1.061E+01	4.800E+01	5.094E+02	4.447E+02	4.190E+01
Xe-135	1.81E-03	6.156E+00	9.400E+02	5.787E+03	5.052E+03	8.206E+02
Xe-137	1.42E-03	4.830E+00	2.700E-01	1.304E+00	1.138E+00	2.357E-01
Xe-138	8.83E-03	3.003E+01	3.200E+00	9.611E+01	8.390E+01	2.794E+00
			Total Xe-133 Equivalent	8.486E+04	7.408E+04	

* Note that the Reduced Ci column is the "Eqv.-RF"/"Ratio" (col.6/col.3).

Using the same methodology as above the Xe-133 equivalency for the Realistic case isotopic source terms resulting from STP is 3.966E+03 Ci (Xe-133) as provided in the following table.

Dose Factors based on RG 1.109 R1 Table B-1 (DFBi)

	Realistic Case			
Nuclide	DFBi mrem-m3/pCi-yr	Ratio DFBi/DFBi Xe-133	Realistic (Ci)	Xe-133 Eqiv. Ci
Kr-83m	7.56E-08	2.571E-04	0.0	0
Kr-85m	1.17E-03	3.980E+00	6.302E+00	2.508E+01
Kr-85	1.61E-05	5.476E-02	7.689E+02	4.211E+01
Kr-87	5.92E-03	2.014E+01	7.418E-01	1.494E+01
Kr-88	1.47E-02	5.000E+01	5.092E+00	2.546E+02
Kr-89	1.66E-02	5.646E+01	0.0	0.0
Xe-131m	9.15E-05	3.112E-01	1.104E+03	3.436E+02
Xe-133m	2.51E-04	8.537E-01	4.546E+01	3.881E+01
Xe-133	2.94E-04	1.0	2.636E+03	2.636E+03
Xe-135m	3.12E-03	1.061E+01	2.611E-02	2.771E-01
Xe-135	1.81E-03	6.156E+00	9.905E+01	6.098E+02
Xe-137	1.42E-03	4.830E+00	3.724E-04	1.799E-03
Xe-138	8.83E-03	3.003E+01	2.026E-02	6.085E-01
			Total Xe-133 Equivalent	3.966E+03

Table 5

Regulatory Guide 1.24 Reduced Case * - TPC (2 TPBAR Failure) (rem)

	30 day LPZ	2 hour SB(EAB)
Gamma (whole body)	1.160E-01	4.994E-01
Beta	3.122E-01	1.344E+00
Iodine (Thyroid) - ICRP-2	4.194E-03	1.806E-02
Iodine (Thyroid) - ICRP-30	2.845E-03	1.225E-02
TEDE*	6.784E-02	2.921E-01

Regulatory Guide 1.24 Reduced Case* - Non-TPC (rem)

	30 day LPZ	2 hour SB(EAB)
Gamma (whole body)	1.160E-01	4.994E-01
Beta	3.118E-01	1.342E+00
Iodine (Thyroid) - ICRP-2	4.194E-03	1.806E-02
Iodine (Thyroid) - ICRP-30	2.845E-03	1.225E-02
TEDE*	6.056E-02	2.607E-01

* Reduced = Limited to Xe-133 equivalent of 7.408E4 Ci

Discussion and Conclusion

The implementation of a TPC core impacts the beta doses determined in Revision 5 by a small amount; however, the tritium does have a significant impact on the TEDE. Thus the following conclusions are applicable to both the TPC and Non-TPC cores.

The 30 day LPZ offsite doses for a realistic and Regulatory guide 1.24 Waste Gas Decay Tank rupture accident were calculated to be substantially below the regulatory limits of 25 rem gamma, 300 rem beta, 300 rem thyroid, and 25 rem TEDE. The control room operator doses for a realistic and Regulatory guide 1.24 WGDT rupture were calculated to be below the regulatory limits of 5 rem gamma, 30 rem beta, 30 rem thyroid, and 5 rem TEDE. The Regulatory Guide 1.24 control room beta dose is relatively high, but this is due to the very conservative (high) noble gas inventory for that case.

For the realistic case, the 2-hr EAB/Site Boundary offsite dose was less than the 500 mrem criterion set forth in NUREG0800 section 11.3. The Reg. Guide 1.24 case exceeds the 500 mrem limit. In order to not exceed the 500 mrem limit, the Xe-133 equivalent for a WGDT must be maintained less than 7.408E+04 Ci. ~~However, PAI 15.01 (ref.22) administratively limits the activity in a tank to 500 Ci (Xe-133 equivalent) or more frequent surveillance would be required. Given this administrative limit, and~~ **By maintaining the Xe-133 equivalency to less than 7.408E+04 Ci** ~~according and that the realistic case does not exceed the offsite dose limits,~~ **a rupture of a single Waste Gas Decay Tank will meet the intent of NUREG0800 section 11.3.** This requirement is implemented by section 4.2 of the Gaseous Waste Disposal System Description, N3-77A-4001.

Note on Methodologies used for Doses:

This calculation determined the doses using 3 different methodologies which are in revision 5 of COROD. The gamma, beta and Thyroid (ICRP-2) doses are all based on TID-14844 methodologies utilizing the ICRP-2 iodine dose conversion factors found in TID-14844 and are the current (as of June 2001) licensing basis of the plant. The second methodology is the Thyroid (ICRP-30) dose, which is also based on TID-14844, but uses the ICRP-30 iodine dose conversion factors. The ICRP-30 iodine dose conversion factors are less conservative than the ICRP-2 factors. This methodology is presented for potential future use. Finally, the third methodology used is the TEDE (Total Effective Dose Equivalent). The TEDE presents an overall weighted dose and is more representative of the impact of all isotopes on the body as a whole. The TEDE dose is presented for potential future use. It is important to note that tritium does not impact the thyroid doses utilizing the TID-14844 methodology, because only iodine is applied to the thyroid dose. However, in fact tritium does contribute to the thyroid dose, as well as other organs of the body. This is why the TEDE is a more representative dose when discussing the impact of tritium. It is up to the end user to choose the dose which is to be used, with the understanding that each methodology has a different meaning

References

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2. Halitsky, James et. al., "Wind Tunnel Tests of Gas Diffusion From a Leak in the Shell of a Nuclear Power Reactor and from a Nearby Stack" Department of Meteorology and Oceanography Geophysical Sciences Laboratory Report No.63-2, New York University, April 1, 1963
3. Computer Code FENCDOSE R4, code I. D. 262358
4. System Description N3-77A-4001 R4 "Gaseous Waste Disposal System"
5. Safety Guide 24 (Regulatory Guide 1.24) "Assumptions Used For Evaluating the Potential Radiological Consequences of a Pressurized Water Reactor Radioactive Storage Tank Failure" 3/23/72
6. WBNNAL3-003 R4 "Reactor Coolant Activities in Accordance with ANS/ANSI-18.1-1984"
7. Computer Code COROD R5, code I. D. 262347
8. TI-RPS-197 R17 "Offsite Doses Due to a Regulatory Guide 1.4 Loss of Coolant Accident"
9. TI-RPS-198 R17 "Dose to Control Room Personnel Due to a Regulatory Guide 1.4 Loss of Coolant Accident"
10. WBNNAL3-006 R1 "Gaseous Source Term Study" RIMS# B26 940916 362
11. WAT-D-10436, September 12, 1997 RIMS# T28 970912 803
12. WBN CCD drawing 1-47W866-2 R10
13. WBN drawing 47W930-5 RE
14. WBN drawing 47W200-1 R11
15. WBN drawing 41N712-1 RD
16. WBN drawing 41N718-1 RE
17. WBN drawing 47W200-13 R5
18. WBN drawing 47W930-2 RP
19. WBN drawing 47W930-3 RP
20. WBN drawing 47W200-8 R7
21. deleted in R4
22. deleted in R6
23. NUREG-0800 R2 section 11.3
24. WBNAPS3-104, R2 "WBN Control Room X/Q"
25. NUREG-0017 R1, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Pressurized Water Reactors', USNRC, April 1985
26. Regulatory Guide 1.109 R1, "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I.
27. Design Criteria WB-DC-40-24 R10, "Radiation Monitoring"
28. EDC E50629A
29. Calculation EPM-PFS-072991 R3 "Air Volumes, Penetrations and Door Opening Data for Auxiliary Building"
30. WBN CCD drawing 1-47W866-2 R24
31. Calculation WBNTSR-009 R11 "Control Room Operator and Offsite Doses From a Fuel Handling Accident"

Appendix A
Input for COROD

```
//TSR64C7A JOB 264360,'9MBERG.BIN111',MSGLEVEL=1,MSGCLASS=T
//*MAIN ORG=LOCAL,CLASS=SB
//JCL JCLLIB ORDER=(APB.NEN.EX262358.PROCLIB)
//STEP1 EXEC CORODV6,COND=(4,LT)
//COROD1.FT05F001 DD *
NIT= 19   NR= 1   ITP= 6   FACT= 1.0
COROD-WBN WGDT                                                    S
KRM 83  KRM 85  KR 85  KR 87  KR 88  KR 89
XEM 131  XEM 133  XE 133  XEM 135  XE 135  XE 137  XE 138
I 131  I 132  I 133  I 134  I 135  H 3
   5  'RG 1.24 REL                      ' $ TN=  0.5722E-02
       1 4.815E-01     2 3.684E+00    3 1.191E+02     4 8.209E-01     5 4.533E+00
       6 2.732E-03     7 2.523E+01    8 2.835E+01     9 1.928E+03    10 1.351E+00
      11 2.664E+01    12 7.423E-03   13 8.997E-02    14 1.361E-03    15 0.0
      16 9.355E-04    17 0.0         18 3.401E-04    19 0.0
   5  'RG 1.24 REL                      ' $ TN=  0.2000E+01
       1 1.534E+01     2 1.224E+02    3 4.081E+03     4 2.534E+01     5 1.480E+02
       6 2.503E-02     7 8.643E+02    8 9.690E+02     9 6.599E+04    10 3.005E+01
      11 8.998E+02    12 7.801E-02   13 1.930E+00    14 4.660E-02    15 0.0
      16 3.185E-02    17 0.0         18 1.141E-02    19 0.0
  -6  'ENVIRONMENT          CURIES      ' $ TN=  0.8000E+01
       1 0.000E+00     2 0.000E+00    3 0.000E+00     4 0.000E+00     5 0.000E+00
       6 0.000E+00     7 0.000E+00    8 0.000E+00     9 0.000E+00    10 0.000E+00
      11 0.000E+00    12 0.000E+00   13 0.000E+00    14 0.000E+00    15 0.000E+00
      16 0.000E+00    17 0.000E+00   18 0.000E+00    19 0.000E-00
  -6  'ENVIRONMENT          CURIES      ' $ TN=  0.2400E+02
       1 0.000E+00     2 0.000E+00    3 0.000E+00     4 0.000E+00     5 0.000E+00
       6 0.000E+00     7 0.000E+00    8 0.000E+00     9 0.000E+00    10 0.000E+00
      11 0.000E+00    12 0.000E+00   13 0.000E+00    14 0.000E+00    15 0.000E+00
      16 0.000E+00    17 0.000E+00   18 0.000E+00    19 0.000E-00
  -6  'ENVIRONMENT          CURIES      ' $ TN=  0.9600E+02
       1 0.000E+00     2 0.000E+00    3 0.000E+00     4 0.000E+00     5 0.000E+00
       6 0.000E+00     7 0.000E+00    8 0.000E+00     9 0.000E+00    10 0.000E+00
      11 0.000E+00    12 0.000E+00   13 0.000E+00    14 0.000E+00    15 0.000E+00
      16 0.000E+00    17 0.000E+00   18 0.000E+00    19 0.000E-00
  -6  'ENVIRONMENT          CURIES      ' $ TN=  0.7200E+03
       1 0.000E+00     2 0.000E+00    3 0.000E+00     4 0.000E+00     5 0.000E+00
       6 0.000E+00     7 0.000E+00    8 0.000E+00     9 0.000E+00    10 0.000E+00
      11 0.000E+00    12 0.000E+00   13 0.000E+00    14 0.000E+00    15 0.000E+00
      16 0.000E+00    17 0.000E+00   18 0.000E+00    19 0.000E-00
2.52E-3 2.52E-3 1.57E-3 6.71E-4 4.99E-4 3.79E-4
20.6  7179.4  21600.0  57600.0  259200.0  2246400.0
3200.0  51.0
711.0  51.0
711.0  51.0
711.0  51.0
711.0  51.0
711.0  51.0
0.0  0.0  0.0  0.0  0.0  0.0  3200.0
0.95  0.70  0.95  0.70  0.99  0.0  2889.0
0.95  0.70  0.95  0.70  0.99  0.0  2889.0
0.95  0.70  0.95  0.70  0.99  0.0  2889.0
0.95  0.70  0.95  0.70  0.99  0.0  2889.0
0.95  0.70  0.95  0.70  0.99  0.0  2889.0
100.0  60.0  40.0  1440.0  5760.0 257198.0
1.2492 0.63  0.8352
322.0 45.0 17.75 46.0 9.0 4.0 161.0 22.5 4.0 0.0
ROOFFLUX DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE THROUGH ROOF
1000.0 1000.0 1000.0  20.0  20.0 20.0  500.0  500.0  -16.0  2.25
ADJACENT DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE FROM AUX BUILDING
270.0 150.0 148.0 27.0 15.0 14.0 135.0 75.0 -25.5  3.0
ADJACENT DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE FROM TURBINE BLDG
322.0  112.0  341.0  32.0 11.0 34.0  161.0  56.0  -25.5  3.0
ADJACENT DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE FROM SPREADING ROOM
322.0  45.0  26.0 32.0 9.0 5.0  22.5  161.0  -4.67  0.67
ADJACENT DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE FROM CR BLDG END
18.0 45.0 460.0 10.0 10.0 100.0 4.0 22.5 -25.5 3.0
ADJACENT DOSE TO CONTROL ROOM PERSONNEL DUE TO SHINE FROM CR BLDG END
18.0 45.0 460.0 10.0 10.0 100.0 4.0 22.5 -25.5 3.0
/*
//
```

Appendix B
Input for FENCDOSE

```
1
KRM-83  KRM-85  KR-85
KR-87  KR-88  KR-89
XEM-131 XEM-133 XE-133 XEM-135 XE-135 XE-137 XE-138
I-131  I-132  I-133  I-134  I-135
T
.141E-3  .668E-4  .459E-4  .204E-4  .635E-5  6.07E-4
WBN WASTE GAS DECAY TANK RUPTURE, 500MREM EQIVALENCY-NON-TPC
TIME TO 2.0 HOURS
  -6 'WG DECAY TANK     CURIES     '$ TN=  0.2000E+01
     1 1.484E+01   2 1.135E+02   3 3.667E+03   4 2.532E+01   5 1.397E+02
     6 8.730E-02   7 7.770E+02   8 8.730E+02   9 5.936E+04  10 4.190E+01
    11 8.206E+02  12 2.357E-01  13 2.794E+00  14 4.800E-02  15 0.000E+00
    16 3.300E-02  17 0.000E+00  18 1.200E-02
WBN WASTE GAS DECAY TANK RUPTURE
TIME TO 8 HOURS
  -6 'WG DECAY TANK     CURIES     '$ TN=  0.8000E+01
     1 0.0      2 0.0      3 0.0      4 0.0      5 0.0
     6 0.0      7 0.0      8 0.0      9 0.0     10 0.0
    11 0.0     12 0.0     13 0.0     14 0.0     15 0.0
    16 0.0     17 0.0     18 0.0
WBN WASTE GAS DECAY TANK RUPTURE
TIME TO 1 DAY
  -6 'WG DECAY TANK     CURIES     '$ TN=  0.2400E+02
     1 0.0      2 0.0      3 0.0      4 0.0      5 0.0
     6 0.0      7 0.0      8 0.0      9 0.0     10 0.0
    11 0.0     12 0.0     13 0.0     14 0.0     15 0.0
    16 0.0     17 0.0     18 0.0
WBN WASTE GAS DECAY TANK RUPTURE
TIME TO 4 DAYS
  -6 'WG DECAY TANK     CURIES     '$ TN=  0.9600E+02
     1 0.0      2 0.0      3 0.0      4 0.0      5 0.0
     6 0.0      7 0.0      8 0.0      9 0.0     10 0.0
    11 0.0     12 0.0     13 0.0     14 0.0     15 0.0
    16 0.0     17 0.0     18 0.0
WBN WASTE GAS DECAY TANK RUPTURE
TIME TO 30 DAYS
  -6 'WG DECAY TANK     CURIES     '$ TN=  0.7200E+03
     1 0.0      2 0.0      3 0.0      4 0.0      5 0.0
     6 0.0      7 0.0      8 0.0      9 0.0     10 0.0
    11 0.0     12 0.0     13 0.0     14 0.0     15 0.0
    16 0.0     17 0.0     18 0.0
```

Attachment 14

TVA Nuclear Power Group Calculation

TI-RPS-197 R21

Offsite Doses Due to a Regulatory Guide 1.4 Loss of Coolant Accident

NPG CALCULATION COVERSHEET/CCRIS UPDATE

Page 1

REV 0 EDMS/RIMS NO. NEB 850213 236	EDMS TYPE: calculations(nuclear)	EDMS ACCESSION NO (N/A for REV. 0) T93100113019

Calc Title:
Offsite Doses Due to a Regulatory Guide 1.4 Loss of Coolant Accident

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	CUR REV	NEW REV	REVISION APPLICABILITY
CURRENT	CN	NUC	WBN	NTB	TI-RPS-197	R20	R21	Entire calc ☒ Selected pages ☐
NEW	CN	NUC						

ACTION	NEW ☐ REVISION ☒	DELETE ☐ RENAME ☐	SUPERSEDE ☐ DUPLICATE ☐	CCRIS UPDATE ONLY ☐ (Verifier Approval Signatures Not Required)	No CCRIS Changes ☐ (For calc revision, CCRIS been reviewed and no CCRIS changes required)

UNITS	SYSTEMS	UNIDS
1,2	NA	NA

DCN,EDC,N/A	APPLICABLE DESIGN DOCUMENT(S)	CLASSIFICATION
EDCR 54956	NA	E

QUALITY RELATED?	SAFETY RELATED? (If yes, QR = yes)	UNVERIFIED ASSUMPTION	SPECIAL REQUIREMENTS AND/OR LIMITING CONDITIONS?	DESIGN OUTPUT ATTACHMENT?	SAR/TS and/or ISFSI SAR/CoC AFFECTED
Yes ☒ No ☐	Yes ☒ No ☐	Yes ☐ No ☒	Yes ☒ No ☐	Yes ☐ No ☒	Yes ☒ No ☐

PREPARER ID	PREPARER PHONE NO	PREPARING ORG (BRANCH)	VERIFICATION METHOD	NEW METHOD OF ANALYSIS
MCBERG	(603) 926-3810	WorleyParsons Polestar	Design Review	☐ Yes ☒ No

PREPARER SIGNATURE Marc C. Berg Marc C. Berg	DATE 1-8-10	CHECKER SIGNATURE Heather Lucek Heather Lucek	DATE 1-8-10
VERIFIER SIGNATURE Heather Lucek Heather Lucek	DATE 1-8-10	APPROVAL SIGNATURE Roshellia Goines Roshellia Goines	DATE 1/09/2010

STATEMENT OF PROBLEM/ABSTRACT

This calculation determined the offsite doses due to a Regulatory Guide 1.4 Loss of Coolant Accident (LOCA). Revision 2 was performed because the dispersion coefficients (X/Q) values have changed. Also, the Interim Auxiliary Building Secondary Containment Enclosure (ABSCE) is being changed to the Final ABSCE. Since the ABSCE has not changed yet, this calculation determined the doses due to both the Interim and Final ABSCE. The calculation was entirely rewritten for legibility and to bring the format into accordance with NEP 3.1.

Computer code STP was used to determine the activity released to the environs and computer code FENCDOSE was used to determine the offsite doses. Initial core inventories came from WBNNAL3-004. It was assumed that 25% of the iodines and 100% of the noble gasses were available for release. The primary containment leak rate was assumed to be 0.25%/day for the first 24 hours and 0.125%/day thereafter. The annulus inleakage (250 cfm), EGTS recirculation flow rates, and EGTS exhaust rates were taken from TI-ANL-166. 75% of the leakage from containment went to the annulus and 25% to the Auxiliary Building. Iodine removal due to the ice condenser was taken into account.

-continued-

Special Requirements/Limiting Conditions

The special requirement/limiting condition of this calculation is: if 2 EGTS fans are operating, one must be turned off between 1 and 2 hours. Failure to turn off the second fan will not result in exceeding the 10CFR100 offsite dose limits.

MICROFICHE/EFICHE Yes ☒ No ☐ FICHE NUMBER(S) TVA-F-W001342

☐ LOAD INTO EDMS AND DESTROY
☒ LOAD INTO EDMS AND RETURN CALCULATION TO CALCULATION LIBRARY. ADDRESS: E98 1M-WBN
☐ LOAD INTO EDMS AND RETURN CALCULATION TO:

Revision 3 was performed because the annulus setpoint was changed from -0.5" to -1.036", which results in different EGTS exhaust curves (TI-ANL-166). The Interim ABSCE case was eliminated from the analysis. Revision 4 was performed to include in the STP model a single failure of the General Ventilation Exhaust Fans in the "on" position concurrent with one isolation damper failing open leading to unfiltered bypass of the ABGTS filters (WBPER930129). Revision 5 was performed because DCN M-29141-A fixed the unfiltered bypass condition described above. Therefore revision 5 re-establishes the revision 3 models and results. Revision 6 was performed to take into account ductwork leakage bypassing the ABGTS and EGTS filters and to also the potential temporary loss of differential pressure in the Auxiliary Building following the single failure of an ABGTS train. Revision 7 includes new X/Q values, added additional justification for ice condenser performance, and updated references. Revision 8 gave later test results for ABGTS leakage which is less than the values in R7. The calculation was not updated because the old leakages are more conservative. Successor calculations do not need to be revised because the results of this calculation were not changed. Revision 9 was performed to increase the ABGTS leakages. Revision 10 was performed to increase the ABGTS leakages. Revision 11 was performed because the annulus setpoint changed from -1.036" to -1.048" H2O.

Revision 12 incorporates new source terms from WBNNAL3-004 for 1000 EFPD (18 month cycle) with 5% U235 enrichment. R13 incorporated the 650 EFPD back into the calculation. Revision 14 was performed because the annulus setpoint was changed to -1.45" H2O and used the 1000 EFPD source. The results were the same as R13 (except for the third decimal point for the gamma, which was less by 0.001). Therefore it can be concluded that the new setpoint does not affect the offsite doses, and the analysis does not have to be performed for the 650 EFPD sources. Successor calculations do not need to be revised due to the change in setpoint.

Revision 15 is performed to establish the offsite doses with a Tritium Production Core (TPC). In addition, the standard core (non-TPC) results were redone to include different thyroid dose determination methodologies. The previous method used ICRP-2 iodine dose conversion factors. Now, ICRP-30 iodine dose conversion factors are also used, and the Total Effective Dose Equivalent (TEDE) are determined. The 650 EFPD results were deleted. Revision 15 added the new methodologies of ICRP-30 dose conversion factors for thyroid, and TEDE. Also, the TPC core was analyzed. The two TPC cores analyses (100% and 3% tritium release to atmosphere) show that the limits are not exceeded. Note that the standard core values do NOT have the same initial core inventories of iodines and noble gasses as the TPC core. This explains the difference in the standard vs. 3% tritium release TPC core results (one would have expected the results to be similar). The results are mixed, in that in some cases the TPC core gives the largest dose (such as 2-hr EAB TEDE). However, in other cases the standard core gives a larger dose (such as 2-hr EAB thyroid). Therefore, both standard and TPC configurations must be examined in any LOCA personnel dose analysis. The offsite doses calculated are below the regulatory limits of 25 rem gamma, 300 rem beta, and 300 rem thyroid (and below the 25 rem TEDE).

Revision 18 is performed to roll calculations WBNNAL3-028 and WBNTSR-073 into this calculation. The EGTS is assumed to fail in such a way so as to have a maximum exhaust for the duration of the accident. This will bound any accident, failure, or abnormal operation which affects the EGTS system.

Revision 19 addresses the changes in the drawdown volume of the Auxiliary Building for ABGTS resulting from the changed ABSCE boundary of DCN 52283A. Revision 19 shows that changes to the ABSCE will create a minimal difference in Auxiliary Building volume that remains bounded by the effective volume applied in this calculation. The DCN 52283-A changes are intended to remain in effect during WBN Unit 2 construction completion activities.

Revision 20 is performed to change the flow rates due to a more rigorous exhaust calculation, and to incorporate an operator action time between 1 and 2 hours to support corrective actions for PER 91670. Revision 20 investigated the impact of a new single failure scenario associated with the control loop for one pair of PCOs. Current procedures require Operations to turn off one EGTS fan subsequent to EGTS start. An operator action between 1 and 2 hours to shut off one of two EGTS fans will impact the results. If there is some recirculation with the second train running, then there will be an insignificant (about 1%) increase in the dose if the action is at 1 hour instead of 2 hours (Appendix H). Per Appendix H, a 1 hour operator action should be the design basis of the plant, since it results in the highest doses for gamma, beta, and TEDE. The EGTS single failure with 250 cfm steady state exhaust results (Appendix I) in higher Inhalation and 2-hr EAB TEDE doses. Per Appendix G, there is not much difference between 8000+10% and 8000-10% EGTS flow. However, the lower flow is slightly higher, and this is primarily due to the increase time at the beginning of the accident when the annulus is at a positive pressure and the slower pump down rates. The offsite doses calculated are below the regulatory limits of 25 rem gamma, 300 rem beta, and 300 rem thyroid (and below the 25 rem TEDE). See Results section for values. Revision 21 performs the PCO control loop single failure for Unit 2 (which is bounded by the Unit 1 LOCA, Appendix J.

Special Note: The EGTS single train (250 cfm steady state exhaust) scenario applies to both units.

NPG CALCULATION COVERSHEET/CCRIS UPDATE

Page 3

CALC ID	TYPE	ORG	PLANT	BRANCH	NUMBER	REV
	CN	NUC	WBN	NTB	TIRPS197	21

ALTERNATE CALCULATION IDENTIFICATION

BLDG	ROOM	ELEV	COORD/AZIM	FIRM	Print Report Yes ☒

CATEGORIES

KEY NOUNS (A-add, D-delete)

ACTION (A/D)	KEY NOUN	A/D	KEY NOUN

CROSS-REFERENCES (A-add, C-change, D-delete)

ACTION (A/C/D)	XREF CODE	XREF TYPE	XREF PLANT	XREF BRANCH	XREF NUMBER	XREF REV
A	P	CN	WBN	MEB	MDQ00206520090368	0
A	P	ED	WBN	MEB	EDCR 54956	

CCRIS ONLY UPDATES:
Following are required only when making keyword/cross reference CCRIS updates and page 1 of form NEDP-2-1 is not included:

PREPARER SIGNATURE	DATE	CHECKER SIGNATURE	DATE
PREPARER PHONE NO.	EDMS ACCESSION NO.		

NPG CALCULATION RECORD OF REVISION

CALCULATION IDENTIFIER TI-RPS-197

Title Offsite Doses Due to a Regulatory Guide 1.4 Loss of Coolant Accident

Revision No.	DESCRIPTION OF REVISION
0	Initial Issue
1	Revision 1 was performed to change the calculation to reflect the Interim ABSCE (10 minute ABGTS bypass) instead of the Final ABSCE (4 minute ABGTS bypass). In addition, the ice condenser iodine removal efficiencies were changed to reflect new ice weight technical specifications. Pages added: 2.1, 2.2, 18.1, 21.1., 22.1 Pages deleted: 1,2,18,21,22 Pages changed: coversheet, 5, 7, 8, 14-16, 24
2	Revision 2 was performed to reflect new X/Q values, and because the configuration of the plant will be changing to the Final ABSCE. However, both the Interim and Final ABSCE results will be presented because the ABSCE changes have not been finalized. The calculation was entirely rewritten for legibility and to bring the format in conformance with NEP 3.1 R1-PCN4. Pages added: all Pages deleted: all of revision 1
3	Revision 3 was performed because the annulus setpoint was changed from -0.5" H2O to -1.036" H2O. This resulted in new EGTS exhaust rates. This revision also eliminated the Interim ABSCE case. Pages added: none Pages deleted: none Pages changed: 1-4, 6-8, 10-12, 14-15, 17-18
4	Revision 4 was performed to add unfiltered leakage past the ABGTS filters for 1 hour at the beginning of the LOCA due to a single failure of the Auxiliary Building General Ventilation Exhaust Fan failure in the "on" position (WBPER930129). Pages added: new cover (p.1) Pages changed: 1.1 (old cover, previously p.1), 2-10, 13, 16-18 Pages deleted: none
5	Revision 5 was performed because the unfiltered bypass leakage from revision 4 was fixed in DCN M-29141-A. The revision 3 models and results were re-established. Pages added: none Pages changed: 2-6, 8, 9, 17, 18 Pages deleted: none
6	Revision 6 was performed to take into account ductwork leakage and the temporary loss of differential pressure in the Auxiliary Building following the single failure of an ABGTS train. Pages added: 19 Pages deleted: none Pages changed: 1-6, 8, 9, 11-13, 17, 18
7	Revision 7 was performed to include new X/Q values, justify ice condenser assumptions, and update references. All pages were renumbered. The "pages changed" listing does not include pages renumbered, but only pages with actual text modifications Pages added: Appendix A, Appendix B, Appendix C Pages deleted: Attachment B, Attachment C Pages changed: 4-13, 15-17, 19-22

NPG CALCULATION RECORD OF REVISION

CALCULATION IDENTIFIER TI-RPS-197

Title Offsite Doses Due to a Regulatory Guide 1.4 Loss of Coolant Accident

Revision No.	DESCRIPTION OF REVISION
8	Revision 8 was performed to address new ABGTS leak test data. The new data shows less leakage, therefore the calculation was not changed because the old leakage values lead to conservative results. Successor calculations do not need to be upgraded due to this revision because results did not change. pages changed: 1, 4, 6-9, 10, 11, 15, 22 pages added: 5.1, Attachment D (3 pages) pages deleted: none
9	Revision 9 was performed because the ABGTS leakage rate changed, but did not significantly impact the results. Therefore, successor calculations do not need to be updated. pages added: none pages deleted: none pages changed: 1, 4, 5.1, 6-9, 11, 12, 15, 20
10	Revision 10 was performed because the ABGTS leakage rate changed, but did not significantly impact the results. Therefore, successor calculations do not need to be updated. pages added: 1, 9.1 pages deleted: none pages changed 1.1 (old page 1), 4, 5.1, 6-12, 15, 20
11	Revision 11 was performed because of a change of the annulus setpoint from -1.036" H2O to -1.048" H2O. pages added: Attachment E (5 pages) pages deleted: none pages changed: 1, 4, 5.1, 6-12, 9.1, 15-18, 20-22
12	Revision 12 was performed because of new source terms. The calculation is based on 5% U235 enrichment, 1000 EFPD (18 month cycle). This was specifically done for cycle 2, however the results are also applicable to cycle 1. The R11 results should be used for cycle 1 until a 50.59 has been performed for the new fuel. pages added: none pages deleted: none pages changed: 1, 4, 5.1, 6-9, 9.1, 11, 12, 20, 21
13	Revision 13 was performed to incorporate the 650 EFPD results (from R11) into the calculation. pages added: 1 pages changed: 1a (old page 1), 4, 5.1, 6-8, 11, 20,21 pages deleted: none
14	Revision 14 was performed because the annulus setpoint changed from -1.048" to -1.45" H2O. pages added: none pages changed: 1, 4, 5.1, 6-9, 8.1, 11, 17, 18, 20, 21 pages deleted: none
15	Revision 15 was performed to incorporate the Tritium Production Core (TPC) as part of the analysis. Included as part of this is the revised version of FENCDOSE which can handle tritium. The answers are now expressed in terms of ICRP-2 thyroid dose (current design basis for the plant), ICRP-30 thyroid dose, and TEDE. 650 EFPD results were deleted as they no longer apply to WBN. Discussion on the limits and new dose methodologies were also added. pages added: Appendix A and B pages changed: 1, 4, 5.1, 6, 9, 9.1, 11-13, 15, 19, 20-22 pages deleted: Classification Forms R15: 50 total pages
16	Revision 16 was performed as part of EDC 50951A. This lowered the ice weight and thus changed the iodine removal efficiencies. The new values were found to give less conservative dose results compared to Revision 15. Therefore the previous results are still acceptable and no successors are impacted by this revision. Also, because the previous results are more conservative, the SAR and T/S are not impacted. Pages deleted: TVAN CTS Form, old coversheets Pages added: CCRIS Update Sheet, Appendix D Pages Changed: 1,5-9,19,21 Total Pages : 47
17	Revision 17 was performed as corrective action to PER 61493. This PER documented that dose calculations did not take into consideration the operation of two trains of ABGTS or EGTS. This calculation models the ABGTS with a conservative arbitrary holdup time of 0.3 hours. Therefore no matter the flow rate of the ABGTS, the volume is adjusted so that the holdup time is 0.3 hours. Therefore since the flowrate with two trains in operation would result in an AB volume less than that of the actual AB volume, the results would not be impacted by having two trains of ABGTS in operation.Operating with two trains of EGTS would achieve the desired annulus pressure differential in less time that with one train in operation. This results in less radioactivity released directly to the environment (i.e. less offsite dose). The steady state flow rate of 250 cfm would not be changed as this is the approximate flowrate required to maintain the desired annulus pressure differential. Therefore operating with two trains of EGTS would not impact the results of this calculation. Since the body of the calculation was not revised, the results remain unchanged and the FSAR and TS's are not impacted. Pages deleted: none Pages added: 12A Pages Changed: 1, 3, 5, 12 Total Pages : 48

NPG CALCULATION RECORD OF REVISION

CALCULATION IDENTIFIER TI-RPS-197

Title Offsite Doses Due to a Regulatory Guide 1.4 Loss of Coolant Accident

Revision No.	DESCRIPTION OF REVISION
18	Revision 18 is performed to address corrective actions for PERs 5313 and 91670 and to roll calculations WBNNAL3-028 and WBNTSR-073 into this calculation. The EGTS system is assumed to fail in such a way so as to have maximum exhaust for the duration of the accident. This will bound any accident, failure, or abnormal operation which affects the EGTS system. The inleakage was increased to 1281 cfm at -13.13" to correspond to maximum exhaust flow. This is intended to become the design basis LOCA for FSAR chapter 15. The FSAR is affected by this revision. Some of the affected successor calculations are: TI-RPS-198, WBNNAL3-028, WBNTSR-073, WBNAPS3-109, WBNAPS3-089, WBNAPS3-050, WBNTSR-028, WBNNAL3-002, WBNNAL3-004, WBNTSR-112, WBNTSR-005, WBNTSR-011, WBNTSR-096, WBNAPS3-049, WBNAPS3-072, WBNTSR-081, WBNTSR-114, WBNTSR-082, WBNTSR-083, WBNTSR-084, WBNTSR-085, WBNTSR-086, WBNTSR-087, WBNAPS3-081, WBNAPS3-078. Successor calculations will be handled by the corrective action plans for PERs 5313 and 91670 i.e. a DCN or EDC will not be issued for these issues. Pages added: 6, App.E Pages deleted: design verification form Pages changed: 1-3, 7-11, 13, 15, 16, 19, 21-26, 31-33 R18: 49 total pages
19	Revision 019 of this calculation supports the implementation of DCN 52283-A. DCN 52283-A removes the Unit 2 Containment from inside the ABSCE (Auxiliary Building Secondary Containment Envelope). Appendix F of this calculation was added to define the new ABSCE boundary as well as confirm that the maximum volume of the revised ABSCE boundary is bound by the applied effective volume. FSAR/TS will be reviewed/modified under DCN 52283A. FSAR Reviewer________________________ Date__________ Pages Added: Calculation Cover Sheet – pgs ii1, i1 Record of Revision – pg 6a Calculation Design Verification Form – pg 9a Appendix F – Modified ABSCE Boundary of DCN 52883-A – pg F1, F2, F3 Pages Revised/Replaced: Table of Contents – pg 7 Purpose – pg 10 Conclusions – pg 19 References – pg 21 Pages Deleted: N/A Total number of pages in this revision including Attachments: 55 Pages
20	Revision 20 is performed to model a new single failure scenario and incorporate an operator time to turn off one fan of EGTS between 1 to 2 hours. Two train EGTS operation with a PCO control loop single failure is now the design basis accident which results in greater flow rates out the shield building stack and correspondingly higher gamma and beta doses. The operator action is to correct the EGTS system such that only one fan is in operation long term. Appendix G is added to evaluate the difference between 2 train EGTS flows of 8000+10% = 8800 cfm versus 8000-10%=7200 cfm flow. Appendix H is added to evaluate the operator action time (1 hour versus 2 hour). The single train EGTS failure case from WBNAL3-028 (250 cfm EGTS steady state exhaust) is presented in Appendix I. SAR has been reviewed by Marc Berg and this revision of the calculation affects SAR section Chapter 15 . A SAR change shall be processed in accordance with NADP-7 to reflect the calculation results as part of EDC 52564.Tech Specs have been reviewed and determined not to be affected. The affected successor calculations are listed in the R18 revision log. Successor calculations will be updated as part of EDC 52564. Pages added: Appendix G, Appendix H, Appendix I Pages deleted: none Pages changed: 1-3, 6, 7, 9-19, 21-28 R20: 61 total pages
21	Revision 21 is performed to model the unit 2 version of the PCO control loop single failure (revision 20 only analyzed Unit 1). SAR has been reviewed by Marc Berg and this revision of the calculation affects Unit 2 SAR section Chapter 15 . A SAR change shall be processed in accordance with NGDC PP-10 to reflect the calculation results as part of EDCR 54956. Tech Specs have been reviewed and determined not to be affected. The affected successor calculations are listed in the R18 revision log. Successor calculations will be updated as part of EDCR 54956. Pages added: 7.1, Appendix J (pages 46-48) Pages deleted: none Pages changed: 1-3, 6-10, 13, 18, 19, 21-23 R21: 65 total pages

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Calculation Identifier: TI-RPS-197	Revision: 21	

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NPG CALCULATION VERIFICATION FORM

Calculation Identifier	TI-RPS-197	Revision 21

Method of verification used:

1. Design Review ☒
2. Alternate Calculation ☐
3. Qualification Test ☐

Verifier Heather Lucek Date 1-7-2010

Comments:

I have reviewed TI-RPS-197 R21 and have found the calculation to have been completed in a technically sound an appropriate manner to address the PCO control loop single failure in Unit 2. In conducting the verification I reviewed the methodology, design input, and assumptions which I found to be valid and conservative. I verified the computer code inputs for correctness and confirmed they only contained the changes as specified in this document. I also confirmed the correct output values were compiled in the results.

NPG COMPUTER INPUT FILE
STORAGE INFORMATION SHEET

Document TI-RPS-197	Rev. 21	Plant: WBN	

Subject:
Offsite Doses Due to a Regulatory Guide 1.4 Loss of Coolant Accident

☐ Electronic storage of the input files for this calculation is not required. Comments:

☒ Input files for this calculation have been stored electronically and sufficient identifying information is provided below for each input file. (Any retrieved file requires re-verification of its contents before use.)

The computer input for R9 is permanently stored in FILEKEEPER file # 263513.
The computer input for R10 is permanently stored in FILEKEEPER file # 263547.
The computer input for R11 is permanently stored in FILEKEEPER file # 263604.
The computer input for R12 is permanently stored in FILEKEEPER file # 292551.
The computer input for R14 is permanently stored in FILEKEEPER file # 292736.
The computer input for R15 is permanently stored in FILEKEEPER file # 303356.
The computer input for R16 is permanently stored in FILEKEEPER file # 303782.
The computer input for R18 is permanently stored in FILEKEEPER file # 308817.
The computer input for R20 is permanently stored in FILEKEEPER file # 311653 through 311668
The computer input for R21 is stored in eFiche TVA-F-W001342

☐ Microfiche/eFiche

NPG COMPUTER OUTPUT
MICROFICHE INFORMATION SHEET

Document TI-RPS-197	Rev. 21	Plant: WBN

Subject:
Offsite Doses Due to a Regulatory Guide 1.4 Loss of Coolant Accident

Microfiche Number	Description		
R2: WRAD-22	R2: note this is microfilm		
R3:TVA-F-G104044			
R4:TVA-F-G104620			
R6: TVA-F-C000022			
R7: TVA-F-C000048 TVA-F-I000084	R7:		
	Name	Code	Description
	RPS197S7	STP	activity released Final ABSCE
	RPS197F7	FENCDOSE	offsite dose Final ABSCE
	CDCONL	MONSTER	blowdown flow determination (Appendix A)
R9: TVA-F-C000094	R9:		
	RPS197S9	STP	activity released Final ABSCE
	RPS197F9	FENCDOSE	offsite dose Final ABSCE
R10: TVA-F-C000098	R10:		
	RP197S10	STP	activity released Final ABSCE
	RP197F10	FENCDOSE	offsite dose Final ABSCE
R11: TVA-F-C00010	R11:		
	RP197S11	STP	activity released Final ABSCE
	RP197F11	FENCDOSE	offsite dose Final ABSCE
R12: TVA-F-C000133	R12:		
	RP197S12	STP	activity released Final ABSCE
	RP197F12	FENCDOSE	offsite dose Final ABSCE
R14: TVA-F-C000161	R14:		
	RP197S14	STP	activity released Final ABSCE
	RP197F14	FENCDOSE	offsite dose Final ABSCE
R15: TVA-F-C000325	R15:		
	R197IS15	STPISOTP	gamma and decay info for STP
	R197S15A	STP	activity released, TPC 100% H3 airborne
	R197S15B	STP	activity released, TPC 3% H3 airborne
	R197F15A	FENCDOSE	offsite dose, TPC 100% H3 airborne
	R197F15B	FENCDOSE	offsite dose, TPC 3% H3 airborne
	R197F15X	FENCDOSE	offsite dose, standard core (non-TPC)
R16: TVA-F-W000237	R16 (efiche):		
	R197S	STP	activity released, TPC 100% H3 airborne
	R197F	FENCDOSE	offsite dose, TPC 100% H3 airborne
R18: TVA-F-W000672	R18 (efiche):		
	R197S18A	STP	activity released, conventional core (non-TPC)
	R197S18B	STP	activity released, TPC 100% H3 airborne
	R197S18C	STP	activity released, TPC 3% H3 airborne
	R197F18A	FENCDOSE	offsite dose, standard core (non-TPC)
	R197F18B	FENCDOSE	offsite dose, TPC 100% airborne
	R197F18C	FENCDOSE	offsite dose, TPC 3% H3 airborne
R20: TVA-F-W000751, TVA-F-W000754, TVA-F-W000814	R20 (efiche):		
	R197S19#	STP	activity released
	R197F19#	FENCDOSE	offsite dose
	A= conventional core, 1-hr operator action		
	B= TPC 100% H3 airborne, 1-hr operator action, 7200 cfm EGTS		
	C= TPC 3% H3 airborne, 1-hr operator action, 7200 cfm EGTS		
	D= TPC 3% H3 airborne, no operator action, 7200 cfm EGTS		
	E= conventional core, no operator action, 7200 cfm EGTS		
	F= TPC 100% H3 airborne, no operator action, 7200 cfm EGTS		
	G= TPC 3% H3 airborne, 2-hr operator action, 7200 cfm EGTS		
	H= TPC 3% H3 airborne, 2-hr operator action, 8800 cfm EGTS		
R21: TVA-F-W001342	R21 (efiche):		
	R197S21#	STP	activity released
	R197F21#	FENCDOSE	offsite dose
	A= conventional core B= TPC 100% H3 airborne, D= TPC 3% H3 airborne		

Purpose

The purpose of this calculation is to determine the offsite doses due to a Regulatory Guide 1.4 (ref.1) Loss of Coolant Accident. Revision 2 is being performed because the X/Q values and EGTS exhaust rates have changed. The calculation is being rewritten for legibility and to bring the format into accordance with NEP 3.1 R1. Revision 3 is performed because the annulus setpoint was changed from -0.5" to -1.036" H2O, which results in different EGTS exhaust curves (ref.19). The Interim ABSCE case was eliminated from the analysis. Revision 4 is performed to include in the STP model a single failure of the General Ventilation Exhaust Fans in the "on" position concurrent with the failure of one of the isolation dampers to close leading to unfiltered bypass of the ABGTS filters (WBPER930129, ref.22). Revision 5 is performed to re-establish the revision 3 models and results because the ABGTS bypass no longer exists due to modifications from DCN M-29141-A (ref.25). Revision 6 is performed to take into account ABGTS and EGTS leakage and also the potential temporary loss of Auxiliary Building differential pressure following a single failure of an ABGTS train. Revision 7 is performed to incorporate new X/Q values, justify Ice Condenser parameters, and update references. Revision 8 is performed to address new ABGTS leakage values. Revision 9 is performed to increase ABGTS leakage. Revision 10 is performed to increase ABGTS leakage. Revision 11 is performed because the annulus setpoint changed from -1.036" to -1,048" H2O. Revision 12 incorporates new source terms from WBNNAL3-004 for 1000 EFPD (18 month cycle) with 5% U235 enrichment. The extended burnup fuel is for cycle 2. R13 is performed to incorporate the R11, 650 EFPD (cycle 1) results into the calculation. Revision 14 is performed because the annulus setpoint was changed from -1.048" to 1.45" H2O.

Revision 15 is performed to establish the offsite doses with a Tritium Production Core (TPC). In addition, the standard core (non-TPC) results were redone to include different thyroid dose determination methodologies. The previous method used ICRP-2 iodine dose conversion factors. This calculation determined the doses using 3 different methodologies. The gamma, beta and Thyroid (ICRP-2) doses are all based on TID-14844 methodologies utilizing the ICRP-2 iodine dose conversion factors found in TID-14844 and are the current (as of June 2001) licensing basis of the plant. The second methodology is the Thyroid (ICRP-30) dose, which is also based on TID-14844, but uses the ICRP-30 iodine dose conversion factors. The ICRP-30 iodine dose conversion factors are less conservative than the ICRP-2 factors. This methodology is presented for potential future use. Finally, the third methodology used is the TEDE (Total Effective Dose Equivalent). The TEDE presents an overall weighted dose and is more representative of the impact of all isotopes on the body as a whole. The TEDE dose is presented for potential future use, however is not currently (as of June 2001) part of the design basis of the plant. It is important to note that tritium does not impact the thyroid doses utilizing the TID-14844 methodology, because only iodine is applied to the thyroid dose. However, in fact tritium does contribute to the thyroid dose, as well as other organs of the body. This is why the TEDE is a more representative dose when discussing the impact of tritium. It is up to the end user to choose the dose which is to be used, with the understanding that each methodology has a different meaning. The 650 EFPD results were deleted as WBN utilizes an extended cycle, ie. 18 months and 1000 EFPD.

Revision 18 is performed to incorporate EGTS exhaust rates which reflect failures in the EGTS system. It is now assumed that the EGTS exhausts at the maximum rate for the entire accident, and the accident starts with the annulus at 0" H2O differential pressure (instead of -5" H2O). The calculations WBNNAL3-028 and WBNTSR-073 are rolled into this calculation.

Revision 19 is performed to address changes in the ABSCE boundary identified as part of DCN 52283-A.

Revision 20 is performed to incorporate a 1 to 2 hour operator action to correct the EGTS system. The EGTS system will be modeled as 2 trains with appropriate recirculation/exhaust based on new more rigorous flow calculations (both initial transient conditions as well as steady state single failure conditions) as opposed to maximum exhaust with no recirculation. Appendix G is added to evaluate the difference between 2 train EGTS flows of 8000+10% = 8800 cfm versus 8000-10%=7200 cfm flow. Appendix H is added to evaluate the operator action time (1 hour versus 2 hour).

Revision 21 is performed to add the Unit 2 evaluation of the PCO control loop single failure (Appendix J). Only the bounding cases (as determined in revision 20) of 1 hour operation action with the 8000-10% = 7200 cfm EGTS flow were evaluated.

Introduction

Guidelines for determining the radiological consequences due to design basis Loss of Coolant Accident (LOCA) for a pressurized water reactor are presented in Regulatory Guide 1.4 (ref.1). These guidelines provided the basis for this analysis. The computer code STP (ref.3) is used to calculate the activity released to the environs during the 30 days following the Reg.Guide 1.4 LOCA, and the computer code FENCDOSE (ref.4) is used to calculate the resulting offsite doses.

The offsite gamma dose limit is 25 rem (10CFR100.11), the thyroid dose limit is 300 rem (10CFR100.11), and the TEDE dose limit is 25 rem (10CFR50.67). SRP 6.4 in NUREG 0800 (ref.32) shows that the thyroid dose and beta dose limits are equivalent for the control room, therefore the offsite beta dose limit can be assumed the same as the offsite thyroid dose limit, 300 rem. 10CFR20.1201 also states that the organ (thyroid) dose and skin (beta) dose are equivalent.

Assumptions and Data

The following assumptions and parameters are used in this analysis:

1. The primary containment free volume available for mixing is: 1.27E6 cuft ref.2
2. The annulus free volume: (50% of which is assumed available for mixing) 3.75E5 cuft ref.19
3. The auxiliary building volume available for mixing is assumed to be: 1.62E5 cuft assumed, see Calc. (this is based on a conservative "effective volume" with an section assumed mean holdup time of 0.3 hours, see calculation section for justification)
4. The primary containment air return fan flow rate (1 of 2 assumed operating): 40,000 cfm ref.5
5. Total EGTS flow rate: 7,200 cfm ref.12,13 (see assumption 23 and 24 and Appendix G)

6a. EGTS exhaust flow rates: variable, Table 3 (see assumption 23)
6b. EGTS recirculation flow rates: variable, Table 3 (see assumption 23)

7. ABGTS flow rate: 9,000 cfm ref.18 see note 1,2
8. Primary containment leak rate: 0.25%/day 0-24 hrs,ref.1,11
   0.125%/day >24 hrs,ref.1,11
9. Annulus Inleakage (from Aux.Building): 957 cfm at -2.1"H2O with 2 EGTS trains, 694 cfm with 1 EGTS assumption 25
10. Primary containment leakage to annulus: 75% ref.11
11. Primary containment leakage to the Aux Bldg 25% ref.11
12. EGTS filter efficiencies: 99% ref.10
13. ABGTS filter efficiencies: 99% ref.10
14. Delay before credit is taken for ABGTS filters 4 min.Final ABSCE,ref.20,14
15. Mean holdup time of activity in the auxiliary building after initial 4 minutes: 0.3 hr assumed (see calculation section for discussion)
16. Ice condenser removal rates: see Table 2 ref.6
17. Meteorology: see Table 4 ref.8
18. Radioisotopes available for release: 25% core iodines ref.1
    100% noble gasses ref.1
19. Releases between time=0 to times up to 66 seconds post LOCA from the various systems breaching containment listed in WB-DC-40-34 (ref.37) are not taken into account. It is assumed that the consequences of any releases from the systems during the time when the system containment isolation valves are open is insignificant.

Technical Justification: The dose due to releases from the systems which are isolated will be very small. Calculation TI-632 (ref.39) analyzed the dose due to releases due to a purge at the start of the accident. Those doses were very small. The purge mass releases will certainly bound any potential release through the other systems being isolated, especially since many of those systems are closed/self contained. Also, most of the systems do not have a credible leakage path for the 0-66 sec time period from the containment atmosphere or reactor coolant into the system in question due to the system being at higher pressure than the containment atmosphere or the depressurized reactor coolant.

note 1) The ABGTS flow is 9000 cfm total, but only 7000 cfm is from the Auxiliary Building. 2000 cfm is from the vacuum relief. If the vacuum relief valves fail, then the flow from the Auxiliary Building will become 9000 cfm. For conservatism, it is assumed in this calculation that the vacuum relief lines fail.

note 2) DCN M-10354-B (ref.31) installed new controllers for the ABGTS. This modification resulted in new setpoints (ref.32). Initially following an accident, both ABGTS trains start up (ref.14). Operator action is needed to turn one of these trains off. If a single failure occurs subsequent to this action, the Auxiliary Building will lose its differential pressure. When the differential pressure reaches the setpoint, the other train is started up, but by this time the differential pressure requirement of -0.25" or greater has been lost. Therefore, according to the Standard Review Plan, secondary containment is lost. The time to reestablish the differential pressure is conservatively assumed to be the same as when the ABGTS first started at the beginning of the accident (4 minutes). The single failure is assumed to occur immediately following the operator action (30 minutes), therefore the direct leakage to the environment occurs from 30 to 34 minutes post LOCA. The leakage is assumed to be 9900 cfm, which is the same as the inleakage when there is a driving force (the differential pressure). This value is chosen because, as the differential pressure decreases, the driving force also decreases. The 9900 cfm is maximum leakage during maximum delta pressure (9000 cfm+10%), therefore, it is expected that during essential zero delta pressure, the outleakage will not exceed 9900 cfm. This calculation establishes 9900 cfm as the maximum permissible leakage. Note: the value of 9000 cfm was actually used in the analysis. This will not affect the results since the volume of the Auxiliary Building is arbitrarily set to have a holdup of 0.3 hour. If the model were changed from 9000 cfm to 9900 cfm, the volume would also change. The net effect would be for the holdup to be the same, and would not change any results.

20. For TPC configurations, two cases are analyzed. One TPC assumes 100% of the core tritium release to the containment atmosphere. The more realistic TPC case assumes 3% of the core tritium is released. (A conventional core is also analyzed)
Technical Justification: The TPC 100% release is clearly conservative since most tritium is expected to be in the form of water (H_2O), especially because of hydrogen recombiners in containment. Therefore, realistically a significant fraction of tritium will be in the sump water. The TPC 100% airborne case clearly provides an upper bound for tritium releases to the environment. The TPC 3% airborne case is a more realistic case where the tritium will mostly be in the sump. This case will maximize tritium in the sump. The 3% value is taken from the topical report, reference 41.

21. It is assumed that tritium is not filtered out by the EGTS or ABGTS system.
Technical Justification: It is expected that a significant fraction of tritium will be in the chemical form of water (HTO). Carbon filters will trap water. Assuming no delay, trapping, or filtration of the tritiated water assures that the results will be conservative.

22. Only one train of ABGTS is in operation. Two trains of EGTS trains are in operation
Technical Justification: This calculation models the ABGTS with a conservative arbitrary holdup time of 0.3 hours. Therefore no matter the flow rate of the ABGTS, the volume is adjusted so that the holdup time is 0.3 hours. Therefore since the flow rate with two trains in operation would result in a AB volume less than that of the actual AB volume, the results would not be impacted by having two trains of ABGTS in operation. With the exception of the thyroid dose, operation with a postulated PCO control loop single failure has greater releases than the previous design basis accident assumption of a single failure of one EGTS train (250 cfm steady state exhaust). The single EGTS failure (250 cfm steady state exhaust) case is presented in Appendix I. For the EGTS, cases with no operator action and with operator action to shut down one EGTS fan are presented in this analysis. In addition, comparisons between EGTS flow of 8000 cfm +10% and 8000 cfm – 10% are examined (Appendix G).

23. The EGTS is assumed to have a PCO control loop single failure at the beginning of the accident, such that the maximum 2 train flow occurs at the beginning of the accident until operator action is credited in turning off one fan between 1 and 2 hours.
Technical Justification: This will bound any operation mode (normal, single failure, or abnormal operation) of the EGTS. With full flow, the beginning of the accident will have variable exhaust flow. As the annulus is depressurized, less exhaust will be available. From MDQ00006520070121 (ref.55), the maximum steady state 2 train EGTS flow is 6131 cfm with an

exhaust of 957 cfm. This set of flows occurs when the EGTS should be set to full recirculation mode due to excessive depressurization (see flow curves taken from TI-ANL-166). At 602 seconds, the variable exhaust flow is reduced linearly to 957 cfm (finally achieving the steady state 957 cfm at 2100 sec) with recirculation of 6131-957=5174 cfm. This will remain the exhaust for the duration of the accident for the no operator action case. For the operator action cases to shut down one EGTS fan, the flows are changed to 694 cfm exhaust and 4278-694=3584 cfm recirculation. For Unit 2, from MDQ00206520090368 (ref. 58), the 2 train EGTS flow is 6569 cfm with an exhaust of 832 cfm and recirculation of 6569-832 = 5737 cfm. The 1 train EGTS flow is 4059 cfm with and exhaust of 604 cfm and recirculation of 4059-604 = 3455 cfm.

24. Prior to 60 seconds with 8000-10% =7200 cfm EGTS flow, the containment leakage goes directly to the environment. For 8000+10%=8800 cfm EGTS flow, the containment leakage directly to the environment last until 56 sec.
Technical Justification: From TI-ANL-166, the pressure in the annulus is positive (>-0.25" H20) for 60 sec or 56 sec. Therefore, there is no secondary containment (annulus) at that time.

25. This analysis was originally based on 250 cfm inleakage to the annulus (the tech spec leakage into the annulus at -0.5" H2O). With the inclusion of EGTS control loop single failure with maximum pumping down and the EGTS exhausting continually for the duration of the accident, the inleakage is assumed to be 957 cfm at -2.1" (ref. 47) with 2 EGTS trains, and 694 cfm at -2.1" with 1 EGTS fan operating. For Unit 2, the inleakage is assumed to be 832 cfm at -1.88" (2 EGTS trains) and 604 cfm at -1.48" (1 EGTS train) (ref.47).
Technical Justification: Due to the increase in steady state exhaust, the inleakage must be at the same as the exhaust rate.

26. For the case of operator action correcting the 2 train EGTS failure scenario described above, it is assumed that the action is between 1 and 2 hours to correct the operation to a single fan.
Technical Justification: The time frame is engineering judgment. Most operator actions are assumed to occur with 30 minutes. However, during discussions with Ops, it has been determined that 30 minutes is too short a time period for the type of accident where this failure could occur. A more reasonable time period of 1 to 2 hours was used in this calculation. Appendix H evaluates the worst case time frame.

Special Requirements/Limiting Conditions

The special requirement/limiting condition of this calculation is: If 2 EGTS fans are operating, one EGTS fan must be turned off between 1 and 2 hours. See assumption 26. The fan shall not be turned off earlier than 1 hour. Failure to turn off the second train will not result in exceeding the 10CFR100 offsite dose limits. However, turning off one fan prior to 1 hour could result in higher doses.

Calculations

The primary containment is modeled as one volume. The reduction of the iodine population due to the ice condenser is modeled as a time dependent removal process. Elemental and particulate species are only removed, the ice condenser removal efficiencies for organic iodines is minimal, thus no credit is assumed (ref.15 sec.8.2.6). The iodine removal rates and the basis for these removal rates are shown in Table 2. The Standard Review Plan 6.5.4 section III.1.a (ref.33) says that the ice condenser is considered ineffective in the removal of particulate iodine. However, Westinghouse has provided WBN with information (WAT-D-9902, ref.34) which shows that particulate iodine has a variety of removal mechanisms. The use of the same ice condenser removal efficiency for particulate as elemental iodine is conservative if no other particulate iodine removal mechanisms are modeled.

A description of the STP models' parameters are shown in Table 1. The activity assumed to be available for immediate release is 25% of the core activity of iodine and 100% of the core activity of noble gasses (ref.1). With the TPC, two cases are analyzed. Case B assumes 100% of the tritium is released to the containment atmosphere. In case C, only 3% is released to the containment atmosphere. The activities are taken from WBNNAL3-004 (ref.7). Activities for the TPC core are taken from WBNAPS3-098 (ref.40). The iodine is assumed to be 91% elemental, 5% particulate, and 4% organic (ref.1). Isotopes Kr-90, Xe-137, Xe-139, and Xe-140 are not used because of the very short half-lives (ranging from 13 seconds to 3.8 minutes). I-130 is not used because it has a very small core inventory (10^3 curies) compared to the other iodine isotopes (10^7-10^8 curies).

The LPZ doses are calculated by using the computer code FENCDOSE. The activity released to the environment during the time intervals 0-2 hrs, 2-8 hrs, 8-24 hrs, 24-96 hrs, and 96-720 hrs is taken directly form the STP results. The respective dispersion coefficients (X/Q) are taken from refs. 8 and 9 (see Table 4).

Figure 1
STP Model

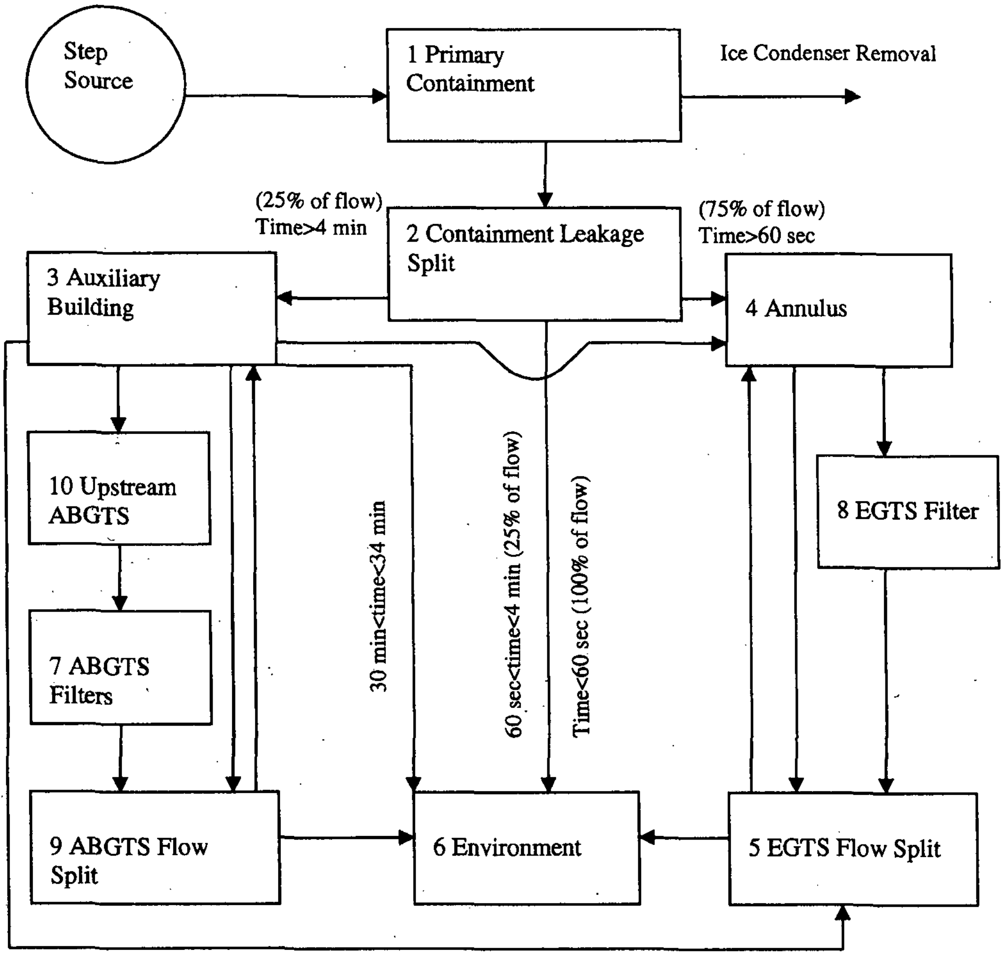


Table 1
STP Parameter Description (see Figure 1)

Step Source: At t=0, 100% of the core inventory of noble gasses and 25% of the core inventory of iodine are stepped into component 1. Core inventories are taken from reference 7 for normal core, reference 40 for TPC. With the TPC core, two cases are analyzed: case B assumes 100% of the tritium is released to the containment atmosphere. Case C assumes only 3% is released. Conventional core is designated as Case A.

Primary Containment: Volume = 1.27E6 cuft (ref.2)
(component 1) Ice condenser removal efficiencies see Table 2.
Flow 1-2: 0-24 hrs: 0.25% vol/day =
(0.25%)(1.27E6 cuft)(day/24hr)=132.3 cuft/hr
24 hrs-30 days: 0.125% vol/day =
(0.125%)(1.27E6 cuft)(day/24hr)=66.1 cuft/hr

Containment Leakage Split: Volume=1E-6 (arbitrarily small)
(component 2) Flow 2-6 = 1.0 for t<114 sec
Flow 2-6 = 0.25 for 114 sec <time<4 minutes (Final ABSCE)
Flow 2-6 = 0 for time>4 min
Flow 2-3=0.25 for t>4 minutes (Final ABSCE)
Flow 2-4=0.75 for t>114 sec

Auxiliary Building: Flow 3-10=9000 cfm or 5.4E5 cfh for t>4 minutes
(component 3) The auxiliary building free volume is about 3.5E6 cuft (ref.14). The exhaust rate is therefore about 0.15 volumes/hour, providing a mean holdup time of more than 6 hours. To account for any short circuits (incomplete mixing) a reduction factor is arbitrarily taken so that the holdup time will be a conservatively low 0.3 hour holdup time (tH):

tH=V/F or V=tH*F=(0.3 hr)(5.4E5 cuft/hr) =1.62E5 cuft

Flow 3-4=957 cfm (5.74E4 cfh) when 2 fans of EGTS operate and 695 cfm (4.16E4 cfh) when one fan is in operation (ref.55, leakage into annulus = EGTS exhaust rate)

Flow 3-6=9900 cfm or 5.94E5 cfh (as mentioned earlier, this is the leakage out of the building during the loss of ABGTS and lasts from 30 minutes to 34 minutes post LOCA)

Flow 3-5 = 10.7 cfm or 642 cfh (ref.30). This is the leakage into the entire EGTS system from the Auxiliary Building. The number is therefore very conservative because this leakage represents the unfiltered bypass of the EGTS, but the actual value includes leakage upstream of (and therefore filtered by) the EGTS filters.

Flow 3-9 = 27.88 cfm or 1672.8 cfh (ref.27). This is the leakage into the ABGTS ductwork downstream (and therefore bypassing) the filters and upstream of the fans. This value is for Unit 1. Unit 2 leakage is only 19.32 cfm, ref.28. Later testing (ref.38) gives the leakage for U1 as 5.39 cfm and for U2 as 3.73 cfm. The 27.88 cfm is conservative (more iodines will get out), therefore the model will not be updated and will bound any future increase (up to 27.88 cfm).

Annulus: Volume=0.5 * annulus free volume (this is assumed in order to account for incomplete mixing)
(component 4) =0.5*3.75E5 cuft =1.88E5 cuft
Flow 4-5=0 for t<8.33E-3 hr (based on 30 second delay in EGTS operation)
Flow 4-5=7200 cfm or 2.16E5 cfh for t>8.33E-3 hr
EGTS Flow Split: Volume=1E-6 (arbitrarily small)
(component 5) Flow 5-6= variable, see Table 3
Flow 5-4= variable, see Table 3

Environment: Volume=1 environment
(component 6) The environment is modeled as an accumulator which accumulates activity with no decay during the time periods for FENCDOSE input.

ABGTS Filters: Charcoal efficiency is 99% for iodine (ref.10), 0% for tritium
(component 7)
EGTS Filters: Charcoal efficiency is 99% for iodine (ref.10), 0% for tritium
(component 8)

Note on filters: In revision 2, the transmission cards "X" are replaced by the "U" filter card (and components 7 and 8 are added). This is done to take into account the transmission of noble gas daughter products through the filters.

ABGTS Flow Split: Volume = 1E-6 (arbitrarily small to prevent holdup)
(component 9) Flow 9-6 = 9000 cfm or 5.4E6 cfh (this is flow through the filters to the environment)
Flow 9-3 = 8.87 cfm or 532.2 cfh (ref.26) This is the leakage from the Unit 1 ABGTS ductwork downstream from the ABGTS filters into the Auxiliary Building. Unit 2 leakage is 24.32 cfm, ref.29, which would result in a smaller release if used. Later testing (ref.38) gives the leakage for U1 as 7.15 cfm and U2 as 5.1 cfm. Again, the old values will remain for conservatism. and for any changes in the future.

Upstream ABGTS:Volume = 1E-6 (arbitrarily small to prevent holdup)
(component 10) Flow = 9000 cfm or 5.4E6 cfh (the card used is "U 10 7 9 5.4E6 0.0 0.0 0.99 0.99 0.0")

Table 2:
Ice Condenser Removal Efficiencies (ref.6) Elemental and Particulate Iodine

Time Interval (hours)	Removal Efficiency (eff)	Lambda* (hr^{-1})
0-0.156	0.96	1.81
0.156-0.267	0.76	1.44
0.267-0.323	0.73	1.38
0.323-0.489	0.71	1.34
0.489-0.615	0.60	1.13
0.615-0.768	0.58	1.10
0.768-0.824	0.40	0.76
0.824-720	0.0	0.0

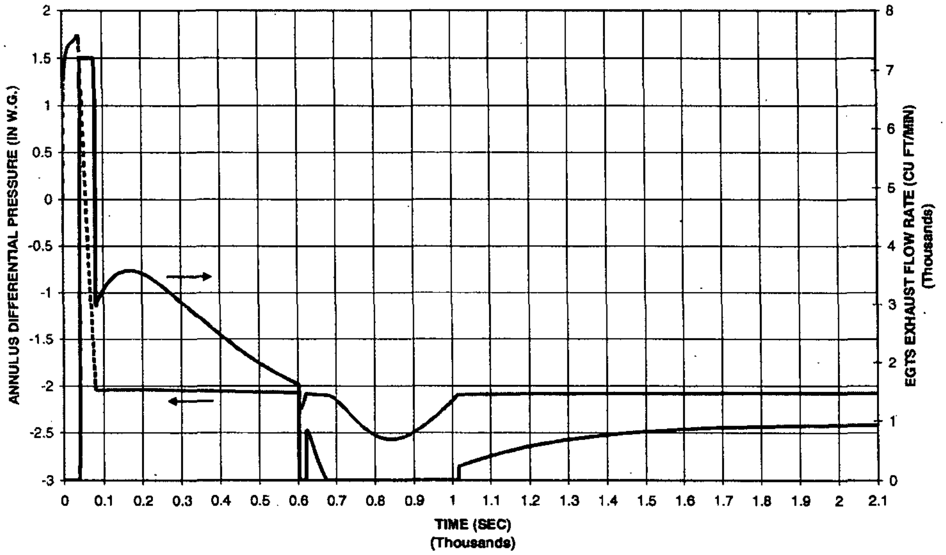
* Based on a primary containment free volume of 1.27E6 cuft and a flow rate of 40,000 cfm where:

$$\text{Lambda} = (F/V)*\text{eff} = (40{,}000\ \text{cfm}/1.27\text{E}6\ \text{cuft})(60\ \text{min/hr})(\text{eff}) = 1.89*\text{eff}\ [hr^{-1}]$$

Note: The lower containment air return fans do not start until 8-10 minutes post LOCA (ref.35,5). However, the normal circulation during this time period is much greater than the fan flow of 40,000 cfm (see Appendix A). Therefore, it is conservative to use the 40,000 cfm for the 0-10 minute time period.

The following is the EGTS performance curve from TI-ANL-166 (ref.19) With Initial Annulus Pressure at 0" H2O for Unit 1.

ANNULUS DIFFERENTIAL PRESSURE AND EGTS EXHAUST FLOW RATES
CASE 3, ANNULUS LEAKAGE = 957 CFM @ -2.10 IN W.G., INITIAL ANNULUS PRESSURE = 0.0 IN W.G.



This is the EGTS profile as modeled for Unit 1. The above curve is modified at 602 sec to have constant flows (see assumptions 22 and 23):

Modified ANNULUS DIFF. PRES. AND EGTS EXHAUST FLOW RATES With Controller Failure
CASE 3, ANNULUS LEAKAGE = 957 CFM @ -2.10 IN W.G., INITIAL ANNULUS PRESSURE = 0.0 IN W.G.

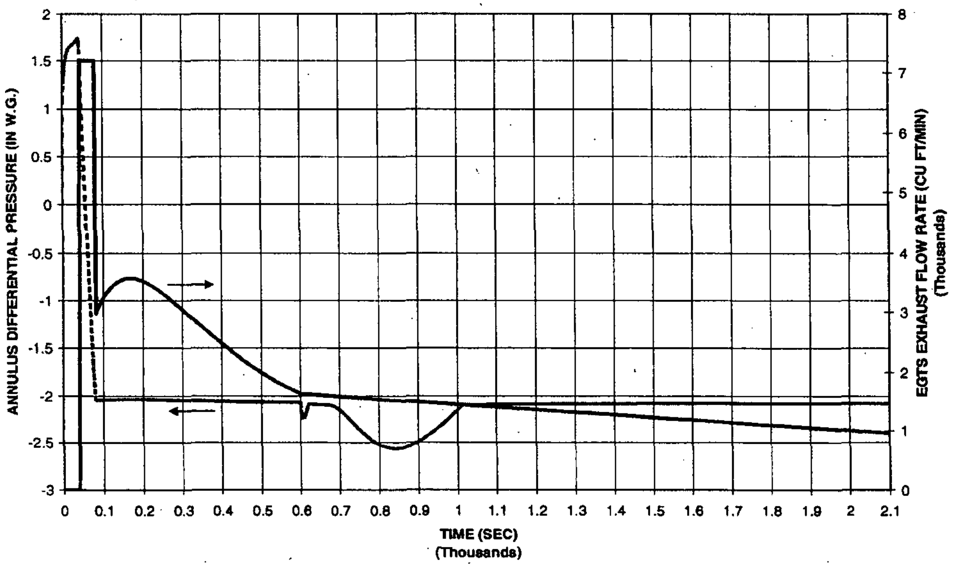


Table 3

EGTS Performance with Annulus Initially at 0" H2O (ref.19: TI-ANL-166) 2 train EGTS 7200 cfm for Unit 1

Time Interval		Time Interval		Recirculation	Rate	Exhaust Rate	
[sec]	[sec]	[hours]	[hours]	[cfm]	[cfh]	[cfm]	[cfh]
0	30	0	0.0083	0	0.00E+00	0	0.00E+00
30	39	0.0083	0.0108	7200	4.32E+05	0	0.00E+00
39	40	0.0108	0.0111	6573.24	3.94E+05	626.76	3.76E+04
40	41	0.0111	0.0114	4704.62	2.82E+05	2495.38	1.50E+05
41	42	0.0114	0.0117	2609.58	1.57E+05	4590.42	2.75E+05
42	43	0.0117	0.0119	725.2	4.35E+04	6474.8	3.88E+05
43	71	0.0119	0.0197	0	0.00E+00	7200	4.32E+05
71	80	0.0197	0.0222	0	0.00E+00	7200	4.32E+05
80	81	0.0222	0.0225	1567.6	9.41E+04	5632.4	3.38E+05
81	82	0.0225	0.0228	4222.38	2.53E+05	2977.62	1.79E+05
82	102	0.0228	0.0283	4064	2.44E+05	3136	1.88E+05
102	132	0.0283	0.0367	3816	2.29E+05	3384	2.03E+05
132	165	0.0367	0.0458	3659	2.20E+05	3541	2.12E+05
165	169	0.0458	0.0469	3619	2.17E+05	3581	2.15E+05
169	210	0.0469	0.0583	3659	2.20E+05	3541	2.12E+05
210	307	0.0583	0.0853	3950	2.37E+05	3250	1.95E+05
307	498	0.0853	0.1383	4701	2.82E+05	2499	1.50E+05
498	602	0.1383	0.1672	5386	3.23E+05	1814	1.09E+05
602	603	0.1672	0.1675	5568.4	3.34E+05	1631.6	9.79E+04
603	850	0.1675	0.2361	4597	2.76E+05	1534	9.20E+04
850	1100	0.2361	0.3056	4694	2.82E+05	1437	8.62E+04
1100	1350	0.3056	0.3750	4791	2.87E+05	1340	8.04E+04
1350	1600	0.3750	0.4444	4888	2.93E+05	1243	7.46E+04
1600	1850	0.4444	0.5139	4985	2.99E+05	1146	6.88E+04
1850	2100	0.5139	0.5833	5082	3.05E+05	1049	6.29E+04
2100	3600*	0.5833	1.0000	5174	3.10E+05	957	5.74E+04
3600*	30 days	1.0000	30days	3584	2.15E+05	694	4.16E+04

* 1 hour operator action. For no operator action cases, the 3600-30 day flows do not change from the 2100-3600 sec case.

Table 4
Dispersion Coefficients (X/Q, ref.8)
(Meteorology)

Period (hours)	Site Boundary (1100m)	Low Population Zone (4828m)
0-2	6.07E-04	1.41E-04
2-8	-	6.68E-05
8-24	-	4.59E-05
24-96	-	2.04E-05
96-720	-	6.35E-06

Note: The Site Boundary is equivalent to the Exclusion Area Boundary

Results

The results for the Unit 1 LOCA with EGTS PCO control loop single failure are (rem):

2-hr EAB

Conventional core	No Operator Action	1 hr Operator Action
Gamma	2.055	2.077
Beta	1.21	1.224
Inhalation (ICRP-30)	29.89*	29.92*
TEDE	3.073*	3.089*
Jj TPC 100%		
Gamma	2.133	2.156
Beta	1.215	1.229
Inhalation (ICRP-30)	28.55*	28.57*
TEDE	3.083*	3.101*
TPC 3%		
Gamma	2.133	2.156
Beta	1.213	1.227
Inhalation (ICRP-30)	28.55*	28.57*
TEDE	3.061*	3.078*

30-Day LPZ

Conventional core	No Operator Action	1 hr Operator Action
Gamma	1.646	1.666
Beta	1.911	1.926
Inhalation (ICRP-30)	9.396*	9.472*
TEDE	1.588	1.606
TPC 100%		
Gamma	1.648	1.668
Beta	1.859	1.873
Inhalation (ICRP-30)	8.973*	9.05*
TEDE	1.797	1.816
TPC 3%		
Gamma	1.648	1.668
Beta	1.846	1.86
Inhalation (ICRP-30)	8.973*	9.045*
TEDE	1.58	1.598

* Note that the Inhalation/Thyroid and TEDE doses for this failure scenario are bounded by the single failure of one EGTS train (see appendix I).

Discussion and Conclusion

The offsite doses calculated are below the regulatory limits of 25 rem gamma, 300 rem beta, and 300 rem thyroid (and below the 25 rem TEDE).

Revision 16 investigated iodine removal efficiencies based on reduced ice weight. The results are found in Appendix D for the bounding case of the 100% airborne TPC case. Previous results were found to be more conservative. Therefore the results found in Revision 15 are still acceptable. The reduced ice weight with updated iodine removal rates do not need to be incorporated into future analyses unless some conservatism needs to be eliminated.

Revision 19 identifies changes in the ABSCE boundary due to DCV52283-A. The offsite doses from the previous revision were found to still be applicable. An explanation can be found in Appendix F.

Revision 20 investigated the impact of an EGTS PCO control loop single failure. This failure still results in doses less than regulatory limits. An operator action between 1 and 2 hours to shut off one of two EGTS fans will impact the results. If there is some recirculation with the second fan running, then there will be an insignificant (about 1%) increase in the dose if the action is at 1 hour instead of 2 hours (Appendix H). Current procedures require Operations to turn off one EGTS fan subsequent to EGTS start. Per Appendix H, a 1 hour operator action should be the design basis of the plant, since it results in the highest doses. Per Appendix G, there is not much difference between 8000+10% and 8000-10% EGTS flow. However, the lower flow is slightly higher, and this is primarily due to the increase time at the beginning of the accident when the annulus is at a positive pressure and the slower pump down rates.. **Per Appendices I and J (revision 21), the Unit 1 EGTS PCO control loop single failure accident analyzed in the main text bounds, except for the thyroid and 2-hr EAB TEDE doses, the single train failure (250 cfm steady state exhaust) previously analyzed in WBNNAL3-028. The single train failure case is presented in Appendix I.**

Special Note:. The EGTS single train (250 cfm steady state exhaust) scenario applies to both units.

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8. Memorandum from Francis P. Weatherford to Walter L.Elliott on January 27, 1995 "Watts Bar Nuclear Plant (WBN) Final Safety Analysis Report (FSAR) Update - Dispersion Meteorology For Accident Analysis" RIMS# T33 950127 962- Attachment B
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16. not used
17. not used
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22. WBPER930129 R0
23. EPM-RAV-081193 R0 "Isolation Damper Leakage Rate for the Aux BLDG Supply and Exhaust Fans" RIMS# B18 930908 251
24. DCN S-27638-A (This revises reference 14 above).
25. DCN M-29141-A
26. Test Package 0-030-AB-LT-35, RIMS# W87 0222K 0208
27. Test Package 0-030-AB-LT-29, RIMS# W87 0222K 0205
28. Test Package 0-030-AB-LT-26, RIMS# W87 0222K 0202
29. Test Package 0-030-AB-LT-27, RIMS# W87 0222K 0203
30. a) Test Package 0-065-AB-LT-3 (no RIMS#) the results of which are also found in:
    b) Memorandum from J.C.Standifer to Guenter Wadewitz, October 22, 1982, RIMS# NEB 821022 256
31. DCN M-10354-B
32. 0-PDT-30-148 R2 "Demonstrated Accuracy Calculation for ABGTS Air Controller to Maintain a Negative Pressure in the ABSCE" RIMS# B26 940616 400
33. NUREG-0800 R3 "Standard Review Plan"
34. WAT-D-9902 "Ice Condenser Iodine Removal Efficiency" - RIMS# T33 950110 822 - Attachment C
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36. System Description N3-65-4001 R3 "Emergency Gas Treatment System" RIMS# T29 930323 951
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38c. Test Report W.O. 94-17127-00 - Attachment E
38d. Test Report W.O. 94-17127-01 - Attachment E
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57. PER 91670
58. MDQ00206520090368 R0 "EGTS Evaluation During Control System Failure"
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APPENDIX A STP Input Deck
(1 hr operator action, TPC 3% H3 airborne)

```
//R197S19I JOB 264318,9MBERG.BIN111,MSGLEVEL=1,MSGCLASS=T
//*MAIN ORG=KNXLCL01,CLASS=MB
//JCL JCLLIB ORDER=(APB.NEN.PS264460.PROCLIB)
//     EXEC STP,SOUT='*'
//GO.FT07F001 DD DSN=$KBI988.R197S19I.OUT,UNIT=ALLOC,
//     DCB=(RECFM=FB,LRECL=80,BLKSIZE=6160),SPACE=(TRK,(5,2),RLSE),
//     DISP=(NEW,CATLG,DELETE)
//GO.FT01F001 DD *
NV= 10  MS= 1
//GO.FT11F001 DD *
NI= 23  NK= 5  NG= 0  NL= 3
    1KRM  83 1 1.0352E-04   10.0000E+00   10.0000E+00   10.0000E+00
    2KRM  85 1 4.2978E-05   10.0000E+00   10.0000E+00   10.0000E+00
    3KR   85 1 2.0470E-09   29.8849E-06   10.0000E+00   10.0000E+00
    4KR   87 1 1.5141E-04   10.0000E+00   10.0000E+00   10.0000E+00
    5KR   88 1 6.8765E-05   10.0000E+00   10.0000E+00   10.0000E+00
    6KR   89 1 3.6328E-03   10.0000E+00   10.0000E+00   10.0000E+00
    7XEM 131 2 6.7414E-07  131.3039E-08  181.3039E-08   10.0000E+00
    8XEM 133 2 3.5656E-06  152.0365E-07  202.0365E-07   10.0000E+00
    9XE  133 2 1.5165E-06   83.5656E-06  159.2568E-06  209.2568E-06
   10XEM 135 2 7.3818E-04  174.8062E-06  224.8062E-06   10.0000E+00
   11XE  135 2 2.1043E-05  107.3818E-04  172.9129E-05  222.9129E-05
   12XE  138 2 8.1528E-04   10.0000E+00   10.0000E+00   10.0000E+00
   13I   131 3 9.9536E-07   10.0000E+00   10.0000E+00   10.0000E+00
   14I   132 3 8.4448E-05   10.0000E+00   10.0000E+00   10.0000E+00
   15I   133 3 9.2568E-06   10.0000E+00   10.0000E+00   10.0000E+00
   16I   134 3 2.1963E-04   10.0000E+00   10.0000E+00   10.0000E+00
   17I   135 3 2.9129E-05   10.0000E+00   10.0000E+00   10.0000E+00
   18I*  131 4 9.9536E-07   10.0000E+00   10.0000E+00   10.0000E+00
   19I*  132 4 8.4448E-05   10.0000E+00   10.0000E+00   10.0000E+00
   20I*  133 4 9.2568E-06   10.0000E+00   10.0000E+00   10.0000E+00
   21I*  134 4 2.1963E-04   10.0000E+00   10.0000E+00   10.0000E+00
   22I*  135 4 2.9129E-05   10.0000E+00   10.0000E+00   10.0000E+00
   23H     3 5 1.7785E-09   10.0000E+00   10.0000E+00   10.0000E+00
0
 1  'TRIT PROD CORE INV, 1000 EFPD, 5% U235 (ORIGEN), REF.WBNAPS3-098 R0'
  1 1.23E7  2 2.69E7  3 8.81E5  4 5.23E7  5 7.38E7  6 9.10E7
  7 9.54E5  8 5.80E6  9 1.88E8  10 3.59E7  11 4.96E7  12 1.59E8
  13 8.65E7  14 1.26E8  15 1.80E8  16 2.00E8  17 1.69E8
  18 3.60E6  19 5.24E6  20 7.52E6  21 8.32E6  22 7.04E6  23 2.68E7
 0
 T
 WBN MHA-4 MIN AUX BLDG BYPASS (FINAL ABSCE)
 NJ= 10
 1 'PRIMARY' 'CONTAINMENT'
 2 'CONT. LEAKAGE' '  SPLIT'
 3 'AUX. BLD        '
 4 'ANNULUS         '
 5 '   EGTS         ' ' FLOW SPLIT      '
 6 'ENVIRONMENT ' '  CURIES '
 7 'ABGTS FILTER'
 8 'EGTS FILTER'
 9 'ABGTS FLOW SPLIT'
 10 'UPSTREAM ABGTS'
 0.00833 HR
 TIME TO 30 SECOND POST LOCA
 V 1 1.27+6 CUFT
 V 2 1.0-6
 V 3 1.62+5 CUFT
 V 4 1.88+5 CUFT
 V 5 1.0-6
 V 6 1.0 ENVIRONMENT
 V 7 1.0E-6
 V 8 1.0E-6
 V 9 1.0E-6
 V 10 1.0E-6
 A 6
 S 1 1 0 1.0 1 1 3 0.25 1 1 4 0.25 1 1 5 0.03
 F 1 2 0 132.3 CFH
 F 2 3 0 0
```

```
$F 2 4 0 0.75
F 2 6 0 1.0
F 3 6 0 0
F 3 4 0 0
F 4 5 0 0
F 5 4 0 0
F 5 6 0 0
R 1 3 1.81
0.0108 HR
TIME TO 39 SEC
F 5 4 0 4.32E5 CFH
F 5 6 0 0.0 CFH
F 3 5 0 642
U 4 8 5 2.16+5 0.0 0.0 0.99 0.99 0.0
0.0111 HR
TIME TO 40 SEC
F 5 4 0 3.94E5
F 5 6 0 3.76E4
0.0114 HR
TIME TO 41 SEC
F 5 4 0 2.82E5
F 5 6 0 1.50E5
0.0117 HR
TIME TO 42 SEC
F 5 4 0 1.57E5
F 5 6 0 2.75E5
0.0119 HR
TIME TO 43 SEC
F 5 4 0 4.35E4
F 5 6 0 3.88E5
0.01667 HR
TIME TO 60 SEC
F 5 4 0 0.0
F 5 6 0 4.32E5
0.0197 HR
TIME TO 71 SEC
F 2 4 0 0.75
F 2 6 0 0.25
0.0222 HR
TIME TO 80 SEC
F 5 4 0 0.0
F 5 6 0 4.32E5
0.0225 HR
TIME TO 81 SEC
F 5 4 0 9.41E4
F 5 6 0 3.38E5
0.0228 HR
TIME TO 82 SEC
F 5 4 0 2.53E5
F 5 6 0 1.79E5
0.0283 HR
TIME TO 102 SEC
F 5 4 0 2.44E5
F 5 6 0 1.88E5
0.0367 HR
TIME TO 132 SEC
F 5 4 0 2.29E5
F 5 6 0 2.03E5
0.0458 HR
TIME TO 165 SEC
F 5 4 0 2.20E5
F 5 6 0 2.12E5
0.0469 HR
TIME TO 169 SEC
F 5 4 0 2.17E5
F 5 6 0 2.15E5
0.0583 HR
TIME TO 210 SEC
F 5 4 0 2.20E5
F 5 6 0 2.12E5
0.0667 HR
TIME TO 4 MIN
F 5 4 0 2.37E5
F 5 6 0 1.95E5
```

```
0.0853 HR
TIME TO 307 SEC
F 2 6 0 0
F 2 3 0 0.25
F 3 4 0 5.74E4 CFH
F 3 10 0 5.4E5
F 3 9 0 1672.8
U 10 7 9 5.4+5 0.0 0.0 0.99 0.99 0.0
F 9 3 0 532.2
F 9 6 0 5.4E5
0.1383 HR
TIME TO 498 SEC
F 5 4 0 2.82E5
F 5 6 0 1.50E5
0.156 HR
TIME TO 0.156 HR
F 5 4 0 3.23E5
F 5 6 0 1.09E5
0.1672 HR
TIME TO 602 SEC
R 1 3 1.44
0.1675 HR
TIME TO 603 SEC
F 5 4 0 3.34E5
F 5 6 0 9.79E4
0.2361 HR
TIME TO 850 SEC
F 5 4 0 2.76E5
F 5 6 0 9.20E4
0.267 HR
TIME TO 0.267 HR
F 5 4 0 2.82E5
F 5 6 0 8.62E4
0.3056 HR
TIME TO 0.1100 SEC
R 1 3 1.38
0.323 HR
TIME TO 0.323
F 5 4 0 2.87E5
F 5 6 0 8.04E4
0.3750 HR
TIME TO 1350 SEC
R 1 3 1.34
0.4444 HR
TIME TO 1600 SEC
F 5 4 0 2.93E5
F 5 6 0 7.46E4
0.489 HR
TIME TO 0.489 HOUR
F 5 4 0 2.99E5
F 5 6 0 6.88E4
R 1 3 1.34
0.5 HR
TIME TO 30 MIN
R 1 3 1.13
0.5139 HR
TIME TO 1850 SEC
F 3 6 0 5.94E5
U 10 7 9 0.0 0.0 0.0 0.99 0.99 0.0
0.5666 HR
TIME TO 34 MIN
F 5 4 0 3.05E5
F 5 6 0 6.29E4
0.5833 HR
TIME TO 2100
U 10 7 9 5.4+5 0.0 0.0 0.99 0.99 0.0
F 3 6 0 0.0
.615 HR
TIME TO 0.615 HOUR
F 5 4 0 3.10E5
F 5 6 0 5.74E4
.768 HR
TIME TO 0.768 HOUR
R 1 3 1.10
```

```
.824 HR
TIME TO 0.824
R 1 3 0.76
1.00 HR
TIME TO 1.00 HOURS
R 1 3 0.0
2.0 HR
TIME TO 2.0 HOURS
F 3 4 0 4.16E4
F 5 4 0 2.150E5
F 5 6 0 4.164E4
N 6 0
P 1 0 6
8 HR
TIME TO 8 HOURS
N 6 0
P 1 0 6
24.0 HR
TIME TO 1 DAY
N 6 0
P 1 0 6
96 HR
TIME TO 4 DAYS
F 1 2 0 66.1 CFH
N 6 0
P 1 0 6
720 HR
TIME TO 30 DAYS
P 1 0 6
T
T
/*
//
```

Appendix B FENCDOSE Input Deck

```
//R197F19F JOB 264360,'9MBERG.BIN111',MSGLEVEL=1,MSGCLASS=T
//*MAIN ORG=LOCAL,CLASS=SB
//JCL JCLLIB ORDER=(APB.NEN.EX262358.PROCLIB)
//STEP1 EXEC FNCDOSV4,COND=(4,LT)
//FNCDOS1.FT05F001 DD *
1
 KRM-83  KRM-85  KR-85
 KR-87   KR-88   KR-89
 XEM-131 XEM-133 XE-133 XEM-135 XE-135 XE-138
 I-131   I-132   I-133  I-134   I-135
 I*-131  I*-132  I*-133 I*-134  I*-135  H-3
 T
 .141E-3  .668E-4  .459E-4  .204E-4  .635E-5  6.07E-4
 WBN MHA-4 MIN AUX BLDG BYPASS (FINAL ABSCE)
 TIME TO 2.0 HOURS
     6  'ENVIRONMENT        CURIES        ' $ TN=  0.2000E+01
          1 5.526E+02    2 1.528E+03    3 5.974E+01    4 1.972E+03    5 3.788E+03
          6 2.378E+02    7 6.454E+01    8 3.879E+02    9 1.268E+04   10 7.974E+02
         11 3.325E+03   12 1.300E+03   13 8.458E+01   14 1.169E+02   15 1.751E+02
         16 1.734E+02   17 1.623E+02   18 4.447E+00   19 5.951E+00   20 9.208E+00
         21 8.491E+00   22 8.440E+00   23 5.452E+01
 WBN MHA-4 MIN AUX BLDG BYPASS (FINAL ABSCE)
 TIME TO 8 HOURS
     6  'ENVIRONMENT        CURIES        ' $ TN=  0.8000E+01
          1 8.983E+02    2 5.238E+03    3 3.741E+02    4 1.915E+03    5 9.316E+03
          6 1.504E-09    7 4.008E+02    8 2.316E+03    9 7.792E+04   10 4.744E+03
         11 1.748E+04   12 7.954E+00   13 1.917E+01   14 7.114E+00   15 3.444E+01
         16 1.938E+00   17 2.295E+01   18 2.378E+00   19 8.783E-01   20 4.284E+00
         21 2.383E-01   22 2.844E+00   23 3.414E+02
 WBN MHA-4 MIN AUX BLDG BYPASS (FINAL ABSCE)
 TIME TO 1 DAY
     6  'ENVIRONMENT        CURIES        ' $ TN=  0.2400E+02
          1 1.536E+02    2 4.389E+03    3 1.385E+03    4 1.109E+02    5 3.775E+03
          6 0.0          7 1.452E+03    8 7.541E+03    9 2.738E+05   10 1.324E+04
         11 3.686E+04   12 2.994E-07   13 4.914E+01   14 1.359E+00   15 6.428E+01
         16 1.704E-02   17 2.130E+01   18 6.118E+00   19 1.689E-01   20 8.029E+00
         21 2.119E-03   22 2.652E+00   23 1.264E+03
 WBN MHA-4 MIN AUX BLDG BYPASS (FINAL ABSCE)
 TIME TO 4 DAYS
     6  'ENVIRONMENT        CURIES        ' $ TN=  0.9600E+02
          1 3.524E-01    2 3.044E+02    3 3.487E+03    4 1.714E-02    5 6.050E+01
          6 0.0          7 3.390E+03    8 1.177E+04    9 5.606E+05   10 6.372E+03
         11 1.385E+04   12 0.0         13 9.541E+01   14 6.319E-03   15 4.242E+01
         16 3.817E-08   17 2.606E+00   18 1.188E+01   19 7.853E-04   20 5.298E+00
         21 4.745E-09   22 3.246E-01   23 3.181E+03
 WBN MHA-4 MIN AUX BLDG BYPASS (FINAL ABSCE)
 TIME TO 30 DAYS
     6  'ENVIRONMENT        CURIES        ' $ TN=  0.7200E+03
          1 4.419E-13    2 3.240E-03    3 2.790E+04    4 2.444E-21    5 7.596E-07
          6 0.0          7 1.404E+04    8 7.087E+03    9 1.048E+06   10 7.528E+00
         11 5.032E+01   12 0.0         13 2.828E+02   14 1.637E-12   15 4.113E+00
         16 0.0         17 1.279E-03   18 3.520E+01   19 1.096E-13   20 5.137E-01
         21 0.0         22 1.592E-04   23 2.546E+04
```

Appendix C

TI-RPS-197
Appendix ~~A~~C

~~B27~~ p.29 p. [illegible] MCB 1-19-95
p. 3 10-27-08 Rev 1/26/95

Flow to Ice Condenser Prior to Air Return Fan Startup

The purpose of this paper is to demonstrate that sufficient containment volume will be directed to the ice condenser compartment during the first 10 minutes of a design basis LOCA to meet statements made concerning the ice condenser's ability to remove iodine.

For this calculation, the containment model used in the safety-related qualification of the MONSTER software was rerun after modifying the printout frequency inputs to secure the flow information which was not readily retrievable from the original run. The containment model is of the SQN containment; however, for the purposes of demonstrating the amount of flow which can reasonably be expected to be directed to the ice condenser, the SQN model is adequate for use at WBN since the mass and energy releases are similar for both plants during the time of interest.

Sufficient flow to the ice condenser is demonstrated if at least 400,000 ft^3 of the lower compartment atmosphere can be shown to enter the ice condenser during the first 10 minutes following the DBA. This requirement comes from the calculations of offsite dose, control room operator dose and equipment qualification considerations, all of which assume that airflow through the ice condenser averages 40,000 cfm for the duration of the event. It should be emphasized that the important parameter for these dose calculations is the total volume that passes through the ice condenser and not the consistency of the volumetric flow rate.

From the following figures, which were generated from the containment model rerun, the volume entering the ice condenser can be estimated during the blowdown period (0 to ~23 seconds, Figure A). During this period, the total mass entering the ice condenser is approximately 519,000 lb which consists of an air/steam mixture. From the computer run, the specific volume during the blowdown period is at least 6 ft^3/lb. The total volume entering the ice condenser is therefore estimated to be 3.114 E6 ft^3. This is well above the required volume of 400,000 ft^3 which demonstrates the conservative assumptions regarding flow into the ice condenser made in the offsite dose, control room operator dose and equipment qualification calculations.

Figure B shows the flow to the ice condenser as calculated by the model for the 50 second to 600 second time period. An estimate of the volume entering the ice condenser during this period was not made. The figure is included simply to show that flow does continue prior to air return fan startup at 600 seconds albeit at a reduced and fluctuating rate caused by the reduced mass and energy release produced by the large break LOCA.

References:
1. MONSTER, Software ID 262303, User Manual R3 (D01930302007)
2. Microfiche TVA-F-1000084
3. MONSTER Input file - Filekeeper Reference Number 263082

Prepared: 1/5/95 Reviewed: Duane [illegible] 1/5/95

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	Checked:	**Date:**	

TI-RPS-197
Appendix ~~B~~ C (continued)
RCS 10-25-01

Prepared: 1/5/95

DPW
RCS 10-25-01
Rev 1/26/95

Checked: 1/5/95

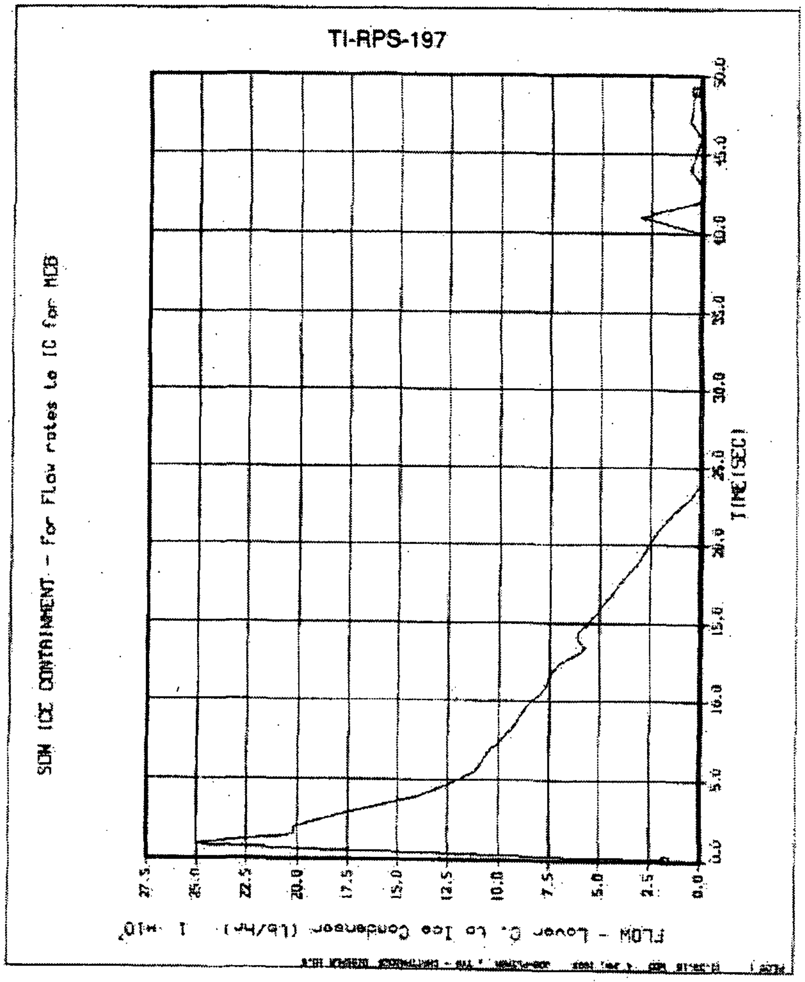

Figure A

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TI-RPS-197
Appendix A (continued)
C
10-25-01

OPM
6/11/01
10-25-01

Prepared: 1/5/95

Checked: 1/5/95

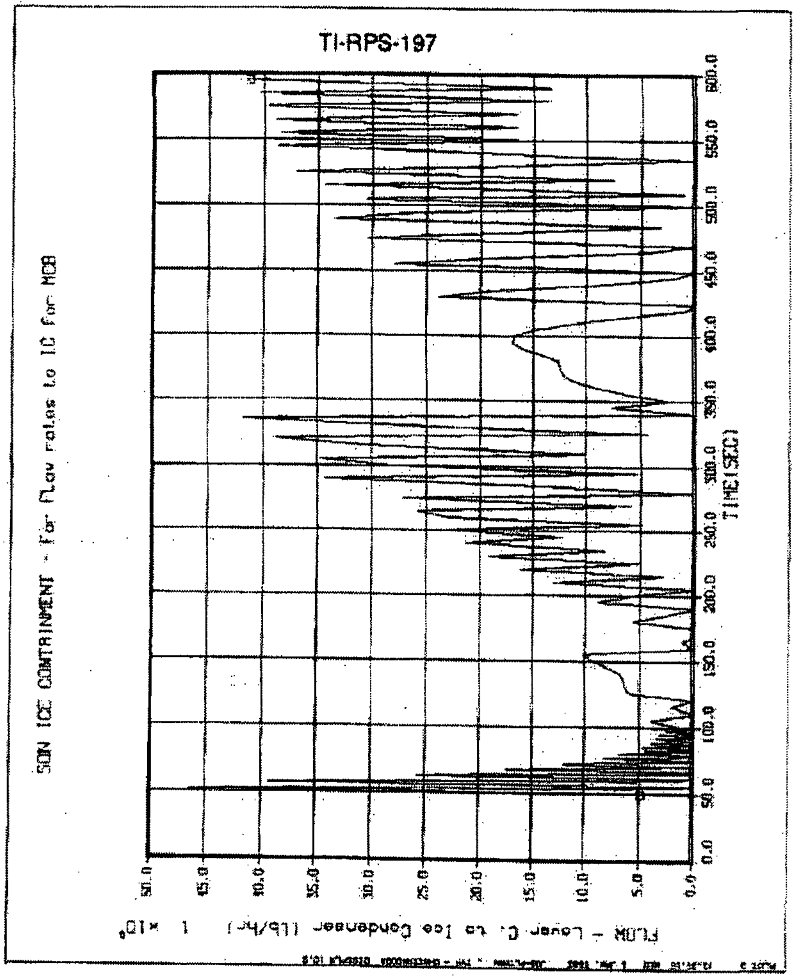

Figure B

Appendix D - Ice Weight Reduction Impact

Revision 16 incorporated EDC 50951A, which reduced the ice weight in containment. This impacts the iodine removal efficiencies for this calculation. As a result of this, the iodine removal efficiencies found in ref. 44 are used in place of the old values found in ref.15. It was found that the previous values found in Revision 15 were conservative and bounded the results in Revision 16, and thus are still acceptable. Therefore successors to this calculation will not need to be revised. The following are the iodine removal efficiencies used in the STP model:

Table 2a Iodine removal efficiencies.

time (hrs)	efficiency	lambda *
0 - 0.0373	0.98	1.85
0.0373-0.154	0.972	1.84
0.154-0.171	0.947	1.79
0.171-0.212	0.71	1.34
0.212-0.272	0.7	1.32
0.272-0.567	0.656	1.24
0.567-0.939	0.5	0.94
0.939-0.982	0.4	0.76
0.982-1.007	0.21	0.40
1.007-720	0	0.00

Note: This table is the equivalent of Table 2 on page 15.

* Lambda = (F/V)*eff = (40,000 cfm/1.27E6 cuft)(60 min/hr)(eff) =1.89*eff [hr^{-1}]

The following is a comparison of the results for the 100% tritium airborne case. The R16 column results use the values in the above table and are less than or equal to the doses found in R15. Only the one case was ran as it was the bounding case in R15.

2-hr EAB	R15	R16
	TPC 100% tritium airborne	TPC 100% tritium airborne
gamma	1.660	1.659
beta	0.955	0.955
thyroid (ICRP-2)	33.84	33.79
thyroid (ICRP-30	19.34	19.32
TEDE	2.240	2.238

30-day LPZ		
	TPC 100% tritium airborne	TPC 100% tritium airborne
gamma	1.328	1.317
beta	1.605	1.598
thyroid (ICRP-2)	10.99	10.68
thyroid (ICRP-30	6.563	6.364
TEDE	1.435	1.415

Appendix E
EGTS Exhaust and Recirculation Rates and old R17 Results

This appendix is to archive the old EGTS exhaust and recirculation rates. These flows are based on the old Revision 17 models. The initial conditions are for the annulus to start at -5" H2O, one train of EGTS operation, and no single failure of any controllers or component in the system and 250 cfm steady state EGTS exhaust. R18 if the calculation assumes EGTS is running abnormally, so as to encompass all possible failure modes.

Revision 17 Table 3
EGTS Flow Rates

Time Interval		Recirculation Rate		Exhaust Rate	
[sec]	[hours]	[cfm]	[cfh]	[cfm]	[cfh]
0-30	0-0.00833	0.00	0.00E+00	0.00	0.00E+00
30-77	0.00833-0.0214	3600.00	2.16E+05	0.00	0.00E+00
77-78	0.0214-0.0217	3286.62	1.97E+05	313.38	1.88E+04
78-79	0.0217-0.0219	2352.31	1.41E+05	1247.69	7.49E+04
79-80	0.0219-0.0222	1304.79	7.83E+04	2295.21	1.38E+05
80-81	0.0222-0.0225	362.60	2.18E+04	3237.40	1.94E+05
81-96	0.0225-0.0267	0.00	0.00E+00	3600.00	2.16E+05
96-97	0.0267-0.0269	1067.04	6.40E+04	2532.96	1.52E+05
97-98	0.0269-0.0272	1074.82	6.45E+04	2525.18	1.52E+05
98-99	0.0272-0.0275	1063.01	6.38E+04	2536.99	1.52E+05
99-113	0.0275-0.0314	986.43	5.92E+04	2613.57	1.57E+05
113-123	0.0314-0.0342	878.98	5.27E+04	2721.02	1.63E+05
123-138	0.0342-0.0383	801.79	4.81E+04	2798.21	1.68E+05
138-153	0.0383-0.0425	741.04	4.45E+04	2858.96	1.72E+05
153-169	0.0425-0.0469	713.24	4.28E+04	2886.76	1.73E+05
169-170	0.0469-0.0472	707.42	4.24E+04	2892.58	1.74E+05
170-180	0.0472-0.05	711.09	4.27E+04	2888.91	1.73E+05
180-200	0.05-0.0556	735.79	4.41E+04	2864.21	1.72E+05
200-220	0.0556-0.0611	791.97	4.75E+04	2808.03	1.68E+05
220-240	0.0611-0.0667	872.06	5.23E+04	2727.94	1.64E+05
240-260	0.0667-0.0722	968.80	5.81E+04	2631.20	1.58E+05
260-446	0.0722-0.1239	1537.22	9.22E+04	2062.78	1.24E+05
446-601	0.1239-0.1669	2357.54	1.41E+05	1242.46	7.45E+04
601-602	0.1669-0.1672	2661.92	1.60E+05	938.08	5.63E+04
602-1700	0.1672-0.4722	3600.00	2.16E+05	0.00	0.00E+00
1700-1701	0.4722-0.4725	3518.30	2.11E+05	81.70	4.90E+03
1701-1702	0.4725-0.4728	3424.95	2.05E+05	175.05	1.05E+04
1702-1703	0.4728-0.4731	3410.95	2.05E+05	189.05	1.13E+04
1703-1704	0.4731-0.4733	3408.70	2.05E+05	191.30	1.15E+04
1704-1705	0.4733-0.4736	3408.18	2.04E+05	191.82	1.15E+04
1705-1855	0.4736-0.5153	3395.35	2.04E+05	204.65	1.23E+04
1855-2100	0.5153-0.5833	3372.37	2.02E+05	227.63	1.37E+04
2100-30days*	0.5833-720	3350.00	2.01E+05	250.00	1.50E+04

*required to maintain annulus pressure when assuming 250 cfm annulus inleakage, ref.19

Note: The annulus exhaust rates from TI-ANL-166 (ref.19) are based on total EGTS flow of 3600 cfm (=4000-10%). This is conservative as it minimizes cleanup of the annulus environment via EGTS filters.

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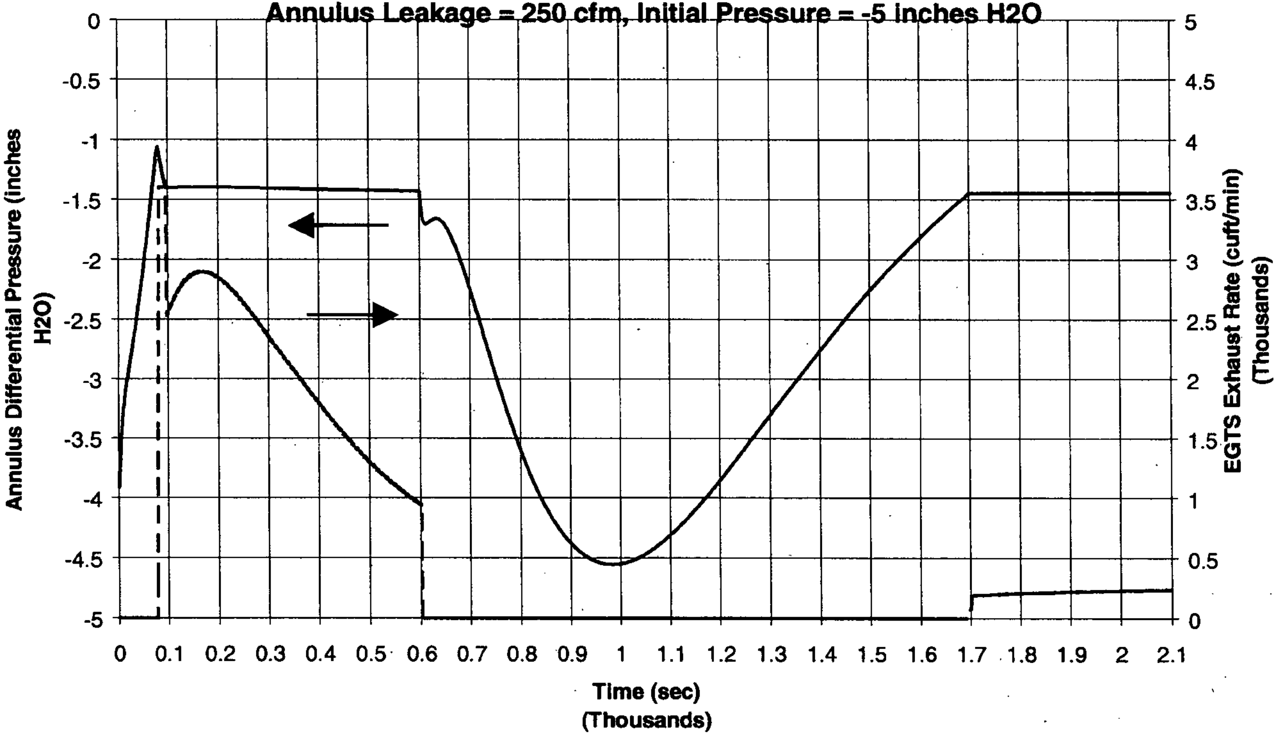
Revision 17 EGTS performance curves:

Figure 6 From TI-ANL-166: WBN LOCA
Annulus Differential Pressure and EGTS Exhaust Rates
Annulus Leakage = 250 cfm, Initial Pressure = -5 inches H2O



Revision 17 Results (with EGTS operating correctly and initial -5" H2O annulus pressure)

2-hr EAB				
		TPC	TPC	
	Standard	100% tritium	3% tritium	
	Core	airborne	airborne	limit
Gamma	1.596	1.660	1.660	25
Beta	0.951	0.955	0.954	300
Thyroid (ICRP-2)	35.42	33.84	33.84	300
Thyroid (ICRP-30)	20.25	19.34	19.34	300
TEDE	2.221	2.240	2.222	25
30-day LPZ				
		TPC	TPC	
	Standard	100% tritium	3% tritium	
	Core	airborne	airborne	limit
Gamma	1.322	1.328	1.328	25
Beta	1.640	1.605	1.593	300
Thyroid (ICRP-2)	11.50	10.99	10.99	300
Thyroid (ICRP-30)	6.872	6.563	6.563	300
TEDE	1.230	1.435	1.229	25

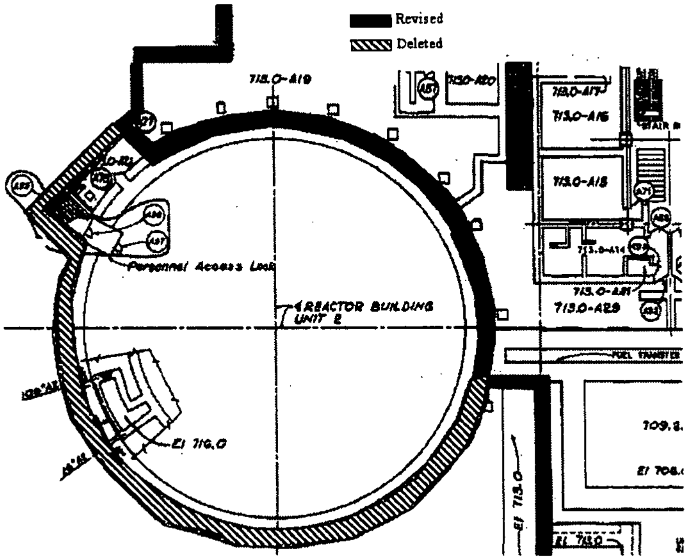
APPENDIX F – Modified ABSCE Boundary of DCN 52283-A

The purpose of this appendix is to address changes in the ABSCE boundary identified as part of DCN 52283-A. In order to complete Watts Bar Unit 2, a construction access opening needs to be created in the Unit 2 reactor building concrete wall. This requires the definition of an interim ABSCE that does not include the Unit 2 reactor building (Ref. 49).

The total ABSCE volume enclosed when one unit's containment with one annulus and Condensate Demineralized Waste Evaporator (CDWE) are added to that of the Auxiliary Building (Ref. 52) is:

Auxiliary Building (net free volume) = 3.5 x 10^6 ft^3
<u>One</u> Containment (net free volume) = 1.27 x 10^6 ft^3
<u>One</u> Annulus (net free volume) = 3.96 x 10^5 ft^3
CDWE (net free volume) = 5.1433 x 10^4 ft^3

Additionally, Door A-77 at elevation 713.0 in the auxiliary building becomes a pressure and security barrier and needs to be sealed:



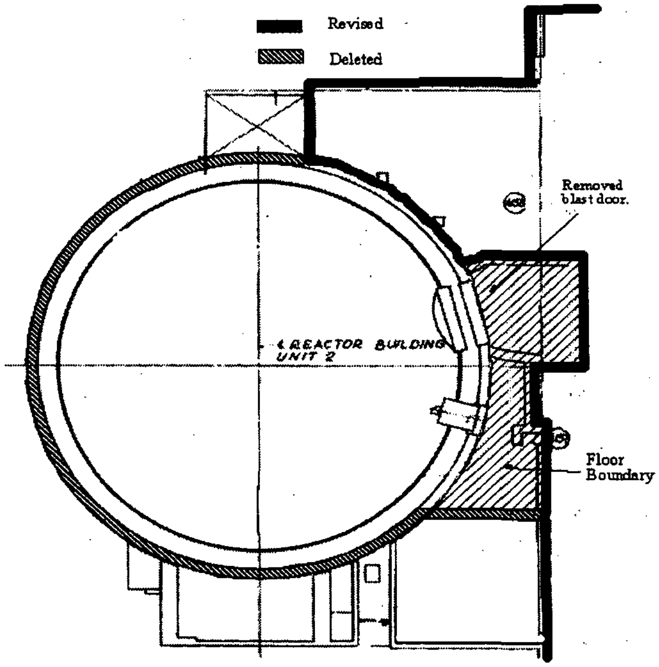
(Ref. 49)

The volume from elevation 713.0 not within the interim ABSCE is approximately

a) $(4.69 \times 10^2\ ft^2) \cdot (24\ ft) = 1.13 \times 10^4\ ft^3$.

This was calculated using dimensions from Ref. 54 and a building height of 24 ft for the building provided in Ref. 52, Appendix A.

Also as part of the ABSCE redefinition, the west wall of room 757.0-A14 in the auxiliary building becomes the revised boundary. Door A157 is sealed and locked. With use of the Unit 2 reactor building equipment hatch during construction, room 757.0-A15 in the auxiliary building can either be within or outside the interim ABSCE boundary.



(Ref. 49)

To correctly estimate the volume of the interim ABSCE boundary under both conditions, calculations were performed that included and excluded the equipment hatch enclosure volume from the ABSCE.

The volume from room 757.0-A14 not within the interim ABSCE is approximately

a) $(1.01 \times 10^3 \text{ ft}^2) \cdot (25 \text{ ft}) = 2.73 \times 10^4 \text{ ft}^3$.

The volume from room 757.0-A15 is approximately

b) $(1.17 \times 10^3 \text{ ft}^2) \cdot (25 \text{ ft}) = 2.93 \times 10^4 \text{ ft}^3$.

The areas for both rooms were calculated using dimensions from Ref. 53 and a building height of 25 ft was provided in Ref. 52, Appendix A.

The volume of the revised auxiliary building is either:

a) $3.5 \times 10^6 \text{ ft}^3 - [1.13 \times 10^4 \text{ ft}^3 + 2.73 \times 10^4 \text{ ft}^3] = \mathbf{3.46 \times 10^6 \text{ ft}^3}$ including room 757.0-A15.

b) $3.5 \times 10^6 \text{ ft}^3 - [1.13 \times 10^4 \text{ ft}^3 + 2.73 \times 10^4 \text{ ft}^3 + 2.93 \times 10^4 \text{ ft}^3] = \mathbf{3.43 \times 10^6 \text{ ft}^3}$ not including 757.0-A15.

The volume of the revised ABSCE boundary is either:

a) $(3.46 + 1.27 + 0.396 + 0.051) \times 10^6\ \text{ft}^3 = \mathbf{5.18 \times 10^6\ ft^3}$ including room 757.0-A15.

b) $(3.43 + 1.27 + 0.396 + 0.051) \times 10^6\ \text{ft}^3 = \mathbf{5.15 \times 10^6\ ft^3}$ not including 757.0-A15.

The new total enclosed volume of the ABSCE is as much as $1.73 \times 10^6\ \text{ft}^3$ less than the original which contained two containments and two annuli (Ref. 52, Section 7.1).

The applied effective auxiliary building volume of $1.62 \times 10^5\ \text{ft}^3$ (see *Assumptions & Data* section, pg 11) is conservatively bounding for both the auxiliary building volume of $3.5 \times 10^6\ \text{ft}^3$ and the smallest possible auxiliary building volume of $3.43 \times 10^6\ \text{ft}^3$ resulting from DCN 52283-A. Thus, the offsite doses calculated are still appropriate for use while the ABSCE boundary is modified.

This Appendix added by Revision 19.

Appendix G
Evaluation of the EGTS Flow Rates (8000+10% vs. 8000-10%)

This appendix is to compare the EGTS flow of 8000+10%=8800 cfm total flow to 8000-10%=7200 cfm total flow. The main text contains the 7200 cfm case. The 8800 cfm case utilizes the following flow profiles from TI-ANL-166 (ref.19)

Table 3
EGTS Performance with Annulus Initially at 0" H2O (ref.19: TI-ANL-166) 2 train EGTS 8800 cfm

Time Interval		Time Interval		Recirculation	Rate	Exhaust Rate	
[sec]	[sec]	[hours]	[hours]	[cfm]	[cfh]	[cfm]	[cfh]
0	30	0	0.0083	0	0.00E+00	0	0.00E+00
30	39	0.0083	0.0108	8800	5.28E+05	0	0.00E+00
39	40	0.0108	0.0111	8033.96	4.82E+05	766.04	4.60E+04
40	41	0.0111	0.0114	5750.1	3.45E+05	3049.9	1.83E+05
41	42	0.0114	0.0117	3189.48	1.91E+05	5610.52	3.37E+05
42	43	0.0117	0.0119	886.35	5.32E+04	7913.65	4.75E+05
43	71	0.0119	0.0197	0	0.00E+00	8800	5.28E+05
71	80	0.0197	0.0222	5647	3.39E+05	3153	1.89E+05
80	81	0.0222	0.0225	5820	3.49E+05	2980	1.79E+05
81	82	0.0225	0.0228	5804.2	3.48E+05	2995.8	1.80E+05
82	102	0.0228	0.0283	5664	3.40E+05	3136	1.88E+05
102	132	0.0283	0.0367	5416	3.25E+05	3384	2.03E+05
132	165	0.0367	0.0458	5259	3.16E+05	3541	2.12E+05
165	169	0.0458	0.0469	5219	3.13E+05	3581	2.15E+05
169	210	0.0469	0.0583	5259	3.16E+05	3541	2.12E+05
210	307	0.0583	0.0853	5550	3.33E+05	3250	1.95E+05
307	498	0.0853	0.1383	6301	3.78E+05	2499	1.50E+05
498	602	0.1383	0.1672	6986	4.19E+05	1814	1.09E+05
602	603	0.1672	0.1675	7168.4	4.30E+05	1631.6	9.79E+04
603	850	0.1675	0.2361	4597	2.76E+05	1534	9.20E+04
850	1100	0.2361	0.3056	4694	2.82E+05	1437	8.62E+04
1100	1350	0.3056	0.3750	4791	2.87E+05	1340	8.04E+04
1350	1600	0.3750	0.4444	4888	2.93E+05	1243	7.46E+04
1600	1850	0.4444	0.5139	4985	2.99E+05	1146	6.88E+04
1850	2100	0.5139	0.5833	5082	3.05E+05	1049	6.29E+04
2100	7200	0.5833	2.0000	5174	3.10E+05	957	5.74E+04
7200	30 days	2.0000	30days	3584	2.15E+05	694	4.16E+04

Results

2 train 7200 cfm
2-Hr EAB

TPC 3%	2 hr op action
Gamma	2.133
Beta	1.213
Inhalation (ICRP-30)	28.55
TEDE	3.061

2 train 8800 cfm
2-Hr EAB

TPC 3%	2 hr op action
Gamma	2.13
Beta	1.211
Inhalation (ICRP-30)	28.54
TEDE	3.058

30-Day LPZ

TPC 3%	2 hr op action
Gamma	1.662
Beta	1.856
Inhalation (ICRP-30)	9.038
TEDE	1.594

30-Day LPZ

TPC 3%	2 hr op action
Gamma	1.662
Beta	1.856
Inhalation (ICRP-30)	9.036
TEDE	1.593

Discussion

As can be seen the 7200 cfm EGTS case is slightly higher than the 8800 cfm case. This is primarily due to the increased time to establish a negative pressure in the annulus and increased time to pump it down.

Appendix H
Evaluation of Operator Action Time (1 Hour vs. 2 Hour)

This appendix is to evaluate the operator action time. As noted in Appendix F, the failure to perform an operator action could result in significant increases in offsite doses. This appendix evaluates a reasonable time frame for operator action. The main text uses a 1 hour time operator action. The 7200 cfm EGTS STP model is modified to have an operator action time at 2 hours instead of 1. The results (rem) were:

2-Hr EAB

TPC 3%	2 hr op action
Gamma	2.133
Beta	1.213
Inhalation (ICRP-30)	28.55
TEDE	3.061

2-Hr EAB

TPC 3%	1 hr op action
Gamma	2.156
Beta	1.227
Inhalation (ICRP-30)	28.57
TEDE	3.078

30-Day LPZ

TPC 3%	2 hr op action
Gamma	1.662
Beta	1.856
Inhalation (ICRP-30)	9.038
TEDE	1.594

30-Day LPZ

TPC 3%	1 hr op action
Gamma	1.668
Beta	1.860
Inhalation (ICRP-30)	9.045
TEDE	1.598

Discussion:

The difference between an operator action of 1 hour or 2 hours is very small (about 1% maximum). The 1 hour action will result in slightly higher doses, therefore it should be used as the design basis of the plant. The window for operator action should be between 1 and 2 hours.

Appendix I - Evaluation of singe EGTS train operation with 250 cfm exhaust

Calculation WBNNAL3-028 R4 determined the offsite and control room doses due to a single EGTS train (one train has a single failure) with a Technical Specification annulus leakage of 250 cfm steady state at -0.5" H2O. The following is the pertinent parts of the calculation that still apply to this analysis.

Assumptions

2. It is assumed that the annulus is at atmospheric pressure (0 inches H2O) at the start of the LOCA.
Technical Justification: This is the basis for this calculation.

Special Requirements/Limiting Conditions

There are no special requirements or limiting conditions in this calculation.

Calculations

The isotope releases are determined by STP. Except for the initial containment leakage and the EGTS recirculation and exhaust flows, the model is the same as the final ABSCE STP model found in TI-RPS-197. The EGTS flows are taken from TI-ANL-166 and are shown in Table 1. Since the annulus starts out at positive pressure (>0.25" H2O), the containment leakage that normally goes to the annulus will instead go directly to the environment. The TI-RPS-197 flow split is 75% to the annulus and 25% to the Auxiliary Building. Since the ABGTS has not started up (until 4 minutes), the entire leakage goes to the environment. The containment flow split is therefore modeled as "F 2 6 0 1.0". This condition lasts for 114 seconds post LOCA. After 114 seconds, the annulus differential pressure falls below -0.25" (see TI-ANL-166). The containment flow split is reset to the 75% split to the annulus (and 25% split to the environment) at this time. The LPZ doses are calculated by using the computer code FENCDOSE. The activity released to the environment during the time intervals 0-2 hours, 2-8 hours, 8-24 hours, 24-96 hours, and 96-720 hours is taken directly from the STP results. The dispersion coefficients (X/Q) are taken from TI-RPS-197.

The control room operator doses are determined by COROD utilizing the STP results as input. The COROD model comes from TI-RPS-198, with the recirculation rates corrected.

Table 1
EGTS Flow Rates

Time Interval [sec]	[sec]	[hours]	[hours]	Recirculation Rate [cfm]	[cfh]	Exhaust Rate [cfm]	[cfh]
0	30	0	0.0083	0.00	0.00E+00	0.00	0.00E+00
30	39	0.0083	0.0108	3600.00	2.16E+05	0.00	0.00E+00
39	40	0.0108	0.0111	3286.62	1.97E+05	313.38	1.88E+04
40	41	0.0111	0.0114	2352.31	1.41E+05	1247.69	7.49E+04
41	42	0.0114	0.0117	1304.79	7.83E+04	2295.21	1.38E+05
42	43	0.0117	0.0119	362.60	2.18E+04	3237.40	1.94E+05
43	190	0.0119	0.0528	0.00	0.00E+00	3600.00	2.16E+05
190	191	0.0528	0.0531	537.28	3.22E+04	3062.72	1.84E+05
191	192	0.0531	0.0533	733.23	4.40E+04	2866.77	1.72E+05
192	193	0.0533	0.0536	735.14	4.41E+04	2864.86	1.72E+05
193	194	0.0536	0.0539	737.51	4.43E+04	2862.49	1.72E+05
194	199	0.0539	0.0553	745.23	4.47E+04	2854.77	1.71E+05
199	207	0.0553	0.0575	764.12	4.58E+04	2835.89	1.70E+05
207	215	0.0575	0.0597	790.80	4.74E+04	2809.20	1.69E+05
215	225	0.0597	0.0625	825.45	4.95E+04	2774.56	1.66E+05
225	245	0.0625	0.0681	892.72	5.36E+04	2707.29	1.62E+05
245	265	0.0681	0.0736	992.80	5.96E+04	2607.20	1.56E+05
265	285	0.0736	0.0792	1102.40	6.61E+04	2497.61	1.50E+05
285	305	0.0792	0.0847	1217.05	7.30E+04	2382.95	1.43E+05
305	446	0.0847	0.1239	1664.05	9.98E+04	1935.96	1.16E+05
446	601	0.1239	0.1669	2356.72	1.41E+05	1243.29	7.46E+04
601	602	0.1669	0.1672	2661.35	1.60E+05	938.65	5.63E+04
602	1700	0.1672	0.4722	3600.00	2.16E+05	0.00	0.00E+00
1700	1701	0.4722	0.4725	3508.13	2.10E+05	91.87	5.51E+03
1701	1702	0.4725	0.4728	3423.44	2.05E+05	176.56	1.06E+04
1702	1703	0.4728	0.4731	3410.73	2.05E+05	189.27	1.14E+04
1703	1704	0.4731	0.4733	3408.66	2.05E+05	191.34	1.15E+04
1704	1705	0.4733	0.4736	3408.17	2.04E+05	191.83	1.15E+04
1705	1706	0.4736	0.4739	3407.91	2.04E+05	192.09	1.15E+04
1706	1855	0.4739	0.5153	3395.23	2.04E+05	204.77	1.23E+04
1855	2100	0.5153	0.5833	3372.37	2.02E+05	227.64	1.37E+04
2100	30days*	0.5833	720	3350.00	2.01E+05	250.00	1.50E+04

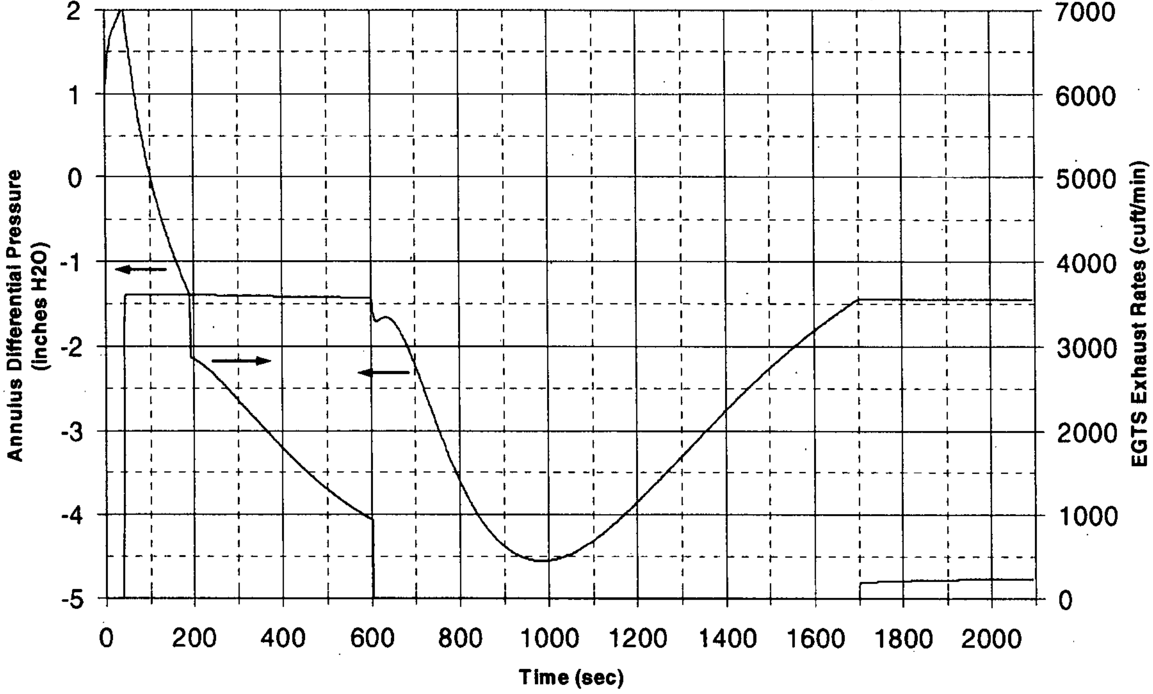
*required to maintain annulus pressure when assuming 250 cfm annulus inleakage

Note: The annulus exhaust rates from TI-ANL-166 are based on total EGTS flow of 3600 cfm (=4000-10%). This is conservative as it minimizes cleanup of the annulus environment via EGTS filters

Figure 1: WBN LOCA

Annulus Differential Pressure and EGTS Exhaust Rates

Annulus Leakage = 250 cfm, Initial Annulus Pressure = 0 inches H2O, -01.45" setpoint



Results

Offsite Doses (rem):

2-hr EAB	Standard Core	TPC 100% H3 Rel.	TPC 3% H3 Rel.	Limit
gamma	1.899	1.963	1.963	25
beta	1.082	1.087	1.086	300
Thyroid (ICRP-30)	38.43	36.7	36.7	300
TEDE	3.433	3.407	3.388	25

30-day LPZ	Standard Core	TPC 100% H3 Rel.	TPC 3% H3 Rel.	Limit
gamma	1.398	1.397	1.397	25
beta	1.677	1.635	1.622	300
Thyroid (ICRP-30)	11.09	10.6	10.6	300
TEDE	1.515	1.705	1.499	25

Discussion and Conclusion

The offsite doses calculated are below the 10CFR100 limits of 25 rem gamma, 300 rem beta, 300 rem thyroid and 25 rem TEDE. The control room operator doses are below the 10CFR50 App.A GDC 19 limits of 5 rem gamma, 30 rem beta, 30 rem thyroid, and 5 rem TEDE. The doses determined in the main text (EGTS PCO control loop single failure case) bound except for the thyroid and 2-hr EAB TEDE doses.

Appendix J: Unit 2 PCO Control Loop Single Failure

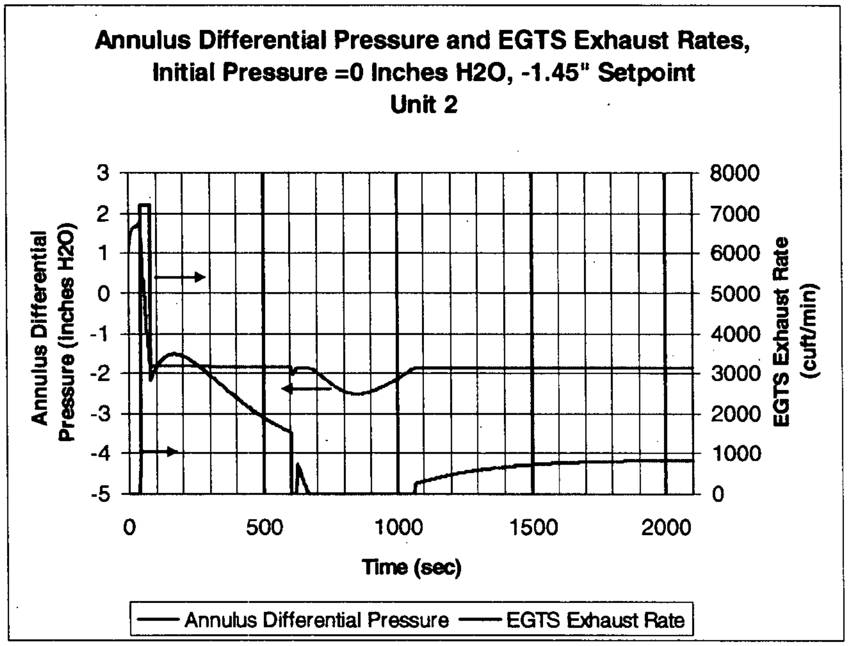
The Unit 2 PCO Control Loop Single Failure evaluation only used the bounding Unit 1 models (7200 cfm EGTS flow, 1 hr operator action). The models were the same except for the EGTS flows (case 3-2 taken from TI-ANL-166, ref. 19).

Table 3a
EGTS Performance with Annulus Initially at 0" H2O (ref.19: TI-ANL-166) 2 train EGTS 7200 cfm for Unit 2 and 1 hour operator action

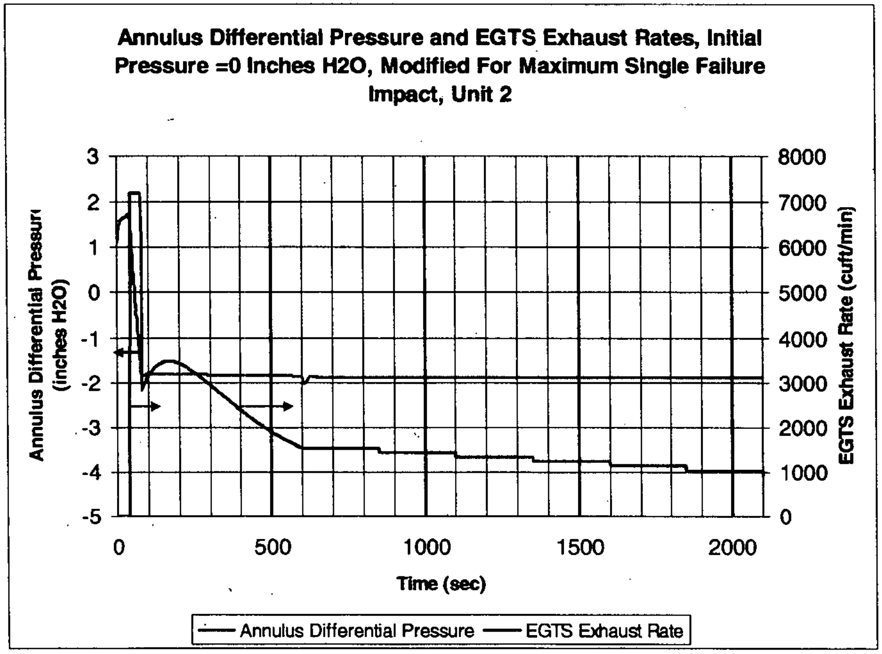
Time Interval		Time Interval		Recirculation	Rate	Exhaust Rate	
[sec]	[sec]	[hours]	[hours]	[cfm]	[cfh]	[cfm]	[cfh]
0	30	0	0.0083	0	0.00E+00	0	0.00E+00
30	39	0.0083	0.0108	7200	4.32E+05	0	0.00E+00
39	40	0.0108	0.0111	6573.24	3.94E+05	626.76	3.76E+04
40	41	0.0111	0.0114	4704.62	2.82E+05	2495.38	1.50E+05
41	42	0.0114	0.0117	2609.58	1.57E+05	4590.42	2.75E+05
42	43	0.0117	0.0119	725.2	4.35E+04	6474.8	3.88E+05
43	71	0.0119	0.0197	0	0.00E+00	7200	4.32E+05
71	78	0.0197	0.0217	0	0.00E+00	7200	4.32E+05
78	79	0.0217	0.0219	1062	6.37E+04	6138	3.68E+05
79	80	0.0219	0.0222	4775	2.87E+05	2425	1.46E+05
80	102	0.0222	0.0283	4337	2.60E+05	2863	1.72E+05
102	132	0.0283	0.0367	4188	2.51E+05	3012	1.81E+05
132	165	0.0367	0.0458	3922	2.35E+05	3278	1.97E+05
165	170	0.0458	0.0472	3762	2.26E+05	3438	2.06E+05
170	210	0.0472	0.0583	3719	2.23E+05	3481	2.09E+05
210	307	0.0583	0.0853	3760	2.26E+05	3440	2.06E+05
307	498	0.0853	0.1383	4050	2.43E+05	3150	1.89E+05
498	602	0.1383	0.1672	4797	2.88E+05	2403	1.44E+05
602	603	0.1672	0.1675	5232	3.14E+05	1968	1.18E+05
603	850	0.1675	0.2361	5137	3.08E+05	1432	8.59E+04
850	1100	0.2361	0.3056	5237	3.14E+05	1332	7.99E+04
1100	1350	0.3056	0.3750	5337	3.20E+05	1232	7.39E+04
1350	1600	0.3750	0.4444	5437	3.26E+05	1132	6.79E+04
1600	1850	0.4444	0.5139	5537	3.32E+05	1032	6.19E+04
1850	2100	0.5139	0.5833	5637	3.38E+05	932	5.59E+04
2100	3600	0.5833	1.0000	5737	3.44E+05	832	4.99E+04
3600	30 days	1.0000	30days	3455	2.07E+05	604	3.62E+04

After 603 sec, total flow is 5737+832= 6596 cfm for 2 trains and 3455+604=4059 cfm for 1 train
based on steady state flow calculation reference 58. This reduces the recirculation cleanup and increases effective releases.

The following is the EGTS performance curve from TI-ANL-166 (ref.19) With Initial Annulus Pressure at 0" H2O for Unit 2:



This is the EGTS profile as modeled for Unit 2. The above curve is modified at 602 sec to have constant flows (see assumptions 22 and 23):



Results

The results are as follows (rem):

Unit 2 LOCA with PCO Control Loop Single Failure

2-Hr EAB

conv core	1 hr op action	10CFR100 Limit
Gamma	2.019	25
Beta	1.187	300
Inhalation (ICRP-30)	29.88	300
TEDE	3.047	25
TPC 100%		
Gamma	2.095	25
Beta	1.192	300
Inhalation (ICRP-30)	28.54	300
TEDE	3.055	25
TPC 3%		
Gamma	2.095	25
Beta	1.191	300
Inhalation (ICRP-30)	28.54	300
TEDE	3.033	25

30-Day LPZ

conv core	1 hr op action	1 hr op action
Gamma	1.629	25
Beta	1.898	300
Inhalation (ICRP-30)	9.404	300
TEDE	1.577	25
TPC 100%		
Gamma	1.630	25
Beta	1.847	300
Inhalation (ICRP-30)	8.980	300
TEDE	1.785	25
TPC 3%		
Gamma	1.630	25
Beta	1.834	300
Inhalation (ICRP-30)	8.980	300
TEDE	1.568	25

Discussion and Conclusion

The Unit 2 LOCA with a PCO control loop single failure does not exceed the 10CFR100 limits. The dose consequences of the Unit 2 LOCA with PCO control loop single failure are bounded by the Unit 1 LOCA with PCO control loop single failure.

Attachment A

TI-RPS-197

Attachment A

p. A1 of 4

TI-RPS-197

Westinghouse Electric Corporation

Water Reactor Divisions

Nuclear Technology Division

Box 355
Pittsburgh Pennsylvania 15230

MAR 01 1985

	DUE DATE	INFO COPY	COMM. COPY	DRAFT REPLY
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February 21, 1985

TVA Contract
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WAT-D-6420
NS-OPLS-OPL-85-073
S.O. WAT/WBT-4705

Jeff Schermerhorn
x7301

SQUAD CHECKS
☐ FULL REVIEW
☐ REVIEW OF SPECIFIC ASPECTS
☐ NO REVIEW
☐ ____________

Mr. J. A. Raulston
Chief Nuclear Engineer
Tennessee Valley Authority
400 W. Summit Hill Drive, W10 C126
Knoxville, Tennessee 37902

Dear Mr. Raulston:

TENNESSEE VALLEY AUTHORITY
WATTS BAR NUCLEAR PLANT
UNITS NUMBERS 1 AND 2
<u>ICE CONDENSER IODINE REMOVAL EFFICIENCY</u>

The attached reference table (15.5-7) was calculated to show the Ice Condenser Iodine Removal Efficiency for an ice weight of 2.125 x 10^6 pounds. The current Watts Bar FSAR Table 15.5-7 was calculated with an ice weight of 2.45 x 10^6 pounds (page 6.2.11-6).

After you have reviewed the preceding, please contact Larry Tomasic at 412 - 374-4715 with any questions or comments.

Very truly yours,

E. A. Novotnak, Manager
Tennessee Valley Authority Projects

L. V. Tomasic/pj
Attachment

J. A. Raulston, 3L, 3A

cc: L. M. Mills, 1L, 1A
J Larkin, 1L
I. R. Williamson, 1L
R. G. Williams 1L

ADVANCE COPY OF THIS LETTER
SENT TO WEP & RMP.

Answered by Ltr # NAR

FAK FAK 3/6/85

MASTER FILE

→ RHB RHB

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N3M-2-79

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p. A2 of A2

TI-RPS-197

TI-RPS-197

TVA
WATTS BAR
(CALCULATIONS FOR ICE WEIGHT OF 2.125 X 10^6 POUNDS)

REFERENCE TABLE (15.5-7)

ICE CONDENSER IODINE REMOVAL EFFICIENCY[1]

Time Interval Post LOCA (Hours)	Iodine Removal Efficiency
0.0 to 0.156	0.96
0.156 to 0.267	0.76
0.267 to 0.323	0.73
0.323 to 0.489	0.71
0.489 to 0.615	0.60
0.615 to 0.768	0.58
0.768 to 0.824	0.40
0.824 to 720	0.0

(1) The ice condenser removal efficiencies given in the above table are used for the conservative Regulatory Guide 1.4 analyses. The inlet steam-air mixture coming into the ice condenser is greater than 90 percent steam by volume initially due to the delaying of the operation of the deck fans. Without the delay of operation of the deck fans the amount of steam by volume in the inlet mixture initially would be much lower and the ice condenser iodine removal efficiencies would be reduced.

TI-RPS-197
Attachment 8

p. B1 of B3
MCB 1-27-95
Rev 1/27/95

JAN 27 1995

January 27, 1995

T33 950127 962

Walter L. Elliott, IOB 1A-WBN

WATTS BAR NUCLEAR PLANT (WBN) FINAL SAFETY ANALYSIS REPORT (FSAR) UPDATE - DISPERSION METEOROLOGY FOR ACCIDENT ANALYSIS

This replaces the January 24, 1995, (RIMS T33 950124 950) memorandum to correct information that was previously provided related to the request for additional information from the Nuclear Regulatory Commission for their environmental review. A typographical error has been corrected in Attachment 1. Attachment 2 is unchanged.

If you have any questions, please call Doyle Pittman at 8097-C.

Kenneth G. Wastrack

for Frances P. Weatherford
Team Leader
Operations Support
Atmospheric Sciences
CEB 2A-M

DEP:JA
cc(Attachments):
M. C. Berg, IOB 1F-WBN
J. M. Loney, WT 8C-K
V. J. Shanks, MOB 2U-WBN
D. J. Voeller, MOB 1F-WBN
K. G. Wastrack, CEB 2A-M
Files, Center, CEB 1B-M

p. 52 of 53
MCO 1-27-95
Rew 1/27/95

Attachment 1

Atmospheric Dispersion Factors χ/Q, sec/m^3, for Design Basis Accident Analyses Based on Onsite Meteorological Data for Watts Bar Nuclear Plant

A. Based on Meteorological Data from 1974-88 (Section B of Table 2.3-66 in WBN FSAR)

Period (hours)	Exclusion Boundary (1100m)	Low Population Zone (4828m)
0-2	0.604E-3	0.145E-3
2-8	-	0.677E-4
8-24	-	0.463E-4
24-96	-	0.203E-4
96-720	-	0.623E-5

B. Based on Meteorological Data from 1974-93

Period (hours)	Exclusion Boundary (1100m)	Low Population Zone (4828m)
0-2	0.607E-3	0.141E-3
2-8	-	0.668E-4
8-24	-	0.459E-4
24-96	-	0.204E-4
96-720	-	0.635E-5

1/27/95

p. 53 of 93
ACB 1-27-[illegible]
Rw 1/27/

Attachment 2

Dispersion Meteorology - Onsite 10-meter Wind Data - 5th Percentile Values of Inverse Wind Speed (1/u) Distributions for Control Room Dose Calculations for Watts Bar Nuclear Plant

A. January 1974 through December 1988 Wind Speed and Direction Data (Section B of Table 2.3-67 in WBN FSAR)

Plume Sectors (degrees)	Averaging Periods 1-hour	8-hour	16-hour	3-day	26-day
89.75-157.25	1.82	1.04	0.852	0.593	0.463
132.25-199.75	1.27	0.760	0.626	0.440	0.316
154.75-222.25	0.866	0.574	0.497	0.360	0.264
192.25-259.75	1.04	0.653	0.576	0.416	0.266

B. January 1974 through December 1993 Wind Speed and Direction Data

Plume Sectors (degrees)	Averaging Periods 1-hour	8-hour	16-hour	3-day	26-day
89.75-157.25	1.97	1.04	0.862	0.607	0.456
132.25-199.75	1.29	0.784	0.626	0.434	0.312
154.75-222.25	0.891	0.606	0.516	0.368	0.255
192.25-259.75	1.10	0.713	0.610	0.435	0.300

1/27/95

Attachment C

TI-RPS-197
Attachment C

T33 950110 822

p. C1 of C
MCB 1-19-95

WAT-D-9902 Rev 1/26/95

Westinghouse
Electric Corporation

Energy Systems

Nuclear and Advanced
Technology Division

Box 355
Pittsburgh Pennsylvania 15230-0355

NTD-NSRLA-OPL-95-012
January 10, 1995

Mr. W.L. Elliott
Manager of Engineering
Watts Bar Nuclear Power Plant
Tennessee Valley Authority
IOB-1A, P.O. Box 2000
Spring City, TN 37381

Ans'd by Ltr # NPR

Attention: Steve Robertson

TENNESSEE VALLEY AUTHORITY
WATTS BAR UNITS 1 & 2
Ice Condenser Iodine Removal Efficiency
FSAR Table 15.5-7

Dear Mr. Elliott:

In response to your request, the attachment addresses the applicability of the subject table to the removal of both elemental iodine and particulate iodine.

If you have any questions, please contact the undersigned.

Very truly yours,

Keith A. [illegible] for
J. W. Irons, Manager
TVA Watts Bar Project

LVT/bbp

Attachments

cc: Mr. S. L. Robertson, 1L

RCR	DRAFT REPLY	COM COPY	INFO COPY	DUE DATE
EEB				
CEB				
MEB				
NEB				
S. Robertson, IOB 1M			1	
McBurney, IOB 1M			1	
C. Carey, IOB 1M			1 →	per your request

NSRLA\95LVT\VA007

TI-RPS-197
Attachment C (continued)

p. C2 of C
RLS 1-19-97
Rev 1/26/95

Attachment To WAT-D-9902

ICE CONDENSER IODINE REMOVAL EFFICIENCY

Purpose

The ice condenser iodine removal efficiencies provided in the FSAR (Table 15.5-7, attached) were used in the LBLOCA offsite dose calculation for both elemental and particulate iodine removal. However, these efficiencies are applicable only to elemental iodine. TVA has asked if the use of the referenced efficiencies for both elemental and particulate removal is conservative in light of the overall iodine removal conservatism that exists in the dose calculation.

Evaluation

Following a LBLOCA, iodine may be removed from the containment atmosphere by the ice condenser, containment sprays, and by deposition or impaction on internal containment surfaces. Of these, only iodine removal by the ice condenser is currently assumed in the TVA iodine release/offsite dose calculation. The table that follows compares the overall elemental and particulate iodine removal coefficients (hr^{-1}) approximated for only the ice condenser and with the combined effects of the ice condenser and containment spray and the overall decontamination factor (DF).

	elemental λ	elemental DF	particulate λ	particulate DF
ice only [1]	1.2	3 [2]	1.2	3 [2]
ice[3] and spray	5	100 to 200	6	50

1. The overall iodine removal coefficient is the numeric average of the initial and final coefficients.

2. The elemental and particulate DFs are based on 49 min of iodine removal.

3. Ice and spray iodine removal is consistent with current Standard Review Plan recommendations. The ice condenser elemental iodine removal efficiency is a constant 30%. The particulate iodine removal efficiency is 0.

TI-RPS-197

p. C3 of C3
MCB 1-19-
Rw 1/20/4

Results

Both the lambdas and DFs for iodine removal by only the ice condenser are less than the corresponding values for the combined effect of ice and spray removal of iodine.

Conclusion

TVA's use of the FSAR ice condenser iodine removal coefficients for both elemental and particulate iodine is conservative.

Attachment D

~~ATTACHMENT C~~
~~ATT PG __ OF __~~
~~W.O. 94-17190-00~~
~~W.O. PG __ OF __~~

TI-RPS-197
Attachment D

~~DCN - 4~~
~~PG. 5 OF __~~
p. D1 of D3

ACTUAL LEAKAGE RATE PER
ANSI N-510

MCS 3-21-95
CC 3/21/95

CALCULATE LEAK RATE:

$$Q = \left[\frac{Pi}{Ti} - \frac{Pf}{Tf}\right] \times \frac{V}{\Delta t(4.00125)}$$

WHERE:

1. AVERAGE LEAKAGE RATE (Q) 5.39 CFM
2. VOLUME WITHIN TEST BOUNDARY (V) 381.40 FT³
3. INITIAL PRESSURE WITHIN TEST BOUNDARY, LB/FT SQ. ABS (SEE CONVERSION BELOW) (Pi) 2143.15 LB/FT²
4. FINAL PRESSURE WITHIN TEST BOUNDARY, LB/FT SQ. ABS (SEE CONVERSION BELOW) (Pf) 2109.86 LB/FT²
5. ABSOLUTE TEMPERATURE AT START OF TEST, DEGREES RANKINE (SEE CONVERSION BELOW) (Ti) 534.8 ° R
6. ABSOLUTE TEMPERATURE AT END OF TEST, DEGREES RANKINE (SEE CONVERSION BELOW) (Tf) 535.8 ° R
7. LAPSED TIME BETWEEN START OF TEST (P1) AND END (P2). (1 SEC. = 0.0167 MIN.) (Δt) 1.23 MINS.

TEMPERATURE: TEST START (T1) 74.8 ° F TEST END (T2) 75.8 ° F

Ti = 74.8 ° F + 460 = 534.8 ° R

Tf = 75.8 ° F + 460 = 535.8 ° R

PRESSURE: TEST START (P1) 15.7 " W.G. TEST END (P2) 9.3 " W.G.

BAROMETER READING (B1) 29.15 " Hg

Pi = (15.7 " W.G. x .07355 + 29.15 " Hg) x 70.72 = 2143.15 LB/FT²

Pf = (9.3 " W.G. x .07355 + 29.15 " Hg) x 70.72 = 2109.86 LB/FT²

PREPARED BY: Bruce Bird DATE 9-27-94

CHECKED BY: BDhan Campbell DATE 3-19-95

~~ATTACHMENT C~~
~~ATT PG ___ OF ___~~ (3) 9-27-94
~~WO94-17190-0001~~
~~WO PG ___ OF ___~~

TI-RPS-197
Attachment D
(continued)

~~UCN-6~~
~~PG 6 OF ___~~

p. D2 of D3
MWS 3-21-95
3/21/95

ACTUAL LEAKAGE RATE PER
ANSI N-510

CALCULATE LEAK RATE:

$$Q = \left[\frac{Pi}{Ti} - \frac{Pf}{Tf}\right] \times \frac{V}{\Delta t(4.00125)}$$

WHERE:

1. AVERAGE LEAKAGE RATE (Q) 7.15 CFM
2. VOLUME WITHIN TEST BOUNDARY (V) 310.93 FT³
3. INITIAL PRESSURE WITHIN TEST BOUNDARY, LB/FT SQ. ABS (SEE CONVERSION BELOW) (Pi) 2132.54 LB/FT²
4. FINAL PRESSURE WITHIN TEST BOUNDARY, LB/FT SQ. ABS (SEE CONVERSION BELOW) (Pf) 2099.25 LB/FT²
5. ABSOLUTE TEMPERATURE AT START OF TEST, DEGREES RANKINE (SEE CONVERSION BELOW) (Ti) 537.0 °R
6. ABSOLUTE TEMPERATURE AT END OF TEST, DEGREES RANKINE (SEE CONVERSION BELOW) (Tf) 536.8 °R
7. LAPSED TIME BETWEEN START OF TEST (P1) AND END (P2). (1 SEC.= 0.0167 MIN.) (Δt) 0.658 MINS.

TEMPERATURE: TEST START (T1) 77.0 °F TEST END (T2) 76.8 °F

Ti = 77.0 °F + 460 = 537.0 °R

Tf = 76.8 °F + 460 = 536.8 °R

PRESSURE: TEST START (P1) 15.7 " W.G. TEST END (P2) 9.3 " W.G.

BAROMETER READING (B1) 29.0 " Hg

Pi = (15.7 " W.G. x .07355 + 29.0 " Hg) x 70.72 = 2132.54 LB/FT²

Pf = (9.3 " W.G. x .07355 + 29.0 " Hg) x 70.72 = 2099.25 LB/FT²

PREPARED BY: Bruce Neal DATE 9-27-94

CHECKED BY: B. Wehan [illegible] DATE 3-19-95

TI-RPS-197
Attachment D (continued)

~~ULN - 4~~
~~PG 2 OF ___~~ MCG 3-21-93

p. D3 of D3

MWS 3-3
CC 8/4/9

1981 ABGTS TESTING	1994 ABGTS TESTING
TEST 0-30-AB-LT-07	TEST 94-17190-00
BOUNDARY: OUTLET U1 FLT. HOUSE TO FAN AA DISCH. FLX	BOUNDARY: OUTLET U1 FLT. HOUSE TO FAN AA SUCT. FLG.
ALLOWABLE LEAKAGE 3.4 CFM	ALLOWABLE LEAKAGE .91 CFM
ACTUAL LEAKAGE 37.3 CFM	ACTUAL LEAKAGE 5.39 CFM
TEST 0-30-AB-LT-02	TEST 94-17190-01
BOUNDARY: FAN AA INLET FLEX TO REACTOR SHIELD WALL	BOUNDARY FAN AA DISCH FLG TO DAMPER 1-FCO-30-146A
ALLOWABLE LEAKAGE 3.1 CFM	ALLOWABLE LEAKAGE .81 CFM
ACTUAL LEAKAGE 12.62 CFM	ACTUAL LEAKAGE 7.15 CFM

NOTE: 1981 ACTUAL LEAKAGE TESTS [illegible]

Attachment E

ACTUAL LEAK RATE
ANSI/ASME N510
POSITIVE ☒ NEGATIVE ☐

TI-RPS-197
Attachment E

I.O.# 94-17127-01
PG. # ____ OF ____
ATT PG ____ OF ____

ATTACHMENT C

p. E1 of E5
MOB 6-12-95
DGF 6/12/95

CALCULATE LEAK RATE:

$$Q = \left(\frac{Pi}{Ti} - \frac{Pf}{Tf}\right) \times \frac{V}{\Delta t(4.00125)}$$

WHERE:

1. AVERAGE LEAKAGE RATE (Q) 5.1 SCFM
2. VOLUME WITHIN TEST BOUNDARY (V) 375.65 FT³
3. INITIAL PRESSURE WITHIN TEST BOUNDARY, LB/FT SQ. ABS (SEE CONVERSION BELOW) (Pi) 2157.95 LB/FT²
4. FINAL PRESSURE WITHIN TEST BOUNDARY, LB/FT SQ. ABS (SEE CONVERSION BELOW) (Pf) 2124.68 LB/FT²
5. ABSOLUTE TEMPERATURE AT START OF TEST, DEGREES RANKINE (SEE CONVERSION BELOW) (Ti) 540.6 ° R
6. ABSOLUTE TEMPERATURE AT END OF TEST, DEGREES RANKINE (SEE CONVERSION BELOW) (Tf) 540.0 ° R
7. LAPSED TIME BETWEEN START OF TEST (P1) AND END (P2). (1 SEC. = 0.0167 MIN.) (Δt) 1.05 MINS.

TEMPERATURE: TEST START (T1) 80.6 ° F TEST END (T2) 80.0 ° F

Ti = 80.6 ° F + 460 = 540.6 ° R

Tf = 80.0 ° F + 460 = 540.0 ° R

PRESSURE: TEST START (P1) 15.7 " W.G. TEST END (P2) 9.3 " W.G.

BAROMETER READING (B1) 29.36 " Hg

Pi = (15.7 " W.G. x .0735 + 29.36 " Hg) x 70.72 = 2157.95 LB/FT²

Pf = (9.3 " W.G. x .0735 + 29.36 " Hg) x 70.72 = 2124.65 LB/FT²

PREPARED BY: ________ DATE 5-24-95

CHECKED BY: ________ DATE 5-31-95

ACTUAL LEAK RATE
ANSI/ASME N510
POSITIVE ☐ NEGATIVE ☒

TI-RPS-197
Attachment F (cont.)

.O. # 94-17127-00
PG. # ______ OF ______
ATT PG ______ OF ______

p. E2 of E5
MCB 6-11-95
DGF 6/17/95

ATTACHMENT C

CALCULATE LEAK RATE:

$$Q = \left[\frac{Pi}{Ti} - \frac{Pf}{Tf} \right] x \frac{V}{\Delta t(4.00125)}$$

WHERE:

1.	AVERAGE LEAKAGE RATE	(Q)	3.73	SCFM
2.	VOLUME WITHIN TEST BOUNDARY	(V)	336.90	FT³
3.	INITIAL PRESSURE WITHIN TEST BOUNDARY, LB/FT SQ. ABS (SEE CONVERSION BELOW)	(Pi)	2157.95	LB/FT²
4.	FINAL PRESSURE WITHIN TEST BOUNDARY, LB/FT SQ. ABS (SEE CONVERSION BELOW)	(Pf)	2124.68	LB/FT²
5.	ABSOLUTE TEMPERATURE AT START OF TEST, DEGREES RANKINE (SEE CONVERSION BELOW)	(Ti)	538.0	° R
6.	ABSOLUTE TEMPERATURE AT END OF TEST, DEGREES RANKINE (SEE CONVERSION BELOW)	(Tf)	539.0	° R
7.	LAPSED TIME BETWEEN START OF TEST (P1) AND END (P2). (1 SEC.= 0.0167 MIN.)	(Δt)	1.56	MINS.

TEMPERATURE: TEST START (T1) 78.0 ° F TEST END (T2) 79.0 ° F

Ti = 78.0 ° F + 460 = 538.0 ° R

Tf = 79.0 ° F + 460 = 539.0 ° R

PRESSURE: TEST START (P1) 15.7 " W.G. TEST END (P2) 9.3 " W.G.

BAROMETER READING (B1) 29.36 " Hg

Pi = (15.7 " W.G. x .0735 + 29.36 " Hg) x 70.72 = 2157.95 LB/FT²

Pf = (9.3 " W.G. x .0735 + 29.36 " Hg) x 70.72 = 2124.68 LB/FT²

PREPARED BY: ______ DATE 5-24-95

CHECKED BY: ______ DATE 5-31-95

TI-RPS-197
Attachment E (cont.)

Page 25 of 32

APPENDIX B
Page 1 of 2

WO 94-17127-00
WO PG
Data Package Page ___ of ___

p. E30FES
MB 1-12-95
DCF 6/15/95

DEFICIENCY LOG

Deficiency Index	Page Numbers	Step/Section Numbers
Test Number : 94-17127-00 Rev Number : R0 ADD 1 DN Number : D-17-300-DN5 DN Page 1 of:	ATTACHMENT 'B' PG 2 OF 5	SECTION/STEP 5.D

All entries below MUST be signed (or initialed) and dated.

DEFICIENCY DESCRIPTION:

STEP 5.D CANNOT BE ACCOMPLISHED THUS STOPPING THE INITIATION AND COMPLETION OF SECTIONS 6 AND 7 OF THIS TEST INSTRUCTION. (REQUIRED ESTIMATED TIME CANNOT BE ATTAINED)

TEST DIRECTOR: 5-24-95

SRO notification for Tech Spec/Tech Req required? [] Yes [✓ No]
Time: ______ Date: ______ N/A SRO: 5-24-95

SIMF notification for compliance instrument required? [] Yes [✓ No]
Time: ______ Date: ______ N/A SIMF: 95

N/A time, date, and SRO or SIMF signoff for those checked "No". ______ TEST DIRECTOR / Date

EVALUATION and PROPOSED CORRECTIVE ACTION (including RETESTING):
(include ACP or SCAR #s, if used)

SIGNATURES FOR STEP 5.D SHALL BE PERFORMED NOTING THIS DN NUMBER TO TEST INSTRUCTION AT STEP 5.D. PROCEED WITH SECTION 6 AND SUBMIT THE RESULTS TO NE FOR EVALUATION OF ACTUAL LEAKAGE. TEST BLINDS/EQUIPMENT MAY BE REMOVED AFTER COMPLETION OF STEP 6.I, AT RISK. SHOULD NE FIND ACTUAL LEAKAGE FIGURES UNACCEPTABLE ENTIRE TEST SHALL BE PERFORMED AGAIN.

Performed by: 5-24-95

ACP or SCAR required? [] Yes [✓ No]
If yes, record # above.
Evaluated by: 5-24-95

CORRECTIVE ACTION (including RETESTING PERFORMED):

TEST DIRECTOR: ______
RESPONSIBLE SUPERVISOR (7 days): ______
RESPONSIBLE ENGINEER: ______

TI-RPS-197
Attachment E (cont.)

APPENDIX B
Page 1 of 2

Page [illegible] of [illegible]
WO 94-17127-01
WO PG __ OF __
Data Package Page __ of __

p. E4 of E5
MCB 6-12-95
DGF 6/12/95

DEFICIENCY LOG

Deficiency Index	Page Numbers	Step/Section Numbers
Test Number : 94-17127-01 Rev Number : RD ADD 2 DN Number : 0-LT-300-D14 DN Page 1 of:	ATTACHMENT 'B' PG 2 OF 5	SECTION/STEP 5.D

All entries below MUST be signed (or initialed) and dated.

DEFICIENCY DESCRIPTION:
STEP 5.D CANNOT BE ACCOMPLISHED THUS STOPPING THE INITIATION AND COMPLETION OF SECTIONS 6 AND 7 OF THIS TEST INSTRUCTION. (REQUIRED ESTIMATED TIME CANNOT BE ATTAINED)

TEST DIRECTOR: 5-24-95

SRO notification for Tech Spec/Tech Req required? [] Yes [✓ No]
~~Time:~~ ~~Date:~~ N/A ~~SRO:~~ 5-24-95

SIMF notification for compliance instrument required? [] Yes [✓ No]
~~Time:~~ ~~Date:~~ N/A ~~SIMF:~~

N/A time, date, and SRO or SIMF signoff for those checked "No". 5/24/95 / 5-24-95
TEST DIRECTOR Date

EVALUATION and PROPOSED CORRECTIVE ACTION (including RETESTING):
(include ACP or SCAR #s, if used)
SIGNATURES FOR STEP 5.D SHALL BE PERFORMED NOTING THIS DN NUMBER TO TEST INSTRUCTION AT STEP 5.D PROCEED WITH SECTION 6 AND SUBMIT THE RESULTS TO NE FOR EVALUATION OF ACTUAL LEAKAGE. TEST BLINDS/EQUIPMENT MAY BE REMOVED AFTER COMPLETION OF STEP 6.I, AT RISK. SHOULD NE FIND ACTUAL LEAKAGE FIGURES UNACCEPTABLE ENTIRE TEST SHALL BE PERFORMED AGAIN.

Performed by: 5-24-95

ACP or SCAR required? [] Yes [✓ No]
If yes, record # above. Evaluated By: 5-24-95

CORRECTIVE ACTION (including RETESTING PERFORMED):

TEST DIRECTOR: ____
RESPONSIBLE SUPERVISOR (if req'd): ____
[illegible]

[illegible] ____

TI-RPS-197
Attachment E (cont.)

p. E5 of E5
KLS 6-12-95
DGF 6/15/95

1981 ABGTS TESTING	1995 ABGTS TESTING
TEST 0-30-AB-LT-08	TEST 94-17127-00
BOUNDARY: OUTLET U2 FLT. HOUSE TO FAN BB OUTLET	BOUNDARY: OUTLET U2 FLT. HOUSE TO FAN BB INLET
ALLOWABLE LEAKAGE: 2.9	ALLOWABLE LEAKAGE: .82 CFM
ACTUAL LEAKAGE: 33.9	ACTUAL LEAKAGE: 3.73 CFM
TEST 0-30-AB-LT-04	TEST 94-17127-01
BOUNDARY: U2 FAN BB INLET FLG TO INSIDE SHIELD WALL	BOUNDART: U2 FAN BB DISCH FLG TO INSIDE SHIELD WALL
ALLOWABLE LEAKAGE: 3.4 CFM	ALLOWABLE LEAKAGE: .95 CFM
ACTUAL LEAKAGE: 10.0 CFM	ACTUAL LEAKAGE: 5.1 CFM

NOTE: 1981 ACTUAL LEAKAGE TOTALS LISTED ABOVE HAVE BEEN PREVIOUSLY ACCEPTED ON NCR-3285R

Attachment 15
(Located on Attached OSM)

Met files used in the ARCON96 X/Q calculations

Metwbnp1976.dat
Metwbnp1977.dat
Metwbnp1978.dat
Metwbnp1979.dat
Metwbnp1980.dat
Metwbnp1981.dat
Metwbnp1982.dat
Metwbnp1983.dat
Metwbnp1984.dat
Metwbnp1985.dat
Metwbnp1986.dat
Metwbnp1987.dat
Metwbnp1988.dat
Metwbnp1989.dat
Metwbnp1990.dat
Metwbnp1991.dat
Metwbnp1992.dat
Metwbnp1993.dat

Attachment 16

1976 TVA Report

Impingement at Watts Bar Steam Plant

6387

IMPINGEMENT AT WATTS BAR STEAM PLANT

Watts Bar Steam Plant, TVA's first fuel-burning electric power plant, is located on the right bank of the Tennessee River (Tennessee River Mile 529.2) near the upper end of Chickamauga Reservoir about 1,036 meters downstream of Watts Bar Dam (Figures 1 and 2). The four-unit plant, rated at 240,000 kW total capacity with a 280,000 gpm condenser cooling water requirement, became fully operational in April 1945. Although the plant operated on base load during much of its early history, it currently operates as a peaking plant.

Physical Data

Pumping Station - The intake screen house for the circulating water supply system is continuous with the upstream face of the service bay at the Watts Bar hydroplant and contains six intake openings at 90° to the axis of the dam. Each of the six $18.3m^2$ intake openings is equipped with a steel trashrack 6.3 meters high by 2.9 meters wide. The trashrack bars are 12.70 cm wide by ? 0.95 cm thick and are spaced 7.52 cm on centers. Following the trashracks, the water passes through the vertical traveling screens. These are made of 0.61 by 1.83 meter screen panels interlocked and attached to chains operating between sprockets at the bottom and drive sprockets supported on the intake deck. These panels are made of 12-gauge galvanized wire with 0.95-cm (3/8 inch) mesh openings.

Circulating water for the condensers is supplied by gravity from the Watts Bar Reservoir through a conduit system approximately 1,036 meters long. The circulating water supply system is designed to produce a maximum flow through from condensers of 17.67 cubic meters per second (624 cfs) when the Watts Bar Reservoir is at elevation 733 (ft) and the tailwater at the steam plant discharge is at elevation

699, a gross head of 10.36 meters. With this flow through the six screens, there is a calculated velocity throug the trashracks of 25.60 cm/sec (.83 fps).

Biological Data

1. Sampling methods

   Samples were collected weekly between August 8, 1974, and May 29, 1975, as follows: at the beginning of the sample period (1,100 hours, Wednesday), all traveling screens were simultaneously rotated and washed clean of fish and debris. Twenty-four hours later, the screens were washed individually, and the impinged fish were collected in a catch basket installed in the screen was sluiceway. All individuals were separated by species into 25 mm length categories and counted. Total weights (grams) for each length class were recorded.

2. Results

   Below are listed (Table 1) the total number of each of the 19 species collected from the 33 samples taken at Watts Bar Steam Plant during the sampling period August 8, 1974 through May 29, 1975. Seventy-three percent of the total 2,130 fish collected were shad. The remaining 16 nonshad species which totaled 575 individuals were impinged at an average rate of 17.4 fish per sample.

Since sampling was done on a fixed schedule, independent of plant operation, the average number of screens counted per twenty-four hour sample is assumed to approximate the average number of screens in operation per day throughout the entire sampling period. In addition, the average number of fish collected per sample through the 10-month sampling period is assumed to approximate the average daily impingement for that period. Since Watts Bar is a peaking plant there were several sampling dates on which the plant was not in operation. The percent of time the plant was not operating on the sampling days (30.3%) is assumed to approximate the percent of time the plant did not operate during the entire 10-month sampling period. Extrapolating the average impingement counts per sample for the number of days the plant presumably operated during the 10-month period August 1974 - May 1975 and will operate during June and July 1975 yields the estimated annual numbers (Table 2) and biomass (Table 3) impinged.

Figure 3 depicts the total number of fish impinged during each of the thirty-three 24-hour samples. The greatest number of fish for a single sample (438) occurred on March 27, 1975, in which 79.9 percent were threadfin shad.

Table 1. Total Number of Each Species Impinged on the Intake Screens of Watts Bar Steam Plant in 33 Samples Collected Between August 8, 1974, and May 29, 1975

Scientific Name	Common Name	Total Number
Alosa chrysochloris	Skipjack Herring	187
Dorosoma cepedianum	Gizzard Shad	36
D. petenense	Threadfin shad	1,333
Hiodon tergisus	Mooneye	13
Notropis autherinoides	Emerald Shiner	1
N. whipplei	Steelcolor Shiner	3
Pimephales vigilax	Bullhead Minnow	1
Ictiobus bubalus	Smallmouth Buffalo	1
Ictalurus furcatus	Blue Catfish	8
I. punctatus	Channel Catfish	17
Pylodictis olivaris	Flathead Catfish	3
Morone chrysops	White Bass	25
M. mississippiensis	Yellow Bass	1
M. saxitilis	Striped bass	1
Lepomis macrochirus	Bluegill	235
Micropterus dolomieui	Smallmouth Bass	5
Pomoxis annularis	White Crappie	19
Apoldinotus grunniens	Freshwater drum	232
Percina caprodes	Logperch	9
Total		2,130

Table 2. Estimated Annual Number of Fish Impinged at Watts Bar Steam Plant (Plant Operating 69.7 Percent of the Time)

Species	Total Number
Clupeidae	11,995
Bluegill	1,812
All other species	2,613
Total	16,421

Table 3. Estimated Annual Biomass (kg) of Fish Impinged at Watts Bar Steam Plant (Plant Operating 69.7 Percent of the Time)

Species	Biomass (kg)
Clupeidae	355.43
Bluegill	25.47
All other species	87.21
Total	468.11

Discussion and Conclusion

Only five of the samples contained more than 100 fish during the sampling period (August 8, 1974, to May 29, 1975). Of the 16 non-shad species collected only bluegill (7.1 per sample) and drum (7.0 per sample) were impinged at an average rate exceeding one individual per 24 hours.

Because Watts Bar is a peaking plant and is of comparatively low generating capacity, its cooling water requirement is low resulting in a low total annual volume of water passed through the plant. These factors undoubtedly account for the low impingement at this plant. Based on the results of this study, we conclude that the impingement of fish at Watts Bar Steam Plant does not constitute an adverse environmental impact to the fish population of Watts Bar Reservoir.

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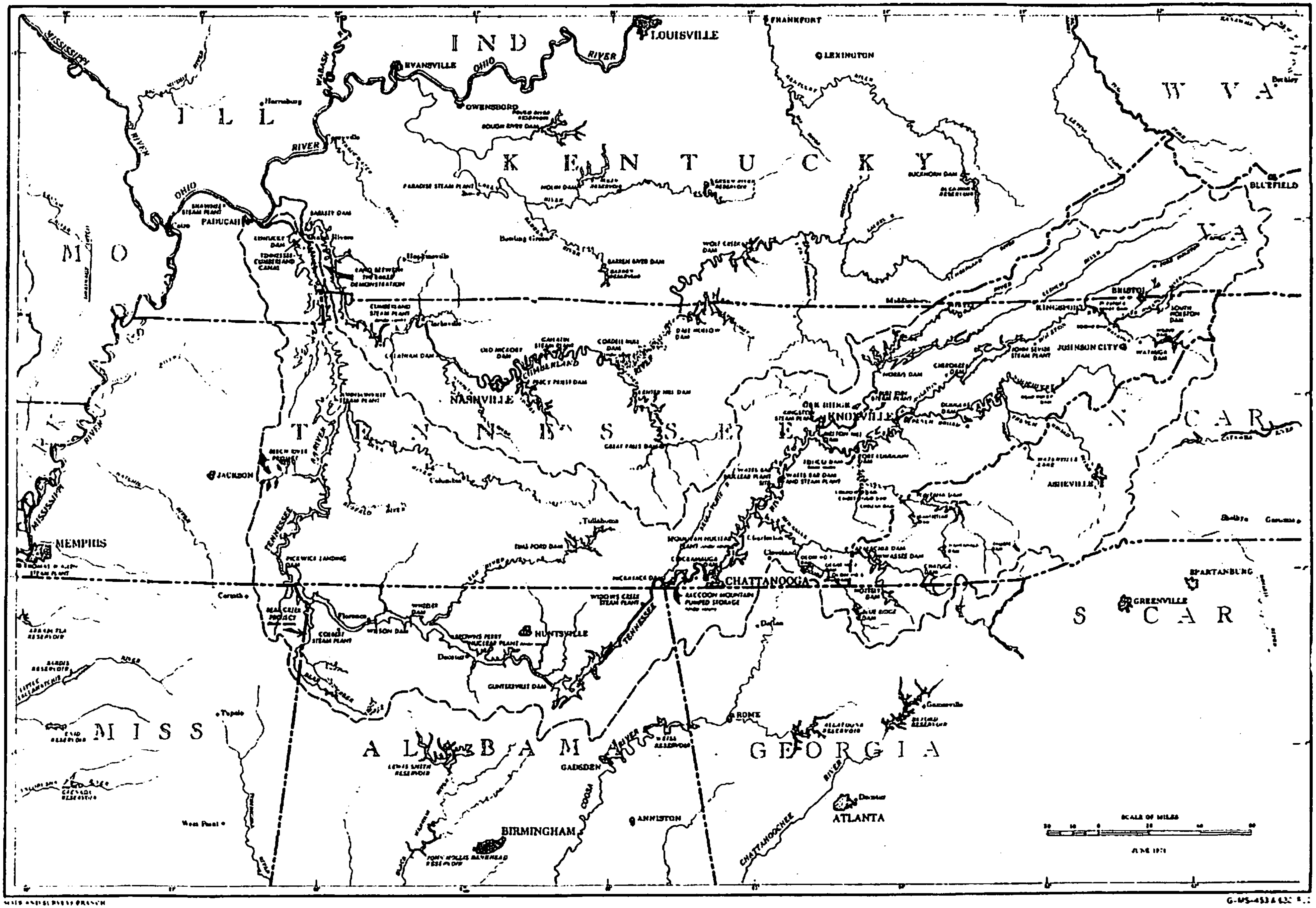

MAPS AND SURVEYS BRANCH

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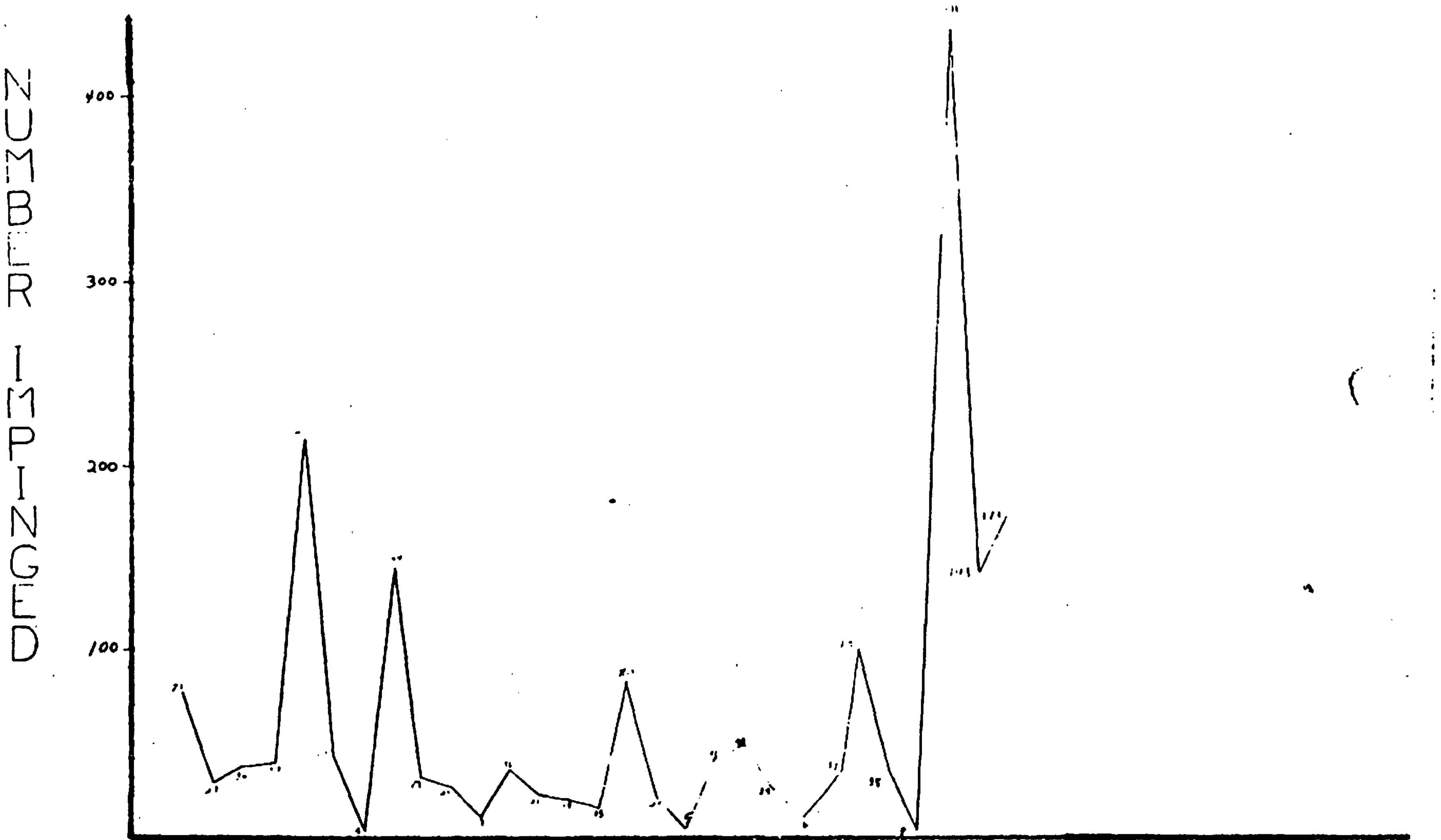

Date	8/3	8/15	8/22	8/29	9/5	9/12	9/19	9/26	10/3	10/10	10/24	10/31	11/7	11/14	[illegible]	[illegible]	[illegible]	12/19	1/9	1/16	1/23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3/27	[illegible]	[illegible]
Screens	6	6	6	5	5	5	5	5	5	4	3	4	5	5	5	5	4	5	5	5	5	[illegible]	[illegible]	[illegible]	5	5	5	[illegible]	[illegible]
Species	6	6	3	5	10	7	5	11	6	6	4	4	6	6	5	[illegible]	3	2	4	5	3	4	[illegible]	[illegible]	[illegible]	2	7	[illegible]	8

WATTS BAR

Attachment 17

Table 3-7

Total Numbers of Each Native Mussel Species Collected During Preoperational (1983-1994) and Operational (1996-1997) Surveys Near Watts Bar Nuclear Plant

Table 3-7. Total numbers of each native mussel species collected during preoperational (1983-1994) and operational (1996-1997) surveys near Watts Bar Nuclear Plant.

	Preoperational												Operational			
	1983	1983 Fall	1984	1984 Fall	1985	1985 Fall	1986	1986 Fall	1988	1990	1992	1994	1996	1997	Totals	Times Found
Elliptio crassidens	754	836	779	984	738	929	734	765	970	524	424	583	594	489	10103	14
Pleurobema cordatum	264	275	220	156	113	177	110	169	224	139	82	95	94	101	2219	14
Cyclonaias tuberculata	88	70	73	62	60	66	55	76	93	90	68	64	38	47	950	14
Quadrula pustulosa	99	75	85	53	53	85	31	41	80	79	48	65	30	24	848	14
Potamilus alatus	14	29	18	29	34	43	41	27	55	45	16	10	35	12	408	14
Ellipsaria lineolata	24	29	24	25	8	27	19	18	23	28	14	11	15	8	273	14
Amblema plicata	18	33	19	11	17	25	23	24	49	10	13	13	11	5	271	14
Anodonta grandis	18	10	5	4	3	7	9	7	29	20	5	7	7	1	132	14
Quadrula metanevra	14	24	11	13	6	10	7	7	8	8	8	4	2	2	124	14
Tritogonia verrucosa	6	12	5	5	4	15	8	13	18	9	9	7	4	1	116	14
Obliquaria reflexa	14	6	8	3	7	5	9	3	7	11	6	11	6	3	99	14
Ligumia recta	6	3	4	10	3	8	8	10	7	2	3	1	2	1	68	14
Lampsilis abrupta	3	7	6	2	1	7	6	2	12	4	6	2	4	-	62	13
Leptodea fragilis	1	3	4	2	3	2	6	3	12	8	-	3	1	2	50	13
Actinonaias ligamentina	3	2	2	-	4	7	-	8	3	5	1	-	-	-	35	9
Megalonaias nervosa	2	1	-	1	1	4	5	1	9	3	4	2	1	-	34	12
Lampsilis ovata	3	1	1	4	5	4	1	2	3	1	-	-	-	1	26	11
Elliptio dilatata	4	2	1	1	-	2	2	1	3	1	-	-	1	-	18	10
Pleurobema oviforme	-	-	2	-	-	1	-	2	2	1	-	1	-	-	9	6
Anodonta imbecillis	-	-	-	2	-	-	-	1	1	1	-	-	-	-	5	4
Cyprogenia stegaria	2	1	-	1	1	-	-	-	-	-	-	-	-	-	5	4
Pleurobema plenum	1	1	2	-	1	-	-	-	-	-	-	-	-	-	5	4
Plethobasus cyphyus	-	2	-	-	-	-	-	-	-	-	1	1	-	-	4	3
Pleurobema rubrum	-	-	-	-	-	3	-	-	1	-	-	-	-	-	4	2
Anodonta suborbiculata	-	-	-	-	-	-	-	-	1	1	-	-	-	-	2	2
Fusconaia subrotunda	2	-	-	-	-	-	-	-	-	-	-	-	-	-	2	1
Lasmigona costata	-	-	-	-	-	-	1	-	-	-	-	-	1	-	2	2
Ptychobranchus fasciolaris	-	-	1	-	-	-	-	-	-	1	-	-	-	-	2	2
Dromus dromas	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Lasmigona complanata	-	-	-	-	1	-	-	-	-	-	-	-	-	-	1	1
Total Mussels	1341	1422	1270	1368	1063	1427	1075	1180	1610	991	708	880	846	697	15878	
Number of Species Collected	22	21	20	19	20	20	18	20	22	22	16	17	17	14	30	

Attachment 18

Appendix A-2

Results of 14 Native Mussel Surveys at 12 Sites in the Vicinity of Watts Bar Nuclear Plant, 1983-1997

Appendix A-2. Results of 14 native mussel surveys at 12 sites in the vicinity of Watts Bar Nuclear Plant, 1983-1997.

September 13-14,1983					Bed					Bed					Bed	Survey	
Species	520.0	520.3	520.6	520.8	Total	526.0	526.3	526.5	526.8	Total	528.2	528.5	528.8	528.9	Total	Total	Percent
Elliptio crassidens	163	71	78	102	414	21	65	12	34	132	53	43	69	43	208	754	56.23
Pleurobema cordatum	17	41	16	16	90	17	82	7	3	109	12	18	20	15	65	264	19.69
Quadrula pustulosa	8	3	6	15	32	4	22	14	5	45	6	5	9	2	22	99	7.38
Cyclonaias tuberculata	8	5	21	11	45	3	7	4	4	18	5	8	8	4	25	88	6.56
Ellipsaria lineolata	2	3	2	8	15	1	4	2	1	8	0	1	0	0	1	24	1.79
Amblema plicata	0	0	1	0	1	0	5	5	5	15	0	1	1	0	2	18	1.34
Anodonta grandis	0	0	0	0	0	4	1	3	6	14	0	0	1	3	4	18	1.34
Obliquaria reflexa	1	0	0	0	1	0	4	6	2	12	0	1	0	0	1	14	1.04
Potamilus alatus	2	1	3	0	6	3	0	1	3	7	0	0	1	0	1	14	1.04
Quadrula metanevra	1	0	5	2	8	2	0	2	0	4	1	1	0	0	2	14	1.04
Ligumia recta	1	1	0	1	3	0	0	0	1	1	0	1	1	0	2	6	0.45
Tritogonia verrucosa	0	0	0	0	0	2	1	0	2	5	0	0	1	0	1	6	0.45
Elliptio dilatata	1	0	1	1	3	0	0	0	0	0	0	0	0	1	1	4	0.30
Actinonaias ligamentina	1	0	0	0	1	0	1	0	0	1	0	1	0	0	1	3	0.22
Lampsilis abrupta	0	0	0	0	0	0	1	0	0	1	0	1	1	0	2	3	0.22
Lampsilis ovata	1	0	1	0	2	0	0	0	0	0	0	0	1	0	1	3	0.22
Cyprogenia stegaria	0	0	1	0	1	0	0	0	0	0	0	0	1	0	1	2	0.15
Fusconaia subrotunda	0	0	0	1	1	0	0	0	0	0	0	0	1	0	1	2	0.15
Megalonaias nervosa	0	0	0	0	0	0	1	1	0	2	0	0	0	0	0	2	0.15
Dromus dromas	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0.07
Leptodea fragilis	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0.07
Pleurobema plenum	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0.07
Grand Total	206	125	136	158	625	58	194	57	66	375	77	81	115	68	341	1341	100.00
Species Count	12	7	12	10	17	10	12	11	11	16	5	11	13	6	18	22	

Appendix A-2. (Continued)

November 1-2,1983					Bed					Bed					Bed	Survey	
Species	520.0	520.3	520.6	520.8	Total	526.0	526.3	526.5	526.8	Total	528.2	528.5	528.8	528.9	Total	Total	Percent
Elliptio crassidens	0	145	100	102	347	21	52	26	72	171	54	108	91	65	318	836	58.79
Pleurobema cordatum	32	13	13	24	82	9	24	22	2	57	8	51	46	31	136	275	19.34
Quadrula pustulosa	6	0	6	10	22	4	8	6	0	18	12	7	1	15	35	75	5.27
Cyclonaias tuberculata	5	4	14	15	38	1	8	5	0	14	1	4	4	9	18	70	4.92
Amblema plicata	2	0	3	1	6	6	6	10	2	24	0	1	0	2	3	33	2.32
Ellipsaria lineolata	1	2	4	6	13	1	1	0	3	5	1	7	0	3	11	29	2.04
Potamilus alatus	1	1	3	0	5	7	0	6	7	20	1	1	1	1	4	29	2.04
Quadrula metanevra	5	2	1	2	10	1	2	0	0	3	2	5	1	3	11	24	1.69
Tritogonia verrucosa	0	0	0	0	0	7	0	2	3	12	0	0	0	0	0	12	0.84
Anodonta grandis	0	0	0	0	0	4	0	1	3	8	0	1	1	0	2	10	0.70
Lampsilis abrupta	0	1	1	0	2	0	0	0	0	0	1	1	1	2	5	7	0.49
Obliquaria reflexa	0	0	0	0	0	1	1	2	2	6	0	0	0	0	0	6	0.42
Leptodea fragilis	0	0	1	1	2	0	0	0	0	0	0	0	0	1	1	3	0.21
Ligumia recta	0	1	0	0	1	0	1	0	0	1	0	0	1	0	1	3	0.21
Actinonaias ligamentina	1	0	0	0	1	0	0	0	0	0	0	0	0	1	1	2	0.14
Elliptio dilatata	0	1	0	0	1	1	0	0	0	1	0	0	0	0	0	2	0.14
Plethobasus cyphyus	0	0	0	0	0	2	0	0	0	2	0	0	0	0	0	2	0.14
Cyprogenia stegaria	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0.07
Lampsilis ovata	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.07
Megalonaias nervosa	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0.07
Pleurobema plenum	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.07
Grand Total	53	172	146	161	532	65	104	80	94	343	81	186	147	133	547	1422	100.00
Species Count	8	11	10	8	15	13	10	9	8	15	9	10	9	11	14	21	

Appendix A-2. (Continued)

July 11-12, 1984 Species	520.0	520.3	520.6	520.8	Bed Total	526.0	526.3	526.5	526.8	Bed Total	528.2	528.5	528.8	528.9	Bed Total	Survey Total	Percent
Elliptio crassidens	110	63	15	44	232	9	33	21	18	81	11	88	195	172	466	779	61.34
Pleurobema cordatum	33	27	24	23	107	4	7	1	0	12	3	18	55	25	101	220	17.32
Quadrula pustulosa	4	0	13	10	27	8	2	6	4	20	5	13	9	11	38	85	6.69
Cyclonaias tuberculata	0	4	33	25	62	0	0	2	0	2	0	3	6	0	9	73	5.75
Ellipsaria lineolata	1	2	7	3	13	2	1	0	1	4	1	4	2	0	7	24	1.89
Amblema plicata	0	0	4	0	4	4	1	7	0	12	1	1	1	0	3	19	1.50
Potamilus alatus	0	2	3	2	7	2	1	0	6	9	0	1	1	0	2	18	1.42
Quadrula metanevra	0	2	2	2	6	0	0	1	0	1	0	2	2	0	4	11	0.87
Obliquaria reflexa	0	0	1	0	1	1	0	5	1	7	0	0	0	0	0	8	0.63
Lampsilis abrupta	0	1	0	0	1	1	1	0	0	2	0	0	2	1	3	6	0.47
Anodonta grandis	0	0	0	0	0	1	2	2	0	5	0	0	0	0	0	5	0.39
Tritogonia verrucosa	0	0	1	0	1	3	0	0	0	3	0	1	0	0	1	5	0.39
Leptodea fragilis	0	0	0	0	0	0	1	0	2	3	0	1	0	0	1	4	0.31
Ligumia recta	2	0	0	0	2	0	0	0	0	0	0	0	2	0	2	4	0.31
Actinonaias ligamentina	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	2	0.16
Pleurobema oviforme	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	0.16
Pleurobema plenum	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	2	0.16
Elliptio dilatata	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0.08
Lampsilis ovata	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.08
Ptychobranchus fasciolaris	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0.08
Grand Total	151	101	106	109	467	35	49	45	32	161	23	133	275	211	642	1270	100.00
Species Count	6	7	12	7	15	10	9	8	6	13	7	11	10	5	15	20	

Appendix A-2. (Continued)

November 1-2, 1984 Species	520.0	520.3	520.6	520.8	Bed Total	526.0	526.3	526.5	526.8	Bed Total	528.2	528.5	528.8	528.9	Bed Total	Survey Total	Survey Percent
Elliptio crassidens	128	58	92	102	380	41	60	36	67	204	18	31	200	151	400	984	71.93
Pleurobema cordatum	12	13	25	20	70	3	27	0	1	31	3	12	25	15	55	156	11.40
Cyclonaias tuberculata	2	11	20	10	43	1	3	1	0	5	1	0	11	2	14	62	4.53
Quadrula pustulosa	3	7	7	9	26	0	7	1	1	9	1	0	10	7	18	53	3.87
Potamilus alatus	1	0	2	4	7	4	0	2	8	14	3	4	1	0	8	29	2.12
Ellipsaria lineolata	0	1	6	3	10	2	2	0	4	8	1	1	4	1	7	25	1.83
Quadrula metanevra	0	4	1	3	8	0	0	0	0	0	1	0	4	0	5	13	0.95
Amblema plicata	0	1	0	1	2	1	1	0	2	4	2	0	2	1	5	11	0.80
Ligumia recta	0	0	1	2	3	0	0	0	0	0	0	5	1	1	7	10	0.73
Tritogonia verrucosa	0	0	0	0	0	2	0	1	0	3	1	1	0	0	2	5	0.37
Anodonta grandis	0	0	0	0	0	2	0	0	1	3	0	0	0	1	1	4	0.29
Lampsilis ovata	0	0	0	0	0	0	0	1	0	1	0	3	0	0	3	4	0.29
Obliquaria reflexa	0	0	0	0	0	0	1	1	0	2	0	0	0	1	1	3	0.22
Anodonta imbecillis	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	2	0.15
Lampsilis abrupta	0	0	0	0	0	0	0	1	0	1	0	0	1	0	1	2	0.15
Leptodea fragilis	0	0	0	0	0	0	1	0	1	2	0	0	0	0	0	2	0.15
Cyprogenia stegaria	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0.07
Elliptio dilatata	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.07
Megalonaias nervosa	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0.07
Grand Total	146	96	156	154	552	56	104	44	85	289	31	57	259	180	527	1368	100.00
Species Count	5	8	10	9	12	8	10	8	8	15	9	7	10	9	14	19	

Appendix A-2. (Continued)

July 31-August 1, 1985 Species	520.0	520.3	520.6	520.8	Bed Total	526.0	526.3	526.5	526.8	Bed Total	528.2	528.5	528.8	528.9	Bed Total	Survey Total	Percent
Elliptio crassidens	39	41	35	88	203	38	25	8	24	95	44	91	150	155	440	738	69.43
Pleurobema cordatum	1	13	5	17	36	2	18	2	1	23	5	11	13	25	54	113	10.63
Cyclonaias tuberculata	3	1	17	13	34	0	5	1	1	7	0	5	11	3	19	60	5.64
Quadrula pustulosa	0	0	1	6	7	0	11	5	2	18	2	4	15	7	28	53	4.99
Potamilus alatus	0	0	0	3	3	3	0	5	17	25	0	0	5	1	6	34	3.20
Amblema plicata	0	0	0	0	0	0	2	7	0	9	2	0	5	1	8	17	1.60
Ellipsaria lineolata	0	0	3	1	4	0	2	0	0	2	0	0	2	0	2	8	0.75
Anodonta grandis	0	0	0	0	0	1	0	0	0	1	0	1	1	0	2	3	0.28
Obliquaria reflexa	0	0	0	0	0	0	2	4	0	6	0	0	0	1	1	7	0.66
Tritogonia verrucosa	0	0	0	0	0	2	0	2	0	4	0	0	0	0	0	4	0.38
Quadrula metanevra	1	1	2	2	6	0	0	0	0	0	0	0	0	0	0	6	0.56
Lampsilis abrupta	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0.09
Leptodea fragilis	0	0	0	0	0	0	0	0	2	2	0	0	1	0	1	3	0.28
Ligumia recta	0	0	0	0	0	0	0	0	0	0	1	1	1	0	3	3	0.28
Megalonaias nervosa	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0.09
Actinonaias ligamentina	0	0	0	1	1	0	0	0	0	0	0	0	3	0	3	4	0.38
Lampsilis ovata	1	0	0	0	1	0	0	0	0	0	2	0	2	0	4	5	0.47
Cyprogenia stegaria	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0.09
Pleurobema plenum	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0.09
Lasmigona complanata	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0.09
Grand Total	45	56	64	131	296	46	66	34	47	193	56	113	211	194	574	1063	100.00
Species Count	5	4	7	8	10	5	8	8	6	12	6	6	14	8	16	20	

Appendix A-2. (Continued)

October 16-17,1985					Bed					Bed					Bed	Survey	
Species	520.0	520.3	520.6	520.8	Total	526.0	526.3	526.5	526.8	Total	528.2	528.5	528.8	528.9	Total	Total	Percent
Elliptio crassidens	79	128	73	47	327	23	32	29	32	116	8	70	182	226	486	929	65.10
Pleurobema cordatum	22	17	10	18	67	2	26	3	9	40	0	18	31	21	70	177	12.40
Quadrula pustulosa	2	7	1	9	19	6	5	6	8	25	0	14	16	11	41	85	5.96
Cyclonaias tuberculata	3	7	6	24	40	0	2	1	1	4	2	9	10	1	22	66	4.63
Potamilus alatus	1	1	5	5	12	7	3	14	0	24	0	3	2	2	7	43	3.01
Ellipsaria lineolata	2	0	0	1	3	2	4	2	3	11	0	3	4	6	13	27	1.89
Amblema plicata	1	1	1	0	3	2	1	3	5	11	0	3	5	3	11	25	1.75
Tritogonia verrucosa	0	0	0	1	1	8	1	2	2	13	1	0	0	0	1	15	1.05
Quadrula metanevra	0	0	1	4	5	2	1	0	0	3	0	0	0	2	2	10	0.70
Ligumia recta	0	1	2	1	4	0	0	1	0	1	0	0	2	1	3	8	0.56
Actinonaias ligamentina	2	0	2	0	4	0	0	0	0	0	0	1	2	0	3	7	0.49
Anodonta grandis	0	0	0	0	0	4	0	0	1	5	0	1	0	1	2	7	0.49
Lampsilis abrupta	0	1	1	0	2	0	0	0	0	0	0	1	4	0	5	7	0.49
Obliquaria reflexa	1	0	0	0	1	1	0	1	0	2	1	0	1	0	2	5	0.35
Lampsilis ovata	0	0	0	0	0	0	2	0	0	2	0	0	2	0	2	4	0.28
Megalonaias nervosa	0	1	0	1	2	0	0	0	0	0	0	0	0	2	2	4	0.28
Pleurobema rubrum	0	1	0	0	1	0	0	0	0	0	0	1	1	0	2	3	0.21
Elliptio dilatata	0	0	1	0	1	0	1	0	0	1	0	0	0	0	0	2	0.14
Leptodea fragilis	0	0	0	0	0	0	0	1	1	2	0	0	0	0	0	2	0.14
Pleurobema oviforme	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.07
Grand Total	114	165	103	111	493	57	78	63	62	260	12	124	262	276	674	1427	100.00
Species Count	10	10	11	10	17	10	11	11	9	15	4	11	13	11	17	20	

Appendix A-2. (Continued)

July 9-10, 1986					Bed					Bed					Bed	Survey	
Species	520.0	520.3	520.6	520.8	Total	526.0	526.3	526.5	526.8	Total	528.2	528.5	528.8	528.9	Total	Total	Percent
Elliptio crassidens	100	56	38	30	224	28	23	47	44	142	86	86	34	162	368	734	68.28
Pleurobema cordatum	7	30	7	11	55	2	1	3	2	8	15	16	4	12	47	110	10.23
Cyclonaias tuberculata	1	2	6	14	23	2	2	4	0	8	9	7	2	6	24	55	5.12
Quadrula pustulosa	1	0	0	2	3	1	4	5	2	12	7	6	1	2	16	31	2.88
Potamilus alatus	2	1	0	1	4	3	6	5	9	23	1	1	4	8	14	41	3.81
Amblema plicata	1	0	0	2	3	1	5	7	1	14	4	2	0	0	6	23	2.14
Ellipsaria lineolata	1	0	1	3	5	0	2	4	0	6	1	2	0	5	8	19	1.77
Anodonta grandis	0	0	0	0	0	1	2	1	0	4	0	0	1	4	5	9	0.84
Obliquaria reflexa	0	0	0	0	0	2	2	4	0	8	0	0	0	1	1	9	0.84
Tritogonia verrucosa	0	0	0	0	0	2	4	1	1	8	0	0	0	0	0	8	0.74
Quadrula metanevra	0	0	1	3	4	0	1	0	0	1	1	0	1	0	2	7	0.65
Lampsilis abrupta	1	2	0	0	3	0	0	0	1	1	1	1	0	0	2	6	0.56
Leptodea fragilis	0	0	0	0	0	0	4	1	0	5	0	0	1	0	1	6	0.56
Ligumia recta	1	0	2	0	3	0	0	0	1	1	0	2	1	1	4	8	0.74
Megalonaias nervosa	1	1	1	0	3	0	1	1	0	2	0	0	0	0	0	5	0.47
Lampsilis ovata	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0.09
Elliptio dilatata	0	0	0	0	0	0	0	1	0	1	1	0	0	0	1	2	0.19
Lasmigona costata	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0.09
Grand Total	116	92	56	67	331	42	57	84	61	244	126	123	50	201	500	1075	100.00
Species Count	10	6	7	9	12	9	13	13	8	16	10	9	10	9	15	18	

Appendix A-2. (Continued)

October 16-17, 1986					Bed					Bed					Bed	Survey	
Species	520.0	520.3	520.6	520.8	Total	526.0	526.3	526.5	526.8	Total	528.2	528.5	528.8	528.9	Total	Total	Percent
Elliptio crassidens	97	29	73	61	260	14	30	20	28	92	13	100	132	168	413	765	64.83
Pleurobema cordatum	6	18	21	9	54	3	28	1	1	33	1	22	34	25	82	169	14.32
Cyclonaias tuberculata	0	5	28	16	49	0	2	7	0	9	3	1	13	1	18	76	6.44
Quadrula pustulosa	3	0	0	11	14	0	1	6	1	8	4	4	10	1	19	41	3.47
Potamilus alatus	0	1	3	3	7	3	4	4	4	15	5	0	0	0	5	27	2.29
Amblema plicata	0	0	1	1	2	1	6	6	0	13	3	0	4	2	9	24	2.03
Ellipsaria lineolata	2	1	3	4	10	0	0	0	1	1	0	2	3	2	7	18	1.53
Tritogonia verrucosa	0	0	0	0	0	5	2	1	4	12	0	1	0	0	1	13	1.10
Ligumia recta	0	1	2	1	4	0	0	0	1	1	0	3	2	0	5	10	0.85
Actinonaias ligamentina	0	1	1	2	4	0	0	0	0	0	0	2	2	0	4	8	0.68
Anodonta grandis	0	2	0	0	2	2	1	0	1	4	0	0	1	0	1	7	0.59
Quadrula metanevra	1	0	1	3	5	0	0	0	0	0	0	1	1	0	2	7	0.59
Leptodea fragilis	0	0	0	0	0	0	1	0	0	1	0	0	2	0	2	3	0.25
Obliquaria reflexa	0	0	0	0	0	0	1	1	0	2	0	1	0	0	1	3	0.25
Lampsilis abrupta	0	0	0	1	1	0	0	0	0	0	0	0	0	1	1	2	0.17
Lampsilis ovata	0	1	0	0	1	0	1	0	0	1	0	0	0	0	0	2	0.17
Pleurobema oviforme	0	0	0	0	0	0	0	0	0	0	0	2	0	0	2	2	0.17
Anodonta imbecillis	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0.08
Elliptio dilatata	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0.08
Megalonaias nervosa	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0.08
Grand Total	109	59	134	113	415	28	77	46	41	192	29	139	204	201	573	1180	100.00
Species Count	5	9	10	12	15	6	11	8	8	13	6	11	11	8	17	20	

Appendix A-2. (Continued)

July 12 & 14, 1988 Species	520.0	520.3	520.6	520.8	Bed Total	526.0	526.3	526.5	526.8	Bed Total	528.2	528.5	528.8	528.9	Bed Total	Total	Survey Percent
Elliptio crassidens	71	43	43	79	236	14	28	25	20	87	76	80	248	243	647	970	60.25
Pleurobema cordatum	8	22	18	20	68	10	28	6	0	44	16	22	38	36	112	224	13.91
Cyclonaias tuberculata	1	14	19	22	56	1	1	3	3	8	4	4	17	4	29	93	5.78
Quadrula pustulosa	0	2	1	2	5	1	3	9	8	21	11	9	25	9	54	80	4.97
Potamilus alatus	0	2	5	3	10	5	4	9	12	30	9	3	0	3	15	55	3.42
Amblema plicata	1	4	4	3	12	4	0	10	9	23	10	1	3	0	14	49	3.04
Ellipsaria lineolata	2	1	2	4	9	0	4	0	0	4	3	3	3	1	10	23	1.43
Anodonta grandis	0	1	2	0	3	9	1	4	5	19	2	0	1	4	7	29	1.80
Obliquaria reflexa	0	0	0	0	0	1	0	3	3	7	0	0	0	0	0	7	0.43
Tritogonia verrucosa	0	0	1	2	3	4	5	0	4	13	0	1	0	1	2	18	1.12
Quadrula metanevra	0	2	3	1	6	0	0	0	0	0	0	0	2	0	2	8	0.50
Lampsilis abrupta	0	0	0	0	0	1	0	1	0	2	4	1	3	2	10	12	0.75
Leptodea fragilis	0	0	0	0	0	1	1	1	6	9	2	1	0	0	3	12	0.75
Ligumia recta	1	0	1	0	2	0	0	0	0	0	0	1	3	1	5	7	0.43
Megalonaias nervosa	0	1	1	2	4	0	0	0	0	0	4	0	1	0	5	9	0.56
Actinonaias ligamentina	0	0	0	2	2	0	0	0	1	1	0	0	0	0	0	3	0.19
Lampsilis ovata	0	1	0	0	1	0	0	1	0	1	0	1	0	0	1	3	0.19
Elliptio dilatata	0	0	1	0	1	0	0	0	0	0	0	0	2	0	2	3	0.19
Pleurobema oviforme	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	2	0.12
Anodonta imbecillis	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0.06
Anodonta suborbiculata	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0.06
Pleurobema pyramidatum	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0.06
Grand Total	84	93	101	140	418	51	76	72	72	271	142	127	346	306	921	1610	100.00
Species Count	6	11	13	11	15	11	10	11	11	16	12	12	12	11	18	22	

Appendix A-2. (Continued)

July 24-25, 1990					Bed					Bed					Bed	Survey	
Species	520.0	520.3	520.6	520.8	Total	526.0	526.3	526.5	526.8	Total	528.2	528.5	528.8	528.9	Total	Total	Percent
Elliptio crassidens	79	21	37	58	195	23	17	18	27	85	25	67	84	68	244	524	52.88
Pleurobema cordatum	11	2	12	9	34	3	13	8	0	24	9	33	19	20	81	139	14.03
Cyclonaias tuberculata	11	26	20	14	71	1	2	2	0	5	6	4	4	0	14	90	9.08
Quadrula pustulosa	2	4	8	3	17	0	9	10	7	26	9	9	13	5	36	79	7.97
Potamilus alatus	2	2	5	4	13	8	2	8	10	28	1	0	2	1	4	45	4.54
Amblema plicata	0	1	0	4	5	0	1	2	1	4	0	1	0	0	1	10	1.01
Ellipsaria lineolata	4	1	8	3	16	3	0	0	0	3	3	3	2	1	9	28	2.83
Anodonta grandis	0	0	0	1	1	5	4	3	5	17	0	1	1	0	2	20	2.02
Obliquaria reflexa	0	1	0	1	2	0	1	2	3	6	0	0	2	1	3	11	1.11
Tritogonia verrucosa	0	1	0	0	1	2	3	0	2	7	1	0	0	0	1	9	0.91
Quadrula metanevra	1	1	0	0	2	1	1	0	0	2	0	1	3	0	4	8	0.81
Lampsilis abrupta	0	0	0	0	0	0	0	0	1	1	0	1	2	0	3	4	0.40
Leptodea fragilis	0	0	2	0	2	3	1	1	0	5	0	0	1	0	1	8	0.81
Ligumia recta	0	0	0	0	0	0	0	1	0	1	0	0	0	1	1	2	0.20
Megalonaias nervosa	1	0	1	0	2	0	0	0	0	0	0	0	0	1	1	3	0.30
Actinonaias ligamentina	0	2	0	0	2	1	0	0	0	1	1	0	1	0	2	5	0.50
Lampsilis ovata	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0.10
Elliptio dilatata	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0.10
Pleurobema oviforme	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0.10
Anodonta imbecillis	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0.10
Anodonta suborbiculata	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0.10
Ptychobranchus fasciolaris	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0.10
Grand Total	111	62	93	98	364	50	54	56	56	216	55	122	135	99	411	991	100.00
Species Count	8	11	8	10	15	10	11	11	8	16	8	11	13	9	20	22	

Appendix A-2. (Continued)

Summer 1992					Bed					Bed					Bed	Survey	
Species	520.0	520.3	520.6	520.8	Total	526.0	526.3	526.5	526.8	Total	528.2	528.5	528.8	528.9	Total	Total	Percent
Elliptio crassidens	82	15	6	7	110	19	8	13	2	42	6	49	118	99	272	424	59.89
Pleurobema cordatum	11	9	2	4	26	3	7	4	13	27	6	6	8	9	29	82	11.58
Cyclonaias tuberculata	9	18	12	5	44	2	4	6	0	12	1	2	6	3	12	68	9.60
Quadrula pustulosa	3	8	2	1	14	0	8	4	4	16	1	1	14	2	18	48	6.78
Potamilus alatus	2	2	0	2	6	1	0	1	3	5	0	3	1	1	5	16	2.26
Amblema plicata	1	0	0	1	2	1	1	2	2	6	1	1	3	0	5	13	1.84
Ellipsaria lineolata	7	1	0	0	8	3	0	0	0	3	0	0	2	1	3	14	1.98
Anodonta grandis	0	0	0	1	1	1	1	0	2	4	0	0	0	0	0	5	0.71
Obliquaria reflexa	0	1	0	0	1	0	1	1	2	4	0	0	0	1	1	6	0.85
Tritogonia verrucosa	1	0	0	1	2	0	2	4	1	7	0	0	0	0	0	9	1.27
Quadrula metanevra	0	0	2	0	2	0	2	1	0	3	0	0	2	1	3	8	1.13
Lampsilis abrupta	0	0	0	0	0	0	0	1	1	2	0	2	2	0	4	6	0.85
Ligumia recta	2	0	0	0	2	0	0	0	0	0	0	0	1	0	1	3	0.42
Megalonaias nervosa	0	0	0	1	1	0	0	2	1	3	0	0	0	0	0	4	0.56
Actinonaias ligamentina	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	1	0.14
Plethobasus cyphyus	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0.14
Grand Total	118	54	25	23	220	31	34	39	31	135	15	64	157	117	353	708	100.00
Species Count	9	7	6	9	14	8	9	11	10	14	5	7	10	8	11	16	

Appendix A-2. (Continued)

Summer 1994 Species	520.0	520.3	520.6	520.8	Bed Total	526.0	526.3	526.5	526.8	Bed Total	528.2	528.5	528.8	528.9	Bed Total	Survey Total	Survey Percent
Elliptio crassidens	85	31	52	29	197	24	50	11	25	110	23	56	75	122	276	583	66.25
Pleurobema cordatum	14	3	7	11	35	1	13	2	3	19	8	6	12	15	41	95	10.80
Quadrula pustulosa	0	1	1	4	6	1	6	11	12	30	1	14	3	11	29	65	7.39
Cyclonaias tuberculata	6	16	13	11	46	1	2	3	2	8	0	6	1	3	10	64	7.27
Amblema plicata	0	1	0	1	2	3	2	4	2	11	0	0	0	0	0	13	1.48
Ellipsaria lineolata	1	0	4	2	7	0	0	0	1	1	0	2	0	1	3	11	1.25
Obliquaria reflexa	0	0	0	0	0	0	1	7	3	11	0	0	0	0	0	11	1.25
Potamilus alatus	0	1	0	1	2	2	1	1	1	5	1	1	0	1	3	10	1.14
Anodonta grandis	0	0	0	0	0	2	0	1	4	7	0	0	0	0	0	7	0.80
Tritogonia verrucosa	0	0	0	0	0	0	0	1	4	5	0	0	1	1	2	7	0.80
Quadrula metanevra	0	1	1	1	3	0	0	0	0	0	0	0	0	1	1	4	0.45
Leptodea fragilis	0	0	0	0	0	0	1	1	0	2	0	1	0	0	1	3	0.34
Lampsilis abrupta	0	0	0	0	0	0	0	0	1	1	0	0	0	1	1	2	0.23
Megalonaias nervosa	0	0	0	1	1	0	0	0	0	0	0	1	0	0	1	2	0.23
Ligumia recta	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0.11
Plethobasus cyphyus	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0.11
Pleurobema oviforme	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0.11
Grand Total	106	54	78	61	299	34	77	43	58	212	33	87	92	157	369	880	100.00
Species Count	4	7	6	9	9	7	9	11	11	14	4	8	5	10	12	17	

Appendix A-2. (Continued)

July 22-23, 1996 Species	520.0	520.3	520.6	520.8	Bed Total	526.0	526.3	526.5	526.8	Bed Total	528.2	528.5	528.8	528.9	Bed Total	Survey Total	Survey Percent
Elliptio crassidens	88	22	76	26	212	10	54	27	23	114	24	71	73	100	268	594	70.21
Pleurobema cordatum	6	4	8	9	27	0	12	7	1	20	9	10	7	21	47	94	11.11
Cyclonaias tuberculata	5	6	5	2	18	0	3	4	0	7	3	6	1	3	13	38	4.49
Potamilus alatus	0	0	2	1	3	8	6	9	5	28	0	0	1	3	4	35	4.14
Quadrula pustulosa	0	0	0	1	1	1	1	3	4	9	8	10	0	2	20	30	3.55
Ellipsaria lineolata	0	0	1	1	2	1	3	0	0	4	0	4	4	1	9	15	1.77
Amblema plicata	0	0	0	2	2	1	4	1	0	6	1	2	0	0	3	11	1.30
Anodonta grandis	0	0	0	0	0	3	0	2	1	6	0	0	0	1	1	7	0.83
Obliquaria reflexa	0	0	0	0	0	0	0	6	0	6	0	0	0	0	0	6	0.71
Lampsilis abrupta	1	0	0	0	1	0	1	1	0	2	0	0	1	0	1	4	0.47
Tritogonia verrucosa	0	0	0	0	0	1	1	0	1	3	0	0	1	0	1	4	0.47
Ligumia recta	0	0	0	1	1	0	0	0	0	0	1	0	0	0	1	2	0.24
Quadrula metanevra	0	0	0	0	0	0	0	1	0	1	0	1	0	0	1	2	0.24
Elliptio dilatata	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.12
Lasmigona costata	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0.12
Leptodea fragilis	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0.12
Megalonaias nervosa	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	1	0.12
Grand Total	100	33	92	43	268	25	86	61	35	207	47	104	89	131	371	846	100.00
Species Count	4	4	5	8	10	7	10	10	6	13	7	7	8	7	14	17	

Appendix A-2. (Continued)

July 7-8, 1997					Bed					Bed					Bed	Survey	
Species	520.0	520.3	520.6	520.8	Total	526.0	526.3	526.5	526.8	Total	528.2	528.5	528.8	528.9	Total	Total	Percent
Elliptio crassidens	24	13	51	35	123	45	33	17	14	109	20	66	126	45	257	489	70.16
Pleurobema cordatum	4	4	9	11	28	2	16	0	0	18	3	33	7	12	55	101	14.49
Cyclonaias tuberculata	1	16	9	5	31	1	2	0	0	3	2	7	4	0	13	47	6.74
Quadrula pustulosa	0	5	2	2	9	1	0	2	3	6	1	7	1	0	9	24	3.44
Potamilus alatus	0	0	1	1	2	0	1	4	1	6	4	0	0	0	4	12	1.72
Ellipsaria lineolata	1	0	2	2	5	0	0	0	1	1	1	0	1	0	2	8	1.15
Amblema plicata	0	0	0	0	0	0	0	3	1	4	0	0	1	0	1	5	0.72
Obliquaria reflexa	0	0	0	1	1	0	0	0	2	2	0	0	0	0	0	3	0.43
Leptodea fragilis	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	2	0.29
Quadrula metanevra	0	0	0	0	0	0	1	0	0	1	1	0	0	0	1	2	0.29
Anodonta grandis	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0.14
Lampsilis ovata	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0.14
Ligumia recta	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0.14
Tritogonia verrucosa	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	1	0.14
Grand Total	30	38	74	57	199	49	53	26	26	154	32	114	141	57	344	697	100.00
Species Count	4	4	6	7	7	4	5	4	9	12	7	5	7	2	10	14	

Appendix A-2. (Continued)

TRM 520-521		Length			Height			Thickness		
and Year 1983	N	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	2	104.30	102.6	106.0	76.50	72.9	80.1	49.50	46.8	52.2
Amblema plicata	7	85.33	74.4	96.1	64.81	56.8	72.3	40.49	36.1	48.7
Cyclonaias tuberculata	72	75.80	62.1	92.6	65.60	52.1	80.2	38.20	32.4	44.1
Cyprogenia stegaria	1	51.60	51.6	51.6	49.70	49.7	49.7	36.00	36.0	36.0
Dromus dromas	1	60.10	60.1	60.1	58.30	58.3	58.3	32.80	32.8	32.8
Ellipsaria lineolata	20	78.94	56.8	94.5	61.21	44.6	72.0	37.78	30.1	48.8
Elliptio crassidens	102	101.28	87.5	125.5	63.90	54.0	80.5	40.59	21.0	50.3
Elliptio dilatata	3	106.37	102.3	113.3	45.70	42.2	48.8	33.40	30.9	34.7
Lampsilis abrupta	2	91.40	83.7	99.1	67.05	61.4	72.7	44.75	43.4	46.1
Lampsilis ovata	3	122.47	122.0	123.2	84.40	74.7	92.3	65.87	62.0	69.4
Leptodea fragilis	2	71.20	59.6	82.8	41.35	34.6	48.1	23.10	20.1	26.1
Ligumia recta	3	150.60	145.1	154.9	59.70	56.6	63.4	45.93	42.5	48.6
Obliquaria reflexa	1	48.30	48.3	48.3	24.10	24.1	24.1	24.60	24.6	24.6
Pleurobema cordatum	102	90.57	72.1	108.8	72.31	60.6	84.8	45.72	31.4	59.8
Pleurobema plenum	1	58.10	58.1	58.1	52.90	52.9	52.9	36.40	36.4	36.4
Potamilus alatus	11	122.31	46.9	156.9	88.34	71.1	104.9	35.58	30.6	40.9
Quadrula metanevra	16	73.55	63.5	85.3	58.82	52.3	68.0	43.65	38.3	49.2
Quadrula pustulosa	38	52.02	43.7	61.7	49.89	40.5	59.6	31.92	26.3	36.9

Appendix A-2. (Continued)

TRM 520-521 and Year 1984	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Amblema plicata	6	96.08	80.5	107.3	72.63	62.6	80.4	42.58	34.6	46.6
Anodonta imbecillis	1	52.50	52.5	52.5	24.70	24.7	24.7	14.30	14.3	14.3
Cyclonaias tuberculata	101	74.39	59.1	92.2	63.86	52.2	76.5	37.48	29.5	44.9
Cyprogenia stegaria	1	52.90	52.9	52.9	51.40	51.4	51.4	36.40	36.4	36.4
Ellipsaria lineolata	23	77.57	56.6	102.2	58.68	44.0	74.2	35.53	26.3	42.0
Elliptio crassidens	101	104.82	89.2	122.7	66.24	56.3	78.4	41.70	24.4	60.9
Elliptio dilatata	1	100.10	100.1	100.1	42.20	42.2	42.2	28.00	28.0	28.0
Lampsilis abrupta	1	90.60	90.6	90.6	60.70	60.7	60.7	48.10	48.1	48.1
Lampsilis ovata	1	102.10	102.1	102.1	72.90	72.9	72.9	56.50	56.5	56.5
Ligumia recta	5	149.30	140.9	155.9	57.52	50.5	60.3	46.68	40.0	49.7
Obliquaria reflexa	1	36.50	36.5	36.5	32.90	32.9	32.9	22.90	22.9	22.9
Pleurobema cordatum	100	90.46	62.1	112.9	71.74	44.7	86.7	44.20	32.8	52.8
Pleurobema plenum	2	60.10	51.3	68.9	57.70	49.4	66.0	44.00	39.4	48.6
Potamilus alatus	14	126.87	96.7	160.0	90.56	74.4	108.0	36.16	30.0	42.5
Ptychobranchus fasciolaris	1	94.40	94.4	94.4	56.70	56.7	56.7	34.80	34.8	34.8
Quadrula metanevra	14	74.78	64.5	82.8	59.29	52.6	66.6	40.09	32.4	50.6
Quadrula pustulosa	53	53.28	40.0	74.1	50.63	39.5	64.1	31.69	22.0	40.1
Tritogonia verrucosa	1	76.70	76.7	76.7	42.70	42.7	42.7	19.70	19.7	19.7

Appendix A-2. (Continued)

TRM 520-521 and Year 1985	N	Length Mean	 Min	 Max	Height Mean	 Min	 Max	Thickness Mean	 Min	 Max
Actinonaias ligamentina	5	105.42	97.4	112.3	75.42	70.6	78.9	52.78	50.2	54.9
Amblema plicata	3	94.77	92.1	97.9	69.83	69.1	70.3	39.80	36.6	42.8
Cyclonaias tuberculata	72	75.62	60.5	86.6	65.14	54.7	74.5	36.95	30.6	43.1
Cyprogenia stegaria	1	57.70	57.7	57.7	55.60	55.6	55.6	44.10	44.1	44.1
Ellipsaria lineolata	7	79.13	62.3	92.5	61.27	46.9	69.9	34.84	32.0	36.2
Elliptio crassidens	101	104.43	90.1	122.5	65.82	54.1	88.5	41.43	29.5	50.9
Elliptio dilatata	1	96.80	96.8	96.8	44.20	44.2	44.2	29.80	29.8	29.8
Lampsilis abrupta	2	96.45	82.3	110.6	71.65	69.8	73.5	51.95	43.5	60.4
Lampsilis ovata	1	121.20	121.2	121.2	86.50	86.5	86.5	62.30	62.3	62.3
Ligumia recta	4	158.93	142.2	170.2	59.88	57.2	60.8	45.15	41.3	48.5
Megalonaias nervosa	2	165.15	160.1	170.2	109.35	102.3	116.4	54.45	52.4	56.5
Obliquaria reflexa	1	46.60	46.6	46.6	36.10	36.1	36.1	23.40	23.4	23.4
Pleurobema cordatum	88	91.57	70.4	108.5	73.40	58.2	89.5	43.91	30.2	52.7
Pleurobema oviforme	1	72.90	72.9	72.9	56.50	56.5	56.5	40.20	40.2	40.2
Pleurobema rubrum	1	80.70	80.7	80.7	64.30	64.3	64.3	44.50	44.5	44.5
Potamilus alatus	15	128.51	98.0	150.7	87.92	76.5	106.7	36.53	30.9	40.7
Quadrula metanevra	11	75.45	67.3	88.2	60.21	56.1	70.3	40.83	36.8	46.2
Quadrula pustulosa	26	54.20	46.3	72.8	51.48	44.7	64.3	31.89	25.7	37.4
Tritogonia verrucosa	1	104.10	104.1	104.1	52.80	52.8	52.8	36.10	36.1	36.1

Appendix A-2. (Continued)

TRM 520-521		Length			Height			Thickness		
and Year 1986	N	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	4	94.93	91.3	97.5	68.15	65.3	71.6	46.03	40.3	53.8
Amblema plicata	5	102.18	90.3	112.9	72.96	66.4	78.2	44.38	39.3	52.1
Anodonta grandis	2	123.05	119.4	126.7	70.00	63.3	76.7	47.05	43.4	50.7
Anodonta imbecillis	1	39.20	39.2	39.2	17.40	17.4	17.4	7.10	7.1	7.1
Cyclonaias tuberculata	72	72.03	56.9	85.1	61.53	47.6	76.6	34.82	23.7	44.9
Ellipsaria lineolata	15	73.42	51.8	86.9	54.71	39.2	65.3	30.81	22.6	42.0
Elliptio crassidens	100	105.59	87.2	151.8	64.88	55.9	82.5	40.83	31.1	51.4
Elliptio dilatata	1	109.40	109.4	109.4	45.50	45.5	45.5	39.90	39.9	39.9
Lampsilis abrupta	4	98.43	86.1	104.7	72.45	66.3	80.7	50.15	48.3	52.2
Lampsilis ovata	1	139.10	139.1	139.1	90.30	90.3	90.3	55.90	55.9	55.9
Lasmigona costata	1	122.10	122.1	122.1	69.90	69.9	69.9	25.50	25.5	25.5
Ligumia recta	7	133.40	107.7	150.2	51.84	45.0	55.9	40.80	33.1	48.6
Megalonaias nervosa	3	148.97	146.9	150.3	102.27	97.6	109.3	57.37	53.9	63.2
Pleurobema cordatum	94	88.69	54.9	109.6	70.34	49.7	88.5	42.39	25.2	54.6
Potamilus alatus	11	127.29	93.4	144.9	84.49	67.9	95.8	32.73	26.8	40.0
Quadrula metanevra	9	69.98	54.9	80.9	54.79	42.4	64.3	37.06	31.0	42.4
Quadrula pustulosa	17	48.40	38.2	55.9	45.26	37.2	52.8	27.30	20.5	35.7

Appendix A-2. (Continued)

TRM 520-521 and Year 1988	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	2	93.00	90.9	95.1	71.65	71.3	72.0	49.35	47.6	51.1
Amblema plicata	12	97.95	73.2	115.3	72.45	53.0	86.1	43.01	33.3	52.1
Anodonta grandis	3	101.60	81.7	119.9	59.83	53.6	65.3	44.00	34.5	50.4
Cyclonaias tuberculata	50	75.88	64.3	88.6	64.96	55.2	75.2	38.08	32.2	44.9
Ellipsaria lineolata	9	79.49	65.1	100.0	59.98	47.5	70.6	37.53	32.7	50.3
Elliptio crassidens	52	104.08	92.4	124.5	66.17	60.1	84.9	42.50	34.1	50.7
Elliptio dilatata	1	96.80	96.8	96.8	45.40	45.4	45.4	26.90	26.9	26.9
Lampsilis ovata	1	110.70	110.7	110.7	76.90	76.9	76.9	61.80	61.8	61.8
Ligumia recta	2	156.05	144.4	167.7	57.45	54.2	60.7	48.65	44.4	52.9
Megalonaias nervosa	4	155.25	144.2	170.2	109.25	100.8	117.2	59.88	53.3	65.6
Pleurobema cordatum	52	91.03	68.5	110.1	73.16	54.9	83.6	46.47	38.2	54.8
Potamilus alatus	10	132.07	114.9	151.0	96.46	76.3	113.4	39.75	34.4	48.3
Quadrula metanevra	6	80.70	66.7	92.1	63.15	54.2	70.1	43.43	38.4	47.3
Quadrula pustulosa	5	57.08	52.2	68.8	52.20	46.9	61.3	34.66	31.3	37.3
Tritogonia verrucosa	3	101.07	91.8	109.4	55.10	50.5	57.4	27.93	23.2	34.0

TRM 520-521 and Year 1990	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	2	97.35	96.0	98.7	72.15	71.4	72.9	49.60	47.6	51.6
Amblema plicata	5	100.30	76.6	120.1	71.08	54.5	87.2	41.74	33.6	47.2
Anodonta grandis	1	136.30	136.3	136.3	76.70	76.7	76.7	51.00	51.0	51.0
Anodonta imbecillis	1	52.00	52.0	52.0	24.80	24.8	24.8	14.30	14.3	14.3
Cyclonaias tuberculata	50	77.43	62.0	111.0	65.32	52.1	92.1	37.12	28.0	46.5
Ellipsaria lineolata	16	85.20	64.2	94.8	63.94	51.6	71.3	37.67	32.1	44.6
Elliptio crassidens	50	109.49	87.5	130.1	68.71	62.4	79.9	42.94	36.3	50.2
Leptodea fragilis	2	100.15	89.9	110.4	67.65	62.7	72.6	37.85	36.5	39.2
Megalonaias nervosa	2	164.85	155.6	174.1	115.65	110.7	120.6	56.20	56.2	56.2
Obliquaria reflexa	2	45.40	44.5	46.3	36.80	36.7	36.9	26.60	25.4	27.8
Pleurobema cordatum	34	91.89	75.6	110.1	71.37	59.5	82.4	42.27	32.9	52.0
Potamilus alatus	13	141.24	131.6	152.9	105.18	83.3	120.9	55.30	37.2	139.8
Quadrula metanevra	2	73.35	65.2	81.5	53.60	48.1	59.1	39.40	35.5	43.3
Quadrula pustulosa	17	52.47	45.7	64.1	49.12	42.8	55.7	31.34	25.3	37.5
Tritogonia verrucosa	1	94.00	94.0	94.0	52.20	52.2	52.2	32.50	32.5	32.5

Appendix A-2. (Continued)

TRM 520-521 and Year 1992	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	1	94.80	94.8	94.8	65.40	65.4	65.4	49.60	49.6	49.6
Amblema plicata	2	119.45	114.2	124.7	85.55	84.7	86.4	51.95	49.1	54.8
Anodonta grandis	1	131.50	131.5	131.5	84.90	84.9	84.9	57.20	57.2	57.2
Cyclonaias tuberculata	44	78.27	63.2	89.0	65.77	53.4	87.1	37.92	30.8	44.7
Ellipsaria lineolata	8	86.17	69.6	95.5	65.55	49.7	75.1	38.46	31.3	44.8
Elliptio crassidens	43	104.55	88.4	116.5	65.75	55.6	74.3	42.35	27.2	51.7
Ligumia recta	2	153.05	148.0	158.1	59.65	56.9	62.4	48.50	47.3	49.7
Megalonaias nervosa	1	182.10	182.1	182.1	116.20	116.2	116.2	58.40	58.4	58.4
Obliquaria reflexa	1	52.70	52.7	52.7	41.60	41.6	41.6	29.80	29.8	29.8
Pleurobema cordatum	26	89.13	64.7	104.0	70.92	60.9	82.9	43.46	37.5	51.2
Potamilus alatus	6	141.35	124.8	155.3	105.82	98.1	114.8	42.15	35.2	45.4
Quadrula metanevra	2	82.65	82.5	82.8	62.55	61.7	63.4	42.80	42.0	43.6
Quadrula pustulosa	14	52.09	45.3	57.4	48.60	40.2	54.9	31.74	25.2	37.9
Tritogonia verrucosa	2	108.60	100.9	116.3	60.15	59.4	60.9	33.45	31.3	35.6

TRM 520-521 and Year 1994	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Amblema plicata	2	97.85	84.7	111.0	65.95	59.2	72.7	43.10	35.0	51.2
Cyclonaias tuberculata	46	77.77	66.2	91.1	65.59	58.4	74.3	38.82	32.9	48.9
Ellipsaria lineolata	7	82.13	76.1	89.6	63.57	57.7	69.0	37.46	32.9	42.1
Elliptio crassidens	65	108.95	96.8	128.7	68.19	61.3	88.6	43.51	36.6	50.4
Megalonaias nervosa	1	180.20	180.2	180.2	119.70	119.7	119.7	69.00	69.0	69.0
Pleurobema cordatum	35	90.84	59.8	107.7	72.35	58.1	86.8	45.37	35.5	53.0
Potamilus alatus	2	129.80	128.3	131.3	103.60	99.6	107.6	38.90	38.5	39.3
Quadrula metanevra	3	71.60	68.4	75.5	56.63	54.4	59.5	40.67	39.9	42.2
Quadrula pustulosa	6	55.28	52.1	57.3	51.02	46.6	54.5	32.85	28.9	35.1

Appendix A-2. (Continued)

TRM 520-521		Length			Height			Thickness		
and Year 1996	N	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Amblema plicata	2	101.80	78.2	125.4	68.60	52.4	84.9	36.70	26.7	46.7
Cyclonaias tuberculata	18	79.90	73.0	91.3	67.10	58.4	75.6	39.30	34.6	45.3
Ellipsaria lineolata	2	79.50	69.7	89.3	59.90	48.0	71.9	37.60	30.8	44.3
Elliptio crassidens	61	108.80	97.8	127.2	66.30	56.9	75.2	43.50	34.2	50.2
Elliptio dilatata	1	95.40	95.4	95.4	41.00	41.0	41.0	29.70	29.7	29.7
Lampsilis abrupta	1	99.40	99.4	99.4	73.10	73.1	73.1	55.30	55.3	55.3
Ligumia recta	1	160.00	160.0	160.0	61.10	61.1	61.1	49.40	49.4	49.4
Pleurobema cordatum	27	94.50	82.8	107.7	72.50	67.2	79.2	46.20	39.0	53.0
Potamilus alatus	3	117.10	98.2	133.0	70.40	60.1	79.9	36.80	28.9	45.5
Quadrula pustulosa	1	56.60	56.6	56.6	54.90	54.9	54.9	34.50	34.5	34.5

TRM 520-521		Length			Height			Thickness		
and Year 1997	N	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Cyclonaias tuberculata	31	78.50	67.0	91.4	65.40	56.5	73.7	41.60	35.6	49.8
Ellipsaria lineolata	5	83.10	56.4	105.5	61.00	45.9	71.6	41.60	33.8	52.6
Elliptio crassidens	52	107.70	92.2	120.8	64.90	53.7	73.1	44.40	34.7	51.1
Obliquaria reflexa	1	50.60	50.6	50.6	34.70	34.7	34.7	33.90	33.9	33.9
Pleurobema cordatum	28	93.40	83.1	117.2	71.70	60.2	92.3	47.50	41.7	52.8
Potamilus alatus	2	113.60	105.7	121.4	70.00	63.3	76.6	36.00	33.3	38.8
Quadrula pustulosa	9	56.60	49.7	65.2	51.50	45.2	57.9	36.00	30.9	45.6

Appendix A-2. (Continued)

TRM 520-521 and Years 1983-1997	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	16	99.43	90.9	112.3	72.23	65.3	80.1	49.66	40.3	54.9
Amblema plicata	44	97.36	73.2	125.4	71.11	52.4	87.2	42.46	26.7	54.8
Anodonta grandis	7	116.96	81.7	136.3	68.73	53.6	84.9	47.76	34.5	57.2
Anodonta imbecillis	3	47.90	39.2	52.5	22.30	17.4	24.8	11.90	7.1	14.3
Cyclonaias tuberculata	556	75.83	56.9	111.0	64.66	47.6	92.1	37.61	23.7	49.8
Cyprogenia stegaria	3	54.07	51.6	57.7	52.23	49.7	55.6	38.83	36.0	44.1
Dromus dromas	1	60.10	60.1	60.1	58.30	58.3	58.3	32.80	32.8	32.8
Ellipsaria lineolata	112	79.78	51.8	105.5	60.54	39.2	75.1	36.80	22.6	52.6
Elliptio crassidens	727	105.54	87.2	151.8	65.89	53.7	88.6	42.08	21.0	60.9
Elliptio dilatata	8	102.20	95.4	113.3	44.42	41.0	48.8	31.81	26.9	39.9
Lampsilis abrupta	10	95.94	82.3	110.6	70.10	60.7	80.7	49.74	43.4	60.4
Lampsilis ovata	7	120.07	102.1	139.1	82.83	72.9	92.3	62.01	55.9	69.4
Lasmigona costata	1	122.10	122.1	122.1	69.90	69.9	69.9	25.50	25.5	25.5
Leptodea fragilis	4	85.67	59.6	110.4	54.50	34.6	72.6	30.48	20.1	39.2
Ligumia recta	24	147.75	107.7	170.2	56.85	45.0	63.4	45.05	33.1	52.9
Megalonaias nervosa	13	160.78	144.2	182.1	109.98	97.6	120.6	58.48	52.4	69.0
Obliquaria reflexa	7	46.50	36.5	52.7	34.72	24.1	41.6	26.83	22.9	33.9
Pleurobema cordatum	586	90.78	54.9	117.2	72.00	44.7	92.3	44.50	25.2	59.8
Pleurobema oviforme	1	72.90	72.9	72.9	56.50	56.5	56.5	40.20	40.2	40.2
Pleurobema plenum	3	59.43	51.3	68.9	56.10	49.4	66.0	41.47	36.4	48.6
Pleurobema rubrum	1	80.70	80.7	80.7	64.30	64.3	64.3	44.50	44.5	44.5
Potamilus alatus	87	129.80	46.9	160.0	92.11	60.1	120.9	39.49	26.8	139.8
Ptychobranchus fasciolaris	1	94.40	94.4	94.4	56.70	56.7	56.7	34.80	34.8	34.8
Quadrula metanevra	63	74.52	54.9	92.1	58.85	42.4	70.3	41.10	31.0	50.6
Quadrula pustulosa	186	52.89	38.2	74.1	49.94	37.2	64.3	31.68	20.5	45.6
Tritogonia verrucosa	8	99.40	76.7	116.3	54.16	42.7	60.9	29.87	19.7	36.1

Appendix A-2. (Continued)

TRM 526-527		Length			Height			Thickness		
and Year 1983	N	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	1	105.50	105.5	105.5	70.30	70.3	70.3	53.60	53.6	53.6
Amblema plicata	41	98.06	76.5	121.1	73.71	56.6	99.7	46.80	34.8	56.9
Anodonta grandis	22	124.84	101.6	154.6	68.28	55.3	89.6	53.76	39.6	67.9
Cyclonaias tuberculata	32	82.55	66.4	94.7	70.40	60.8	78.1	40.98	34.2	49.8
Ellipsaria lineolata	13	90.57	71.1	96.5	71.33	61.5	78.6	42.22	36.6	50.9
Elliptio crassidens	104	112.07	93.1	134.2	69.83	59.4	79.1	44.82	36.3	52.5
Elliptio dilatata	1	102.20	102.2	102.2	46.30	46.3	46.3	31.20	31.2	31.2
Lampsilis abrupta	1	103.10	103.1	103.1	84.40	84.4	84.4	58.20	58.2	58.2
Leptodea fragilis	1	112.40	112.4	112.4	66.40	66.4	66.4	32.70	32.7	32.7
Ligumia recta	2	162.50	160.0	165.0	66.05	63.8	68.3	55.35	54.0	56.7
Megalonaias nervosa	3	173.83	164.4	180.6	117.43	111.7	120.7	60.50	57.2	63.0
Obliquaria reflexa	18	54.35	45.1	64.1	44.40	35.3	51.5	34.88	25.5	41.4
Plethobasus cyphyus	2	91.80	89.3	94.3	64.55	62.8	66.3	45.00	43.6	46.4
Pleurobema cordatum	94	98.39	81.1	129.1	78.17	62.2	99.5	49.67	39.0	62.9
Potamilus alatus	27	142.29	96.6	162.8	104.00	79.3	120.9	38.95	24.1	46.5
Quadrula metanevra	7	84.54	75.1	92.2	64.21	60.1	71.1	47.81	44.0	50.9
Quadrula pustulosa	63	57.01	46.2	66.0	55.09	46.3	66.0	35.49	28.2	43.8
Tritogonia verrucosa	17	110.26	96.0	128.7	58.53	54.3	64.1	36.48	30.1	42.7

Appendix A-2. (Continued)

TRM 526-527		Length			Height			Thickness		
and Year 1984	N	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Amblema plicata	16	100.54	84.8	120.1	73.24	62.3	88.0	44.96	38.9	52.4
Anodonta grandis	8	127.31	104.3	144.3	68.77	56.6	74.1	50.76	42.1	54.6
Anodonta imbecillis	1	54.70	54.7	54.7	23.20	23.2	23.2	16.90	16.9	16.9
Cyclonaias tuberculata	7	80.50	66.6	92.6	70.53	60.5	80.9	37.67	31.5	43.1
Ellipsaria lineolata	12	90.98	62.7	109.7	70.40	50.4	86.0	40.49	31.3	50.2
Elliptio crassidens	100	111.95	96.9	130.8	70.98	60.5	82.4	44.64	38.2	53.1
Lampsilis abrupta	3	98.63	96.4	100.2	70.80	66.1	74.8	57.07	54.7	60.2
Lampsilis ovata	1	139.80	139.8	139.8	92.60	92.6	92.6	68.80	68.8	68.8
Leptodea fragilis	5	109.62	104.5	118.1	65.02	62.1	68.4	35.10	30.9	38.4
Megalonaias nervosa	1	180.00	180.0	180.0	130.20	130.2	130.2	63.00	63.0	63.0
Obliquaria reflexa	9	55.80	49.2	64.0	43.27	36.1	52.3	34.44	26.3	39.8
Pleurobema cordatum	31	98.37	82.0	119.1	77.38	69.3	99.8	47.24	40.6	58.7
Potamilus alatus	23	153.90	132.3	182.1	105.20	80.5	134.5	41.12	36.8	46.5
Quadrula metanevra	1	79.10	79.1	79.1	64.60	64.6	64.6	54.90	54.9	54.9
Quadrula pustulosa	29	59.12	50.2	66.8	55.92	49.5	61.7	34.46	29.4	40.8
Tritogonia verrucosa	6	118.87	94.2	134.9	61.53	56.1	66.8	38.98	29.3	44.8

Appendix A-2. (Continued)

TRM 526-527		Length			Height			Thickness		
and Year 1985	N	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Amblema plicata	20	100.06	84.1	119.5	71.56	58.2	84.8	43.86	36.1	56.7
Anodonta grandis	6	122.98	108.7	142.6	72.18	62.9	80.4	50.47	41.9	58.7
Cyclonaias tuberculata	11	82.09	73.5	91.5	70.28	62.1	76.6	39.97	35.6	42.7
Ellipsaria lineolata	13	89.20	80.9	100.4	69.52	62.3	76.9	39.52	34.9	46.8
Elliptio crassidens	105	111.88	90.7	134.8	70.36	60.1	82.9	43.96	34.2	53.7
Elliptio dilatata	1	100.80	100.8	100.8	44.20	44.2	44.2	34.80	34.8	34.8
Lampsilis ovata	2	127.20	120.8	133.6	81.15	76.1	86.2	63.05	61.5	64.6
Leptodea fragilis	4	103.30	86.9	114.7	61.30	55.4	66.8	34.38	30.2	39.8
Ligumia recta	1	170.10	170.1	170.1	72.40	72.4	72.4	50.10	50.1	50.1
Megalonaias nervosa	1	190.80	190.8	190.8	121.10	121.1	121.1	57.10	57.1	57.1
Obliquaria reflexa	8	57.25	52.4	66.9	43.74	40.1	50.8	33.39	30.1	36.6
Pleurobema cordatum	52	103.59	83.6	160.2	81.47	66.5	134.9	46.31	34.3	54.4
Potamilus alatus	49	143.15	104.7	170.2	103.43	81.6	125.6	40.52	28.4	49.6
Quadrula metanevra	3	85.90	80.6	88.9	67.27	64.7	70.3	43.80	40.2	50.3
Quadrula pustulosa	43	60.61	46.3	72.3	57.34	32.1	68.1	36.61	28.9	44.2
Tritogonia verrucosa	17	125.20	92.3	148.8	61.35	40.6	70.0	40.43	34.1	48.7

Appendix A-2. (Continued)

TRM 526-527		Length			Height			Thickness		
and Year 1986	N	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Amblema plicata	27	97.68	66.7	121.4	69.54	50.6	84.9	44.09	26.8	57.4
Anodonta grandis	8	125.85	80.9	147.8	70.95	50.7	82.0	52.32	35.1	63.2
Cyclonaias tuberculata	17	79.26	63.2	96.7	67.04	55.9	80.2	39.89	33.1	51.0
Ellipsaria lineolata	7	96.04	83.6	112.3	70.80	61.5	78.2	43.99	34.1	52.5
Elliptio crassidens	105	113.05	92.3	145.2	68.73	59.1	87.1	43.35	35.1	54.1
Elliptio dilatata	1	107.10	107.1	107.1	50.00	50.0	50.0	35.40	35.4	35.4
Lampsilis abrupta	1	114.80	114.8	114.8	77.70	77.7	77.7	57.20	57.2	57.2
Lampsilis ovata	1	132.90	132.9	132.9	91.30	91.3	91.3	72.60	72.6	72.6
Leptodea fragilis	6	100.25	80.1	112.1	57.62	46.6	67.5	31.87	25.3	36.0
Ligumia recta	2	158.55	153.1	164.0	67.00	66.4	67.6	49.75	48.8	50.7
Megalonaias nervosa	2	145.80	124.6	167.0	103.25	87.2	119.3	58.35	57.0	59.7
Obliquaria reflexa	10	55.84	46.6	66.7	44.39	34.1	52.4	34.92	25.7	41.2
Pleurobema cordatum	38	96.12	75.7	117.9	75.20	63.2	83.5	47.08	42.4	56.3
Potamilus alatus	38	142.16	79.8	174.0	90.65	56.7	112.8	40.22	26.7	57.9
Quadrula metanevra	1	81.40	81.4	81.4	70.40	70.4	70.4	55.30	55.3	55.3
Quadrula pustulosa	20	57.10	42.4	67.0	54.51	42.4	66.1	33.57	25.7	40.0
Tritogonia verrucosa	20	111.93	87.1	133.0	56.05	47.6	66.7	33.90	24.7	42.9

Appendix A-2. (Continued)

TRM 526-527		Length			Height			Thickness		
and Year 1988	N	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	1	107.60	107.6	107.6	76.80	76.8	76.8	55.40	55.4	55.4
Amblema plicata	22	105.73	64.8	117.6	77.38	51.1	89.3	49.21	34.8	56.9
Anodonta grandis	19	131.44	101.0	155.1	72.65	56.1	89.9	55.26	43.5	71.2
Anodonta imbecillis	1	54.00	54.0	54.0	24.10	24.1	24.1	16.20	16.2	16.2
Cyclonaias tuberculata	8	82.56	63.4	94.7	71.49	60.7	78.1	41.26	31.3	45.0
Ellipsaria lineolata	4	88.22	81.7	94.3	68.20	61.5	72.8	40.80	38.4	42.3
Elliptio crassidens	51	113.30	100.1	129.2	70.47	44.2	79.3	45.82	39.9	55.3
Lampsilis abrupta	2	96.10	93.4	98.8	69.75	69.5	70.0	57.50	51.4	63.6
Lampsilis ovata	1	139.90	139.9	139.9	90.40	90.4	90.4	77.30	77.3	77.3
Leptodea fragilis	9	98.76	70.4	126.3	61.44	44.9	76.0	32.27	23.8	39.8
Obliquaria reflexa	7	54.84	44.2	62.7	43.20	36.2	49.6	32.27	24.4	36.0
Pleurobema cordatum	31	100.33	83.4	113.9	79.15	70.3	89.2	49.45	43.1	54.5
Pleurobema rubrum	1	88.30	88.3	88.3	69.50	69.5	69.5	46.70	46.7	46.7
Potamilus alatus	29	147.89	110.3	187.7	109.59	86.7	131.2	41.57	31.0	50.3
Quadrula pustulosa	21	58.90	52.6	64.0	55.89	46.6	64.1	36.14	30.0	40.6
Tritogonia verrucosa	13	114.88	96.3	140.8	64.74	50.1	76.3	41.53	29.7	50.7

Appendix A-2. (Continued)

TRM 526-527 and Year 1990	N	Length Mean	Min	Max	Height Mean	Min	Max	Thickness Mean	Min	Max
Actinonaias ligamentina	1	115.40	115.4	115.4	82.60	82.6	82.6	58.30	58.3	58.3
Amblema plicata	4	102.48	87.2	112.4	73.68	66.7	80.7	48.68	43.4	50.9
Anodonta grandis	17	136.27	108.7	159.1	76.23	61.5	99.9	56.54	44.4	68.8
Anodonta suborbiculata	1	126.20	126.2	126.2	96.40	96.4	96.4	48.30	48.3	48.3
Cyclonaias tuberculata	5	80.92	73.5	86.7	69.12	64.2	72.2	39.28	35.8	43.2
Ellipsaria lineolata	3	87.13	64.7	101.6	67.33	53.1	76.9	41.37	39.5	42.3
Elliptio crassidens	50	115.95	104.0	149.3	71.21	61.4	82.1	45.56	38.3	51.0
Lampsilis abrupta	1	98.10	98.1	98.1	83.70	83.7	83.7	62.10	62.1	62.1
Leptodea fragilis	5	111.74	101.8	130.1	69.30	61.0	89.5	36.24	32.8	40.0
Ligumia recta	1	173.10	173.1	173.1	73.50	73.5	73.5	59.90	59.9	59.9
Obliquaria reflexa	6	57.62	48.5	64.6	45.73	39.6	49.9	36.08	29.9	45.1
Pleurobema cordatum	24	102.52	90.2	120.7	78.21	69.0	90.6	48.51	41.7	52.8
Potamilus alatus	28	146.09	120.1	169.1	108.90	88.4	126.3	40.99	33.1	47.7
Quadrula metanevra	2	84.35	77.9	90.8	66.20	62.3	70.1	50.65	49.9	51.4
Quadrula pustulosa	26	60.05	50.1	74.4	55.38	44.9	66.9	35.37	28.0	42.1
Tritogonia verrucosa	7	105.43	78.1	130.1	56.16	43.4	65.9	35.67	26.6	42.5

Appendix A-2. (Continued)

TRM 526-527 and Year 1992	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Amblema plicata	6	99.72	94.7	105.1	73.83	65.5	82.1	47.28	44.7	51.6
Anodonta grandis	4	129.70	122.0	136.8	73.85	67.3	79.2	58.88	54.0	65.1
Cyclonaias tuberculata	12	84.87	75.5	92.4	70.85	64.1	75.4	40.52	36.5	43.2
Ellipsaria lineolata	3	95.83	94.6	96.7	73.90	71.1	77.2	41.23	36.1	44.5
Elliptio crassidens	42	113.78	100.1	126.7	71.49	63.2	81.6	45.96	39.1	52.3
Lampsilis abrupta	2	107.55	99.8	115.3	72.35	66.3	78.4	52.55	52.2	52.9
Megalonaias nervosa	3	170.43	155.9	183.2	122.43	112.2	128.2	61.77	53.1	69.3
Obliquaria reflexa	4	57.75	52.0	61.5	44.05	40.9	47.9	33.78	30.9	36.7
Plethobasus cyphyus	1	91.40	91.4	91.4	64.80	64.8	64.8	50.30	50.3	50.3
Pleurobema cordatum	27	103.31	82.5	127.9	78.67	68.5	90.7	45.82	39.5	49.7
Potamilus alatus	5	142.44	116.6	161.2	106.72	94.0	116.9	40.20	35.1	47.4
Quadrula metanevra	3	79.53	75.7	87.2	61.43	58.3	66.5	44.37	40.9	48.2
Quadrula pustulosa	16	58.32	51.5	64.7	54.97	50.1	62.7	35.34	30.3	44.8
Tritogonia verrucosa	7	105.57	77.0	127.3	58.67	43.1	66.7	37.10	21.7	48.3

TRM 526-527 and Year 1994	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Amblema plicata	11	108.42	97.6	119.1	78.67	72.2	89.7	49.41	45.2	54.7
Anodonta grandis	7	135.29	121.4	142.7	79.13	66.7	85.1	57.84	47.6	64.6
Cyclonaias tuberculata	8	79.01	72.0	85.1	68.94	63.7	73.5	38.94	34.8	41.6
Ellipsaria lineolata	1	96.10	96.1	96.1	76.70	76.7	76.7	42.30	42.3	42.3
Elliptio crassidens	85	116.05	96.5	129.8	72.99	62.5	82.4	46.66	39.4	52.9
Lampsilis abrupta	1	101.20	101.2	101.2	86.10	86.1	86.1	65.40	65.4	65.4
Leptodea fragilis	2	117.15	112.2	122.1	74.05	71.2	76.9	39.70	39.4	40.0
Ligumia recta	1	161.40	161.4	161.4	73.30	73.3	73.3	61.20	61.2	61.2
Obliquaria reflexa	11	57.30	52.8	69.5	45.68	41.4	51.7	35.04	29.6	42.7
Plethobasus cyphyus	1	88.60	88.6	88.6	59.40	59.4	59.4	46.20	46.2	46.2
Pleurobema cordatum	19	103.80	83.1	116.5	79.25	69.1	90.1	48.48	37.4	57.6
Potamilus alatus	5	153.00	131.9	168.6	117.24	109.4	128.5	43.88	38.4	46.5
Quadrula pustulosa	30	57.93	49.5	66.0	54.34	45.7	64.1	35.61	27.1	49.9
Tritogonia verrucosa	5	113.86	95.8	127.7	56.80	52.4	60.6	36.54	30.7	39.9

Appendix A-2. (Continued)

TRM 526-527 and Year 1996	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Amblema plicata	6	103.30	84.0	117.1	73.70	59.1	86.5	49.20	41.0	57.3
Anodonta grandis	6	144.90	130.6	160.0	84.20	71.9	102.4	58.50	52.1	64.2
Cyclonaias tuberculata	7	84.50	75.5	87.9	69.80	67.8	71.5	42.30	40.0	46.5
Ellipsaria lineolata	4	94.40	89.0	100.9	71.10	66.5	75.6	43.30	42.0	44.4
Elliptio crassidens	29	118.20	101.4	151.1	73.10	63.5	82.5	48.40	42.3	56.9
Lampsilis abrupta	2	115.70	109.1	122.4	84.30	83.0	85.5	63.00	59.1	66.9
Megalonaias nervosa	1	180.00	180.0	180.0	123.60	123.6	123.6	66.00	66.0	66.0
Obliquaria reflexa	6	56.10	51.8	59.6	43.90	39.8	50.1	36.40	33.4	40.3
Pleurobema cordatum	20	102.60	77.1	120.9	79.30	65.2	91.2	50.20	41.2	56.0
Potamilus alatus	28	148.90	125.9	180.0	83.90	70.8	97.3	41.30	32.2	51.5
Quadrula metanevra	1	77.80	77.8	77.8	61.00	61.0	61.0	51.60	51.6	51.6
Quadrula pustulosa	9	59.60	50.6	68.6	55.40	48.9	60.0	38.10	31.3	47.7
Tritogonia verrucosa	3	101.60	88.5	127.5	54.20	49.4	60.8	35.50	29.6	40.3

TRM 526-527 and Year 1997	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Amblema plicata	4	100.60	73.5	123.0	71.90	57.0	78.9	47.40	35.1	53.2
Anodonta grandis	1	147.00	147.0	147.0	81.00	81.0	81.0	63.40	63.4	63.4
Cyclonaias tuberculata	3	86.20	75.3	96.8	71.10	60.4	78.8	42.70	37.8	49.4
Ellipsaria lineolata	1	85.10	85.1	85.1	71.60	71.6	71.6	41.50	41.5	41.5
Elliptio crassidens	50	115.60	96.7	131.5	71.50	58.8	80.5	46.90	39.6	59.8
Leptodea fragilis	2	92.20	69.3	115.0	56.10	40.5	71.7	26.90	21.5	37.3
Obliquaria reflexa	2	55.80	54.2	57.4	45.70	44.6	46.7	34.80	33.0	36.6
Pleurobema cordatum	18	103.20	93.5	112.6	77.60	70.5	83.9	52.40	43.8	57.3
Potamilus alatus	6	154.00	142.4	166.9	87.10	78.4	95.8	43.20	39.7	48.9
Quadrula metanevra	1	85.00	85.0	85.0	65.70	65.7	65.7	45.40	45.4	45.4
Quadrula pustulosa	6	60.50	53.7	65.3	55.80	51.6	58.9	37.20	31.9	42.0
Tritogonia verrucosa	1	109.60	109.6	109.6	52.80	52.8	52.8	38.30	38.3	38.3

Appendix A-2. (Continued)

TRM 526-527		Length			Height			Thickness		
and Years 1983-1997	N	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	3	109.50	105.5	115.4	76.57	70.3	82.6	55.77	53.6	58.3
Amblema plicata	157	100.74	64.8	123.0	73.92	50.6	99.7	46.47	26.8	57.4
Anodonta grandis	98	130.67	80.9	160.0	73.11	50.7	102.4	54.85	35.1	71.2
Anodonta imbecillis	2	54.35	54.0	54.7	23.65	23.2	24.1	16.55	16.2	16.9
Anodonta suborbiculata	1	126.20	126.2	126.2	96.40	96.4	96.4	48.30	48.3	48.3
Cyclonaias tuberculata	110	82.01	63.2	96.8	69.81	55.9	80.9	40.37	31.3	51.0
Ellipsaria lineolata	61	91.17	62.7	112.3	70.50	50.4	86.0	41.38	31.3	52.5
Elliptio crassidens	721	113.59	90.7	151.1	70.76	44.2	87.1	45.15	34.2	59.8
Elliptio dilatata	3	103.37	100.8	107.1	46.83	44.2	50.0	33.80	31.2	35.4
Lampsilis abrupta	13	103.98	93.4	122.4	76.00	66.1	86.1	58.47	51.4	65.4
Lampsilis ovata	5	133.40	120.8	139.9	87.32	76.1	92.6	68.96	61.5	77.3
Leptodea fragilis	34	104.16	69.3	130.1	63.01	40.5	89.5	33.58	21.5	40.0
Ligumia recta	7	163.81	153.1	173.1	69.33	63.8	73.5	54.49	48.8	61.2
Megalonaias nervosa	11	170.47	124.6	190.8	118.27	87.2	130.2	60.87	53.1	69.3
Obliquaria reflexa	81	56.00	44.2	69.5	44.35	34.1	52.4	34.63	24.4	45.1
Plethobasus cyphyus	4	90.90	88.6	94.3	63.33	59.4	66.3	46.63	43.6	50.3
Pleurobema cordatum	354	100.51	75.7	160.2	78.49	62.2	134.9	48.39	34.3	62.9
Pleurobema rubrum	1	88.30	88.3	88.3	69.50	69.5	69.5	46.70	46.7	46.7
Potamilus alatus	238	145.99	79.8	187.7	91.15	56.7	134.5	40.76	24.1	57.9
Quadrula metanevra	19	83.16	75.1	92.2	64.72	58.3	71.1	47.77	40.2	55.3
Quadrula pustulosa	263	58.64	42.4	74.4	55.53	32.1	68.1	35.59	25.7	49.9
Tritogonia verrucosa	96	113.63	77.0	148.8	59.09	40.6	76.3	37.46	21.7	50.7

Appendix A-2. (Continued)

TRM 528-529		Length			Height			Thickness		
and Year 1983	N	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	2	102.95	92.5	113.4	72.95	69.3	76.6	53.40	48.3	58.5
Amblema plicata	5	103.20	84.7	132.3	75.74	64.1	94.6	40.42	30.4	51.3
Anodonta grandis	6	111.01	83.0	128.0	63.24	46.1	72.3	46.23	35.4	54.9
Cyclonaias tuberculata	43	82.19	66.8	96.5	69.89	57.3	79.9	40.56	32.6	46.6
Cyprogenia stegaria	2	56.45	52.9	60.0	51.14	50.9	51.4	38.71	36.8	40.6
Ellipsaria lineolata	12	90.16	66.4	108.8	67.22	52.4	76.8	42.40	36.6	51.3
Elliptio crassidens	105	110.49	86.8	134.6	68.14	54.4	89.9	43.39	34.9	56.1
Elliptio dilatata	1	95.30	95.3	95.3	44.10	44.1	44.1	30.50	30.5	30.5
Fusconaia subrotunda	1	66.09	66.1	66.1	53.56	53.6	53.6	36.58	36.6	36.6
Lampsilis abrupta	7	94.00	70.5	106.4	70.46	59.4	80.4	51.68	39.8	60.1
Lampsilis ovata	1	132.30	132.3	132.3	91.64	91.6	91.6	76.30	76.3	76.3
Leptodea fragilis	1	81.70	81.7	81.7	48.20	48.2	48.2	29.50	29.5	29.5
Ligumia recta	3	155.31	145.8	160.1	62.95	60.3	65.1	51.84	50.6	53.8
Obliquaria reflexa	1	49.00	49.0	49.0	39.70	39.7	39.7	34.30	34.3	34.3
Pleurobema cordatum	105	97.39	73.3	114.2	76.61	59.3	86.7	49.44	32.3	61.2
Potamilus alatus	5	126.89	110.3	141.8	88.62	69.1	119.8	39.26	34.5	44.1
Quadrula metanevra	13	75.86	46.9	92.6	59.96	42.2	74.4	42.98	26.2	54.7
Quadrula pustulosa	57	57.27	44.8	69.9	54.45	42.1	66.9	35.05	28.8	43.5
Tritogonia verrucosa	1	106.72	106.7	106.7	62.81	62.8	62.8	32.64	32.6	32.6

Appendix A-2. (Continued)

TRM 528-529		Length			Height			Thickness		
and Year 1984	N	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	2	109.55	99.4	119.7	81.00	74.0	88.0	53.25	53.1	53.4
Amblema plicata	8	95.05	73.6	113.8	71.76	59.5	84.3	37.02	26.8	48.4
Anodonta grandis	1	102.70	102.7	102.7	56.90	56.9	56.9	39.60	39.6	39.6
Cyclonaias tuberculata	23	82.19	69.4	99.1	69.40	60.3	79.1	39.06	33.5	46.3
Ellipsaria lineolata	14	84.82	63.6	108.7	63.59	50.1	78.3	39.51	34.1	46.3
Elliptio crassidens	101	112.00	94.7	129.8	69.07	58.0	78.5	43.58	36.0	54.5
Elliptio dilatata	1	92.60	92.6	92.6	43.70	43.7	43.7	21.50	21.5	21.5
Lampsilis abrupta	4	96.70	86.8	106.8	68.78	64.6	74.0	57.80	52.9	62.4
Lampsilis ovata	3	132.67	118.5	142.7	88.90	82.0	102.7	70.83	63.5	76.7
Leptodea fragilis	1	119.90	119.9	119.9	66.50	66.5	66.5	40.80	40.8	40.8
Ligumia recta	9	162.78	146.6	185.2	60.77	56.1	66.6	51.30	44.0	54.9
Obliquaria reflexa	1	51.20	51.2	51.2	40.20	40.2	40.2	30.80	30.8	30.8
Pleurobema cordatum	103	98.58	76.1	132.6	77.42	52.1	90.6	47.97	34.2	79.9
Pleurobema oviforme	2	69.80	63.5	76.1	55.70	50.6	60.8	40.35	40.0	40.7
Potamilus alatus	10	139.25	110.2	163.2	91.64	72.5	102.3	40.80	34.3	44.8
Quadrula metanevra	9	84.71	72.5	94.8	67.19	56.9	76.1	46.33	39.7	50.9
Quadrula pustulosa	56	58.80	46.4	72.0	55.34	44.4	64.8	34.54	20.2	40.9
Tritogonia verrucosa	3	104.83	84.6	121.4	59.37	49.5	64.4	29.40	24.3	32.4

Appendix A-2. (Continued)

TRM 528-529		Length			Height			Thickness		
and Year 1985	N	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	6	104.13	92.7	113.4	72.30	66.8	80.3	50.88	46.6	54.6
Amblema plicata	19	108.21	76.3	132.5	79.99	62.9	94.9	42.61	30.5	54.4
Anodonta grandis	4	123.38	107.9	130.1	65.80	60.9	69.6	46.20	40.7	50.1
Cyclonaias tuberculata	41	82.26	70.5	94.6	68.68	59.5	78.4	38.85	32.0	44.9
Ellipsaria lineolata	15	90.71	70.1	98.4	68.05	52.2	76.1	40.40	36.4	44.7
Elliptio crassidens	100	114.33	99.1	130.5	69.92	20.1	84.7	44.20	36.1	52.4
Lampsilis abrupta	6	103.77	92.6	113.3	75.07	64.4	81.1	56.83	50.6	64.4
Lampsilis ovata	6	128.43	114.0	142.0	84.58	70.0	103.4	62.65	57.3	70.2
Lasmigona complanata	1	180.20	180.2	180.2	114.30	114.3	114.3	40.30	40.3	40.3
Leptodea fragilis	1	88.20	88.2	88.2	50.20	50.2	50.2	28.60	28.6	28.6
Ligumia recta	6	168.92	154.4	180.3	64.07	60.2	72.4	53.33	49.9	60.4
Megalonaias nervosa	2	173.70	172.2	175.2	118.25	116.8	119.7	66.15	60.9	71.4
Obliquaria reflexa	3	54.67	50.5	58.8	43.13	40.2	46.8	33.50	30.9	36.7
Pleurobema cordatum	105	96.94	76.3	112.2	76.82	60.6	89.9	46.09	34.1	59.1
Pleurobema plenum	1	84.60	84.6	84.6	70.20	70.2	70.2	50.60	50.6	50.6
Pleurobema rubrum	2	91.60	90.4	92.8	73.20	71.6	74.8	50.60	49.8	51.4
Potamilus alatus	13	140.13	102.6	155.2	102.73	80.6	119.5	41.25	30.6	46.8
Quadrula metanevra	2	80.70	76.9	84.5	63.45	62.8	64.1	48.90	43.6	54.2
Quadrula pustulosa	69	57.78	48.5	80.5	54.68	44.8	68.8	34.83	26.3	42.8
Tritogonia verrucosa	1	136.10	136.1	136.1	72.00	72.0	72.0	34.00	34.0	34.0

Appendix A-2. (Continued)

TRM 528-529		Length			Height			Thickness		
and Year 1986	N	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	4	103.52	88.2	116.3	71.28	63.2	75.7	48.63	43.4	52.8
Amblema plicata	15	113.97	80.9	137.4	79.28	58.0	94.9	43.03	27.8	55.3
Anodonta grandis	6	117.00	102.2	135.2	64.53	57.0	79.4	46.35	37.2	56.7
Cyclonaias tuberculata	42	81.98	68.4	94.3	69.32	57.0	79.3	39.83	33.0	48.1
Ellipsaria lineolata	15	89.69	63.9	110.8	66.99	50.1	78.8	41.21	35.1	53.3
Elliptio crassidens	99	112.84	93.4	136.2	68.64	53.8	85.2	42.61	31.0	55.5
Elliptio dilatata	1	111.20	111.2	111.2	52.60	52.6	52.6	42.20	42.2	42.2
Lampsilis abrupta	3	98.33	90.3	108.6	72.07	66.4	76.2	53.30	50.7	56.7
Lampsilis ovata	1	152.20	152.2	152.2	101.40	101.4	101.4	72.00	72.0	72.0
Leptodea fragilis	3	90.10	79.4	111.1	51.33	47.3	59.1	29.23	26.7	33.1
Ligumia recta	9	155.47	135.3	173.1	58.03	48.0	64.5	50.77	44.5	55.9
Megalonaias nervosa	1	175.60	175.6	175.6	117.90	117.9	117.9	58.00	58.0	58.0
Obliquaria reflexa	2	51.45	50.7	52.2	36.15	32.0	40.3	25.75	21.6	29.9
Pleurobema cordatum	99	95.61	74.4	116.0	74.47	57.4	84.8	46.86	36.2	61.9
Pleurobema oviforme	2	68.90	68.4	69.4	50.70	48.6	52.8	35.60	33.0	38.2
Potamilus alatus	19	141.82	112.8	164.1	90.17	72.9	123.6	41.89	30.9	79.6
Quadrula metanevra	4	83.83	75.7	91.2	68.80	61.1	84.2	50.20	46.4	54.1
Quadrula pustulosa	35	56.95	46.5	71.6	53.18	43.4	64.2	33.65	24.7	42.1
Tritogonia verrucosa	1	78.80	78.8	78.8	41.40	41.4	41.4	26.70	26.7	26.7

Appendix A-2. (Continued)

TRM 528-529		Length			Height			Thickness		
and Year 1988	N	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Amblema plicata	14	101.22	82.3	119.8	74.19	63.5	89.8	44.59	32.1	52.0
Anodonta grandis	7	125.20	109.7	136.1	66.87	57.6	81.3	52.64	48.4	58.7
Anodonta suborbiculata	1	107.80	107.8	107.8	79.20	79.2	79.2	38.70	38.7	38.7
Cyclonaias tuberculata	29	83.77	67.2	97.5	69.95	58.9	97.7	41.00	36.1	49.3
Ellipsaria lineolata	10	93.77	83.5	102.8	69.20	62.1	77.4	41.00	36.1	44.5
Elliptio crassidens	51	112.93	99.6	136.4	69.48	61.3	76.2	44.49	36.3	54.6
Elliptio dilatata	2	103.25	95.6	110.9	45.45	40.8	50.1	29.15	27.5	30.8
Lampsilis abrupta	10	101.72	86.8	119.8	72.11	62.7	79.8	57.43	51.9	60.9
Lampsilis ovata	1	140.50	140.5	140.5	87.70	87.7	87.7	58.00	58.0	58.0
Leptodea fragilis	3	102.97	98.2	106.4	60.70	56.7	63.0	31.67	28.8	34.0
Ligumia recta	5	161.96	146.6	175.1	64.36	62.0	68.7	53.08	50.2	55.1
Megalonaias nervosa	5	164.90	155.1	170.8	118.14	110.4	126.6	61.18	53.6	68.7
Pleurobema cordatum	50	99.99	86.1	119.1	78.51	69.2	87.5	48.33	39.4	58.6
Pleurobema oviforme	2	72.20	70.2	74.2	55.00	54.0	56.0	40.70	40.7	40.7
Potamilus alatus	15	139.96	118.6	155.2	107.58	90.1	120.9	40.10	34.8	49.3
Quadrula metanevra	2	91.25	90.7	91.8	67.40	67.2	67.6	52.10	50.6	53.6
Quadrula pustulosa	51	58.83	36.1	81.1	55.00	40.7	98.4	35.02	26.2	43.1
Tritogonia verrucosa	2	115.75	98.3	133.2	56.80	51.4	62.2	43.55	26.7	60.4

Appendix A-2. (Continued)

TRM 528-529		Length			Height			Thickness		
and Year 1990	N	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	2	120.90	120.8	121.0	81.30	80.1	82.5	60.95	60.1	61.8
Amblema plicata	1	110.20	110.2	110.2	75.70	75.7	75.7	38.50	38.5	38.5
Anodonta grandis	2	127.75	126.4	129.1	74.10	69.2	79.0	52.95	46.8	59.1
Cyclonaias tuberculata	14	87.13	76.3	94.9	73.68	66.8	83.3	40.56	34.1	49.6
Ellipsaria lineolata	9	85.23	72.7	102.3	64.28	53.2	74.6	41.13	36.2	47.4
Elliptio crassidens	60	119.35	104.6	134.7	72.48	61.1	82.7	46.00	38.2	51.6
Elliptio dilatata	1	94.60	94.6	94.6	46.90	46.9	46.9	28.60	28.6	28.6
Lampsilis abrupta	3	108.57	101.0	120.6	83.23	81.8	86.0	62.17	55.7	67.7
Lampsilis ovata	1	121.70	121.7	121.7	78.10	78.1	78.1	68.30	68.3	68.3
Leptodea fragilis	1	124.70	124.7	124.7	69.60	69.6	69.6	39.70	39.7	39.7
Ligumia recta	1	172.10	172.1	172.1	68.30	68.3	68.3	58.70	58.7	58.7
Megalonaias nervosa	1	170.10	170.1	170.1	118.40	118.4	118.4	57.10	57.1	57.1
Obliquaria reflexa	3	56.40	54.8	58.0	42.90	40.3	46.4	30.37	28.5	31.7
Pleurobema cordatum	74	98.21	85.4	116.8	76.30	67.2	90.1	47.50	39.6	56.9
Pleurobema oviforme	1	72.80	72.8	72.8	56.00	56.0	56.0	41.70	41.7	41.7
Potamilus alatus	4	124.70	83.2	147.6	101.20	72.6	116.9	36.65	21.5	43.5
Ptychobranchus fasciolaris	1	116.80	116.8	116.8	61.40	61.4	61.4	44.70	44.7	44.7
Quadrula metanevra	4	89.70	85.3	100.7	66.98	60.2	71.5	48.43	46.3	51.8
Quadrula pustulosa	35	58.17	44.1	82.8	54.31	43.3	67.4	34.77	25.2	45.4
Tritogonia verrucosa	1	136.30	136.3	136.3	70.90	70.9	70.9	34.70	34.7	34.7

Appendix A-2. (Continued)

TRM 528-529 and Year 1992	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Amblema plicata	5	106.76	89.9	118.2	78.08	68.4	88.8	39.76	24.9	50.4
Cyclonaias tuberculata	12	82.04	70.3	97.1	70.42	59.6	79.4	39.90	29.5	44.5
Ellipsaria lineolata	3	96.67	90.8	99.6	68.43	67.9	69.1	40.80	39.6	42.2
Elliptio crassidens	52	117.40	99.7	136.6	71.86	63.2	83.3	45.77	39.2	53.3
Lampsilis abrupta	4	109.50	96.8	116.3	75.78	68.8	83.4	55.78	50.7	59.8
Ligumia recta	1	165.70	165.7	165.7	60.70	60.7	60.7	59.90	59.9	59.9
Obliquaria reflexa	1	59.30	59.3	59.3	42.90	42.9	42.9	28.90	28.9	28.9
Pleurobema cordatum	29	102.50	86.8	119.8	78.50	72.0	94.2	49.27	39.3	59.8
Potamilus alatus	5	145.50	139.3	150.1	103.32	90.6	109.4	42.50	39.0	46.8
Quadrula metanevra	3	75.00	61.9	84.7	61.57	60.7	62.0	44.23	37.4	47.7
Quadrula pustulosa	18	57.97	52.2	66.9	53.86	47.6	59.7	33.30	28.2	40.3

TRM 528-529 and Year 1994	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Cyclonaias tuberculata	10	81.57	58.4	91.2	67.30	50.3	72.9	39.50	28.3	46.9
Ellipsaria lineolata	3	97.83	94.0	100.2	71.60	69.5	73.1	46.57	44.4	48.6
Elliptio crassidens	66	115.95	104.6	129.2	71.54	62.5	84.7	45.53	39.2	50.8
Lampsilis abrupta	1	108.90	108.9	108.9	82.30	82.3	82.3	65.90	65.9	65.9
Leptodea fragilis	1	118.70	118.7	118.7	70.50	70.5	70.5	39.40	39.4	39.4
Megalonaias nervosa	1	168.70	168.7	168.7	119.20	119.2	119.2	58.70	58.7	58.7
Pleurobema cordatum	41	100.75	84.4	110.7	77.52	68.1	86.3	47.35	34.3	62.7
Pleurobema oviforme	1	71.90	71.9	71.9	59.80	59.8	59.8	41.70	41.7	41.7
Potamilus alatus	3	158.20	145.7	172.3	119.43	108.8	128.6	45.40	43.6	46.5
Quadrula metanevra	1	81.90	81.9	81.9	60.20	60.2	60.2	39.30	39.3	39.3
Quadrula pustulosa	29	58.69	46.2	66.6	54.43	43.8	64.8	35.44	29.8	42.5
Tritogonia verrucosa	2	119.95	99.6	140.3	64.15	58.7	69.6	36.90	31.8	42.0

Appendix A-2. (Continued)

TRM 528-529 and Year 1996	N	Length Mean	Min	Max	Height Mean	Min	Max	Thickness Mean	Min	Max
Amblema plicata	3	109.90	100.4	122.5	76.50	72.1	79.0	46.30	38.0	52.3
Anodonta grandis	1	118.10	118.1	118.1	67.70	67.7	67.7	47.40	47.4	47.4
Cyclonaias tuberculata	13	86.50	75.3	94.9	71.90	65.1	80.8	42.50	35.5	47.7
Ellipsaria lineolata	9	94.00	72.6	107.5	68.30	49.7	80.7	44.70	34.5	50.7
Elliptio crassidens	50	114.90	88.9	131.3	68.90	53.5	85.7	46.30	39.4	61.7
Lampsilis abrupta	1	110.10	110.1	110.1	75.70	75.7	75.7	60.30	60.3	60.3
Lasmigona costata	1	118.40	118.4	118.4	60.60	60.6	60.6	35.20	35.2	35.2
Leptodea fragilis	1	126.20	126.2	126.2	71.30	71.3	71.3	40.70	40.7	40.7
Ligumia recta	1	155.00	155.0	155.0	61.90	61.9	61.9	49.50	49.5	49.5
Pleurobema cordatum	46	100.80	85.3	112.5	78.90	65.4	90.5	49.60	38.3	59.6
Potamilus alatus	4	145.90	135.5	154.1	110.60	86.7	131.7	44.20	39.2	46.8
Quadrula metanevra	1	86.10	86.1	86.1	66.10	66.1	66.1	47.70	47.7	47.7
Quadrula pustulosa	19	61.60	53.0	77.3	56.00	49.6	62.5	38.20	31.1	49.5
Tritogonia verrucosa	1	134.10	134.1	134.1	61.30	61.3	61.3	31.60	31.6	31.6

Appendix A-2. (Continued)

TRM 528-529 and Year 1997	N	Length Mean	 Min	 Max	Height Mean	 Min	 Max	Thickness Mean	 Min	 Max
Amblema plicata	1	77.60	77.6	77.6	57.10	57.1	57.1	31.50	31.5	31.5
Cyclonaias tuberculata	13	87.40	79.3	96.2	72.70	65.4	78.8	44.10	38.5	51.9
Ellipsaria lineolata	2	77.00	69.4	84.6	57.70	54.3	61.0	38.80	35.5	42.2
Elliptio crassidens	50	116.10	101.7	134.5	68.40	59.1	83.4	45.80	33.5	65.0
Lampsilis ovata	1	115.30	115.3	115.3	74.10	74.1	74.1	69.50	69.5	69.5
Ligumia recta	1	160.00	160.0	160.0	71.50	71.5	71.5	59.60	59.6	59.6
Pleurobema cordatum	36	99.50	87.1	107.9	77.30	68.7	88.4	50.50	42.9	57.1
Potamilus alatus	4	151.50	122.0	168.8	85.00	74.6	92.9	44.90	42.4	46.6
Quadrula metanevra	1	91.00	91.0	91.0	63.50	63.5	63.5	46.40	46.4	46.4
Quadrula pustulosa	9	60.50	49.2	67.3	55.60	48.7	60.7	35.80	28.4	41.8

Appendix A-2. (Continued)

TRM 528-529		Length			Height			Thickness		
and Years 1983-1997	N	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	16	106.61	88.2	121.0	74.34	63.2	88.0	52.19	43.4	61.8
Amblema plicata	71	105.77	73.6	137.4	76.80	57.1	94.9	42.13	24.9	55.3
Anodonta grandis	27	119.14	83.0	136.1	65.58	46.1	81.3	48.21	35.4	59.1
Anodonta suborbiculata	1	107.80	107.8	107.8	79.20	79.2	79.2	38.70	38.7	38.7
Cyclonaias tuberculata	240	83.12	58.4	99.1	69.95	50.3	97.7	40.27	28.3	51.9
Cyprogenia stegaria	2	56.45	52.9	60.0	51.14	50.9	51.4	38.71	36.8	40.6
Ellipsaria lineolata	92	89.83	63.6	110.8	66.77	50.1	80.7	41.39	34.1	53.3
Elliptio crassidens	734	114.11	86.8	136.6	69.70	20.1	89.9	44.44	31.0	65.0
Elliptio dilatata	6	100.03	92.6	111.2	46.37	40.8	52.6	30.18	21.5	42.2
Fusconaia subrotunda	1	66.09	66.1	66.1	53.56	53.6	53.6	36.58	36.6	36.6
Lampsilis abrupta	39	101.59	70.5	120.6	73.51	59.4	86.0	56.51	39.8	67.7
Lampsilis ovata	14	130.76	114.0	152.2	86.23	70.0	103.4	66.60	57.3	76.7
Lasmigona complanata	1	180.20	180.2	180.2	114.30	114.3	114.3	40.30	40.3	40.3
Lasmigona costata	1	118.40	118.4	118.4	60.60	60.6	60.6	35.20	35.2	35.2
Leptodea fragilis	12	103.22	79.4	126.2	59.36	47.3	71.3	33.45	26.7	40.8
Ligumia recta	36	161.29	135.3	185.2	61.85	48.0	74.1	52.42	44.0	60.4
Megalonaias nervosa	10	168.63	155.1	175.6	118.27	110.4	126.6	61.20	53.6	71.4
Obliquaria reflexa	11	54.15	49.0	59.3	41.20	32.0	46.8	30.65	21.6	36.7
Pleurobema cordatum	688	98.28	73.3	132.6	76.89	52.1	94.2	47.97	32.3	79.9
Pleurobema oviforme	8	70.81	63.5	76.1	54.82	48.6	60.8	39.59	33.0	41.7
Pleurobema plenum	1	84.60	84.6	84.6	70.20	70.2	70.2	50.60	50.6	50.6
Pleurobema rubrum	2	91.60	90.4	92.8	73.20	71.6	74.8	50.60	49.8	51.4
Potamilus alatus	82	140.65	83.2	172.3	98.58	69.1	131.7	41.34	21.5	79.6
Ptychobranchus fasciolaris	1	116.80	116.8	116.8	61.40	61.4	61.4	44.70	44.7	44.7
Quadrula metanevra	40	81.77	46.9	100.7	64.09	42.2	84.2	45.96	26.2	54.7
Quadrula pustulosa	378	58.29	36.1	82.8	54.64	40.7	98.4	34.90	20.2	49.5
Tritogonia verrucosa	12	114.82	78.8	140.3	60.70	41.4	72.0	34.06	24.3	60.4

Appendix A-2. (Continued)

Three Bed Composite and Year 1983	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	5	104.00	92.5	113.4	73.84	69.3	80.1	51.88	46.8	58.5
Amblema plicata	53	96.86	74.4	132.3	72.73	56.6	99.7	45.37	30.4	56.9
Anodonta grandis	28	121.88	83.0	154.6	67.20	46.1	89.6	52.15	35.4	67.9
Cyclonaias tuberculata	147	79.14	62.1	96.5	67.90	52.1	80.2	39.50	32.4	49.8
Cyprogenia stegaria	3	54.83	51.6	60.0	50.66	49.7	51.4	37.81	36.0	40.6
Dromus dromas	1	60.10	60.1	60.1	58.30	58.3	58.3	32.80	32.8	32.8
Ellipsaria lineolata	45	85.29	56.8	108.8	65.74	44.6	78.6	40.30	30.1	51.3
Elliptio crassidens	311	107.96	86.8	134.6	67.29	54.0	89.9	42.93	21.0	56.1
Elliptio dilatata	5	103.32	95.3	113.3	45.50	42.2	48.8	32.38	30.5	34.7
Fusconaia subrotunda	1	66.09	66.1	66.1	53.56	53.6	53.6	36.58	36.6	36.6
Lampsilis abrupta	10	94.39	70.5	106.4	71.17	59.4	84.4	50.94	39.8	60.1
Lampsilis ovata	4	124.93	122.0	132.3	86.21	74.7	92.3	68.48	62.0	76.3
Leptodea fragilis	4	84.13	59.6	112.4	49.33	34.6	66.4	27.10	20.1	32.7
Ligumia recta	8	155.34	145.1	165.0	62.50	56.6	68.3	50.50	42.5	56.7
Megalonaias nervosa	3	173.83	164.4	180.6	117.43	111.7	120.7	60.50	57.2	63.0
Obliquaria reflexa	20	53.78	45.1	64.1	43.15	24.1	51.5	34.33	24.6	41.4
Plethobasus cyphyus	2	91.80	89.3	94.3	64.55	62.8	66.3	45.00	43.6	46.4
Pleurobema cordatum	301	95.39	72.1	129.1	75.65	59.3	99.5	48.25	31.4	62.9
Pleurobema plenum	1	58.10	58.1	58.1	52.90	52.9	52.9	36.40	36.4	36.4
Potamilus alatus	43	135.39	46.9	162.8	98.20	69.1	120.9	38.12	24.1	46.5
Quadrula metanevra	36	76.52	46.9	92.6	60.28	42.2	74.4	44.22	26.2	54.7
Quadrula pustulosa	158	55.91	43.7	69.9	53.61	40.5	66.9	34.47	26.3	43.8
Tritogonia verrucosa	18	110.06	96.0	128.7	58.77	54.3	64.1	36.27	30.1	42.7

Appendix A-2. (Continued)

Three Bed Composite and Year 1984	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	2	109.55	99.4	119.7	81.00	74.0	88.0	53.25	53.1	53.4
Amblema plicata	30	98.18	73.6	120.1	72.73	59.5	88.0	42.37	26.8	52.4
Anodonta grandis	9	124.58	102.7	144.3	67.46	56.6	74.1	49.52	39.6	54.6
Anodonta imbecillis	2	53.60	52.5	54.7	23.95	23.2	24.7	15.60	14.3	16.9
Cyclonaias tuberculata	131	76.09	59.1	99.1	65.19	52.2	80.9	37.77	29.5	46.3
Cyprogenia stegaria	1	52.90	52.9	52.9	51.40	51.4	51.4	36.40	36.4	36.4
Ellipsaria lineolata	49	82.92	56.6	109.7	62.95	44.0	86.0	37.88	26.3	50.2
Elliptio crassidens	302	109.58	89.2	130.8	68.75	56.3	82.4	43.30	24.4	60.9
Elliptio dilatata	2	96.35	92.6	100.1	42.95	42.2	43.7	24.75	21.5	28.0
Lampsilis abrupta	8	96.66	86.8	106.8	68.52	60.7	74.8	56.31	48.1	62.4
Lampsilis ovata	5	127.98	102.1	142.7	86.44	72.9	102.7	67.56	56.5	76.7
Leptodea fragilis	6	111.33	104.5	119.9	65.27	62.1	68.4	36.05	30.9	40.8
Ligumia recta	14	157.96	140.9	185.2	59.61	50.5	66.6	49.65	40.0	54.9
Megalonaias nervosa	1	180.00	180.0	180.0	130.20	130.2	130.2	63.00	63.0	63.0
Obliquaria reflexa	11	53.63	36.5	64.0	42.05	32.9	52.3	33.06	22.9	39.8
Pleurobema cordatum	234	95.08	62.1	132.6	74.99	44.7	99.8	46.26	32.8	79.9
Pleurobema oviforme	2	69.80	63.5	76.1	55.70	50.6	60.8	40.35	40.0	40.7
Pleurobema plenum	2	60.10	51.3	68.9	57.70	49.4	66.0	44.00	39.4	48.6
Potamilus alatus	47	142.73	96.7	182.1	97.96	72.5	134.5	39.57	30.0	46.5
Ptychobranchus fasciolaris	1	94.40	94.4	94.4	56.70	56.7	56.7	34.80	34.8	34.8
Quadrula metanevra	24	78.68	64.5	94.8	62.47	52.6	76.1	43.05	32.4	54.9
Quadrula pustulosa	138	56.75	40.0	74.1	53.65	39.5	64.8	33.43	20.2	40.9
Tritogonia verrucosa	10	110.44	76.7	134.9	59.00	42.7	66.8	34.18	19.7	44.8

Appendix A-2. (Continued)

Three Bed Composite and Year 1985		Length			Height			Thickness		
	N	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	11	104.72	92.7	113.4	73.72	66.8	80.3	51.75	46.6	54.9
Amblema plicata	42	103.37	76.3	132.5	75.25	58.2	94.9	43.01	30.5	56.7
Anodonta grandis	10	123.14	107.9	142.6	69.63	60.9	80.4	48.76	40.7	58.7
Cyclonaias tuberculata	124	78.39	60.5	94.6	66.76	54.7	78.4	37.85	30.6	44.9
Cyprogenia stegaria	1	57.70	57.7	57.7	55.60	55.6	55.6	44.10	44.1	44.1
Ellipsaria lineolata	35	87.83	62.3	100.4	67.24	46.9	76.9	38.96	32.0	46.8
Elliptio crassidens	306	110.22	90.1	134.8	68.72	20.1	88.5	43.21	29.5	53.7
Elliptio dilatata	2	98.80	96.8	100.8	44.20	44.2	44.2	32.30	29.8	34.8
Lampsilis abrupta	8	101.94	82.3	113.3	74.21	64.4	81.1	55.61	43.5	64.4
Lampsilis ovata	9	127.36	114.0	142.0	84.03	70.0	103.4	62.70	57.3	70.2
Lasmigona complanata	1	180.20	180.2	180.2	114.30	114.3	114.3	40.30	40.3	40.3
Leptodea fragilis	5	100.28	86.9	114.7	59.08	50.2	66.8	33.22	28.6	39.8
Ligumia recta	11	165.39	142.2	180.3	63.30	57.2	72.4	50.06	41.3	60.4
Megalonaias nervosa	5	173.70	160.1	190.8	115.26	102.3	121.1	59.66	52.4	71.4
Obliquaria reflexa	12	55.72	46.6	66.9	42.95	36.1	50.8	32.58	23.4	36.7
Pleurobema cordatum	245	96.42	70.4	160.2	76.58	58.2	134.9	45.35	30.2	59.1
Pleurobema oviforme	1	72.90	72.9	72.9	56.50	56.5	56.5	40.20	40.2	40.2
Pleurobema plenum	1	84.60	84.6	84.6	70.20	70.2	70.2	50.60	50.6	50.6
Pleurobema rubrum	3	87.97	80.7	92.8	70.23	64.3	74.8	48.57	44.5	51.4
Potamilus alatus	77	139.79	98.0	170.2	100.29	76.5	125.6	39.87	28.4	49.6
Quadrula metanevra	16	78.07	67.3	88.9	61.94	56.1	70.3	42.39	36.8	54.2
Quadrula pustulosa	138	57.98	46.3	80.5	54.91	32.1	68.8	34.83	25.7	44.2
Tritogonia verrucosa	19	124.66	92.3	148.8	61.46	40.6	72.0	39.86	34.0	48.7

Appendix A-2. (Continued)

Three Bed Composite		Length			Height			Thickness		
and Year 1986	N	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	8	99.23	88.2	116.3	69.71	63.2	75.7	47.32	40.3	53.8
Amblema plicata	47	103.36	66.7	137.4	73.01	50.6	94.9	43.79	26.8	57.4
Anodonta grandis	16	122.18	80.9	147.8	68.42	50.7	82.0	49.42	35.1	63.2
Anodonta imbecillis	1	39.20	39.2	39.2	17.40	17.4	17.4	7.10	7.1	7.1
Cyclonaias tuberculata	131	76.16	56.9	96.7	64.74	47.6	80.2	37.08	23.7	51.0
Ellipsaria lineolata	37	84.30	51.8	112.3	62.73	39.2	78.8	37.52	22.6	53.3
Elliptio crassidens	304	110.53	87.2	151.8	67.43	53.8	87.1	42.28	31.0	55.5
Elliptio dilatata	3	109.23	107.1	111.2	49.37	45.5	52.6	39.17	35.4	42.2
Lampsilis abrupta	8	100.44	86.1	114.8	72.96	66.3	80.7	52.21	48.3	57.2
Lampsilis ovata	3	141.40	132.9	152.2	94.33	90.3	101.4	66.83	55.9	72.6
Lasmigona costata	1	122.10	122.1	122.1	69.90	69.9	69.9	25.50	25.5	25.5
Leptodea fragilis	9	96.87	79.4	112.1	55.52	46.6	67.5	30.99	25.3	36.0
Ligumia recta	18	147.23	107.7	173.1	56.62	45.0	67.6	46.78	33.1	55.9
Megalonaias nervosa	6	152.35	124.6	175.6	105.20	87.2	119.3	57.80	53.9	63.2
Obliquaria reflexa	12	55.11	46.6	66.7	43.02	32.0	52.4	33.39	21.6	41.2
Pleurobema cordatum	231	92.87	54.9	117.9	72.90	49.7	88.5	45.07	25.2	61.9
Pleurobema oviforme	2	68.90	68.4	69.4	50.70	48.6	52.8	35.60	33.0	38.2
Potamilus alatus	68	139.66	79.8	174.0	89.52	56.7	123.6	39.47	26.7	79.6
Quadrula metanevra	14	74.75	54.9	91.2	59.91	42.4	84.2	42.11	31.0	55.3
Quadrula pustulosa	72	54.97	38.2	71.6	51.68	37.2	66.1	32.13	20.5	42.1
Tritogonia verrucosa	21	110.36	78.8	133.0	55.36	41.4	66.7	33.56	24.7	42.9

Appendix A-2. (Continued)

Three Bed Composite and Year 1988	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	3	97.87	90.9	107.6	73.37	71.3	76.8	51.37	47.6	55.4
Amblema plicata	48	102.47	64.8	119.8	75.22	51.1	89.8	46.31	32.1	56.9
Anodonta grandis	29	126.85	81.7	155.1	69.93	53.6	89.9	53.46	34.5	71.2
Anodonta imbecillis	1	54.00	54.0	54.0	24.10	24.1	24.1	16.20	16.2	16.2
Anodonta suborbiculata	1	107.80	107.8	107.8	79.20	79.2	79.2	38.70	38.7	38.7
Cyclonaias tuberculata	87	79.12	63.4	97.5	67.22	55.2	97.7	39.34	31.3	49.3
Ellipsaria lineolata	23	87.22	65.1	102.8	65.42	47.5	77.4	39.61	32.7	50.3
Elliptio crassidens	154	110.06	92.4	136.4	68.69	44.2	84.9	44.26	34.1	55.3
Elliptio dilatata	3	101.10	95.6	110.9	45.43	40.8	50.1	28.40	26.9	30.8
Lampsilis abrupta	12	100.78	86.8	119.8	71.72	62.7	79.8	57.44	51.4	63.6
Lampsilis ovata	3	130.37	110.7	140.5	85.00	76.9	90.4	65.70	58.0	77.3
Leptodea fragilis	12	99.81	70.4	126.3	61.26	44.9	76.0	32.12	23.8	39.8
Ligumia recta	7	160.27	144.4	175.1	62.39	54.2	68.7	51.81	44.4	55.1
Megalonaias nervosa	9	160.61	144.2	170.8	114.19	100.8	126.6	60.60	53.3	68.7
Obliquaria reflexa	7	54.84	44.2	62.7	43.20	36.2	49.6	32.27	24.4	36.0
Pleurobema cordatum	133	96.57	68.5	119.1	76.57	54.9	89.2	47.87	38.2	58.6
Pleurobema oviforme	2	72.20	70.2	74.2	55.00	54.0	56.0	40.70	40.7	40.7
Pleurobema rubrum	1	88.30	88.3	88.3	69.50	69.5	69.5	46.70	46.7	46.7
Potamilus alatus	54	142.76	110.3	187.7	106.60	76.3	131.2	40.82	31.0	50.3
Quadrula metanevra	8	83.34	66.7	92.1	64.21	54.2	70.1	45.60	38.4	53.6
Quadrula pustulosa	77	58.73	36.1	81.1	55.06	40.7	98.4	35.31	26.2	43.1
Tritogonia verrucosa	18	112.68	91.8	140.8	62.25	50.1	76.3	39.49	23.2	60.4

Appendix A-2. (Continued)

Three Bed Composite and Year 1990		Length			Height			Thickness		
	N	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	5	110.38	96.0	121.0	77.90	71.4	82.6	55.88	47.6	61.8
Amblema plicata	10	102.16	76.6	120.1	72.58	54.5	87.2	44.19	33.6	50.9
Anodonta grandis	20	135.42	108.7	159.1	76.04	61.5	99.9	55.90	44.4	68.8
Anodonta imbecillis	1	52.00	52.0	52.0	24.80	24.8	24.8	14.30	14.3	14.3
Anodonta suborbiculata	1	126.20	126.2	126.2	96.40	96.4	96.4	48.30	48.3	48.3
Cyclonaias tuberculata	69	79.65	62.0	111.0	67.29	52.1	92.1	37.97	28.0	49.6
Ellipsaria lineolata	28	85.42	64.2	102.3	64.41	51.6	76.9	39.18	32.1	47.4
Elliptio crassidens	160	115.21	87.5	149.3	70.91	61.1	82.7	44.91	36.3	51.6
Elliptio dilatata	1	94.60	94.6	94.6	46.90	46.9	46.9	28.60	28.6	28.6
Lampsilis abrupta	4	105.95	98.1	120.6	83.35	81.8	86.0	62.15	55.7	67.7
Lampsilis ovata	1	121.70	121.7	121.7	78.10	78.1	78.1	68.30	68.3	68.3
Leptodea fragilis	8	110.46	89.9	130.1	68.93	61.0	89.5	37.08	32.8	40.0
Ligumia recta	2	172.60	172.1	173.1	70.90	68.3	73.5	59.30	58.7	59.9
Megalonaias nervosa	3	166.60	155.6	174.1	116.57	110.7	120.6	56.50	56.2	57.1
Obliquaria reflexa	11	55.06	44.5	64.6	43.34	36.7	49.9	32.80	25.4	45.1
Pleurobema cordatum	132	97.37	75.6	120.7	75.38	59.5	90.6	46.34	32.9	56.9
Pleurobema oviforme	1	72.80	72.8	72.8	56.00	56.0	56.0	41.70	41.7	41.7
Potamilus alatus	45	142.78	83.2	169.1	107.14	72.6	126.3	44.74	21.5	139.8
Ptychobranchus fasciolaris	1	116.80	116.8	116.8	61.40	61.4	61.4	44.70	44.7	44.7
Quadrula metanevra	8	84.28	65.2	100.7	63.44	48.1	71.5	46.72	35.5	51.8
Quadrula pustulosa	78	57.56	44.1	82.8	53.53	42.8	67.4	34.22	25.2	45.4
Tritogonia verrucosa	9	107.59	78.1	136.3	57.36	43.4	70.9	35.21	26.6	42.5

Appendix A-2. (Continued)

Three Bed Composite		Length			Height			Thickness		
and Year 1992	N	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	1	94.80	94.8	94.8	65.40	65.4	65.4	49.60	49.6	49.6
Amblema plicata	13	105.46	89.9	124.7	77.27	65.5	88.8	45.11	24.9	54.8
Anodonta grandis	5	130.06	122.0	136.8	76.06	67.3	84.9	58.54	54.0	65.1
Cyclonaias tuberculata	68	80.10	63.2	97.1	67.49	53.4	87.1	38.73	29.5	44.7
Ellipsaria lineolata	14	90.49	69.6	99.6	67.96	49.7	77.2	39.56	31.3	44.8
Elliptio crassidens	137	112.26	88.4	136.6	69.83	55.6	83.3	44.75	27.2	53.3
Lampsilis abrupta	6	108.85	96.8	116.3	74.63	66.3	83.4	54.70	50.7	59.8
Ligumia recta	3	157.27	148.0	165.7	60.00	56.9	62.4	52.30	47.3	59.9
Megalonaias nervosa	4	173.35	155.9	183.2	120.88	112.2	128.2	60.93	53.1	69.3
Obliquaria reflexa	6	57.17	52.0	61.5	43.45	40.9	47.9	32.30	28.9	36.7
Plethobasus cyphyus	1	91.40	91.4	91.4	64.80	64.8	64.8	50.30	50.3	50.3
Pleurobema cordatum	82	98.53	64.7	127.9	76.15	60.9	94.2	46.29	37.5	59.8
Potamilus alatus	16	142.99	116.6	161.2	105.32	90.6	116.9	41.65	35.1	47.4
Quadrula metanevra	8	78.61	61.9	87.2	61.76	58.3	66.5	43.92	37.4	48.2
Quadrula pustulosa	48	56.37	45.3	66.9	52.70	40.2	62.7	33.52	25.2	44.8
Tritogonia verrucosa	9	106.24	77.0	127.3	59.00	43.1	66.7	36.29	21.7	48.3

Appendix A-2. (Continued)

Three Bed Composite and Year 1994	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Amblema plicata	13	106.79	84.7	119.1	76.72	59.2	89.7	48.44	35.0	54.7
Anodonta grandis	7	135.29	121.4	142.7	79.13	66.7	85.1	57.84	47.6	64.6
Cyclonaias tuberculata	64	78.52	58.4	91.2	66.28	50.3	74.3	38.94	28.3	48.9
Ellipsaria lineolata	11	87.68	76.1	100.2	66.95	57.7	76.7	40.38	32.9	48.6
Elliptio crassidens	216	113.88	96.5	129.8	71.10	61.3	88.6	45.37	36.6	52.9
Lampsilis abrupta	2	105.05	101.2	108.9	84.20	82.3	86.1	65.65	65.4	65.9
Leptodea fragilis	3	117.67	112.2	122.1	72.87	70.5	76.9	39.60	39.4	40.0
Ligumia recta	1	161.40	161.4	161.4	73.30	73.3	73.3	61.20	61.2	61.2
Megalonaias nervosa	2	174.45	168.7	180.2	119.45	119.2	119.7	63.85	58.7	69.0
Obliquaria reflexa	11	57.30	52.8	69.5	45.68	41.4	51.7	35.04	29.6	42.7
Plethobasus cyphyus	1	88.60	88.6	88.6	59.40	59.4	59.4	46.20	46.2	46.2
Pleurobema cordatum	95	97.71	59.8	116.5	75.96	58.1	90.1	46.85	34.3	62.7
Pleurobema oviforme	1	71.90	71.9	71.9	59.80	59.8	59.8	41.70	41.7	41.7
Potamilus alatus	10	149.92	128.3	172.3	115.17	99.6	128.6	43.34	38.4	46.5
Quadrula metanevra	4	74.18	68.4	81.9	57.53	54.4	60.2	40.33	39.3	42.2
Quadrula pustulosa	65	58.02	46.2	66.6	54.08	43.8	64.8	35.28	27.1	49.9
Tritogonia verrucosa	7	115.60	95.8	140.3	58.90	52.4	69.6	36.64	30.7	42.0

Appendix A-2. (Continued)

Three Bed Composite and Year 1996	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Amblema plicata	11	104.90	78.2	125.4	73.50	52.4	86.5	46.10	26.7	57.3
Anodonta grandis	7	141.10	118.1	160.0	81.80	67.7	102.4	56.90	47.4	64.2
Cyclonaias tuberculata	38	83.00	73.0	94.9	69.20	58.4	80.8	40.90	34.6	47.7
Ellipsaria lineolata	15	92.20	69.7	107.5	67.90	48.0	80.7	43.40	30.8	50.7
Elliptio crassidens	140	112.90	88.9	151.1	68.60	53.5	85.7	45.50	34.2	61.7
Elliptio dilatata	1	95.40	95.4	95.4	41.00	41.0	41.0	29.70	29.7	29.7
Lampsilis abrupta	4	110.20	99.4	122.4	79.30	73.1	85.5	60.40	55.3	66.9
Lasmigona costata	1	118.40	118.4	118.4	60.60	60.6	60.6	35.20	35.2	35.2
Leptodea fragilis	1	126.20	126.2	126.2	71.30	71.3	71.3	40.70	40.7	40.7
Ligumia recta	2	157.50	155.0	160.0	61.50	61.1	61.9	49.40	49.4	49.5
Megalonaias nervosa	1	180.00	180.0	180.0	123.60	123.6	123.6	66.00	66.0	66.0
Obliquaria reflexa	6	56.10	51.8	59.6	43.90	39.8	50.1	36.40	33.4	40.3
Pleurobema cordatum	93	99.40	77.1	120.9	77.20	65.2	91.2	48.70	38.3	59.6
Potamilus alatus	35	145.90	98.2	180.0	85.80	60.1	131.7	41.30	28.9	51.5
Quadrula metanevra	2	81.90	77.8	86.1	63.50	61.0	66.1	49.60	47.7	51.6
Quadrula pustulosa	29	60.80	50.6	77.3	55.80	48.9	62.5	38.10	31.1	49.5
Tritogonia verrucosa	4	109.70	88.5	134.1	56.00	49.4	61.3	34.50	29.6	40.3

Three Bed Composite and Year 1997	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Amblema plicata	5	96.00	73.5	123.0	68.90	57.0	78.9	44.20	31.5	53.2
Anodonta grandis	1	147.00	147.0	147.0	81.00	81.0	81.0	63.40	63.4	63.4
Cyclonaias tuberculata	47	81.50	67.0	96.8	67.80	56.5	78.8	42.40	35.6	51.9
Ellipsaria lineolata	8	81.80	56.4	105.5	61.50	45.9	71.6	40.90	33.8	52.6
Elliptio crassidens	152	113.10	92.2	134.5	68.20	53.7	83.4	45.70	33.5	65.0
Lampsilis ovata	1	115.30	115.3	115.3	74.10	74.1	74.1	69.50	69.5	69.5
Leptodea fragilis	2	92.20	69.3	115.0	56.10	40.5	71.7	26.90	21.5	37.3
Ligumia recta	1	160.00	160.0	160.0	71.50	71.5	71.5	59.60	59.6	59.6
Obliquaria reflexa	3	54.10	50.6	57.4	42.00	34.7	46.7	34.50	33.0	36.6
Pleurobema cordatum	82	98.20	83.1	117.2	75.50	60.2	92.3	49.90	41.7	57.3
Potamilus alatus	12	146.40	105.7	168.8	83.50	63.3	95.8	42.60	33.3	48.9
Quadrula metanevra	2	88.00	85.0	91.0	64.60	63.5	65.7	45.90	45.4	46.4
Quadrula pustulosa	24	59.00	49.2	67.3	54.10	45.2	60.7	36.20	28.4	45.6
Tritogonia verrucosa	1	109.60	109.6	109.6	52.80	52.8	52.8	38.30	38.3	38.3

Appendix A-2. (Continued)

Three Bed Composite and Years 1983-1997	N	Length			Height			Thickness		
		Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
Actinonaias ligamentina	35	103.57	88.2	121.0	73.57	63.2	88.0	51.34	40.3	61.8
Amblema plicata	272	101.52	64.8	137.4	73.97	50.6	99.7	44.66	24.9	57.4
Anodonta grandis	132	127.57	80.9	160.0	71.34	46.1	102.4	53.12	34.5	71.2
Anodonta imbecillis	5	50.48	39.2	54.7	22.84	17.4	24.8	13.76	7.1	16.9
Anodonta suborbiculata	2	117.00	107.8	126.2	87.80	79.2	96.4	43.50	38.7	48.3
Cyclonaias tuberculata	897	79.30	56.9	111.0	67.36	47.6	97.7	39.04	23.7	51.9
Cyprogenia stegaria	5	55.02	51.6	60.0	51.80	49.7	55.6	38.78	36.0	44.1
Dromus dromas	1	60.10	60.1	60.1	58.30	58.3	58.3	32.80	32.8	32.8
Ellipsaria lineolata	265	85.90	51.8	112.3	64.99	39.2	86.0	39.27	22.6	53.3
Elliptio crassidens	2182	111.08	86.8	151.8	68.76	20.1	89.9	43.88	21.0	65.0
Elliptio dilatata	17	101.64	92.6	113.3	45.54	40.8	52.6	31.59	21.5	42.2
Fusconaia subrotunda	1	66.09	66.1	66.1	53.56	53.6	53.6	36.58	36.6	36.6
Lampsilis abrupta	62	101.18	70.5	122.4	73.62	59.4	86.1	55.83	39.8	67.7
Lampsilis ovata	26	128.39	102.1	152.2	85.52	70.0	103.4	65.83	55.9	77.3
Lasmigona complanata	1	180.20	180.2	180.2	114.30	114.3	114.3	40.30	40.3	40.3
Lasmigona costata	2	120.25	118.4	122.1	65.25	60.6	69.9	30.35	25.5	35.2
Leptodea fragilis	50	102.46	59.6	130.1	61.45	34.6	89.5	33.30	20.1	40.8
Ligumia recta	67	156.70	107.7	185.2	60.84	45.0	73.5	49.99	33.1	61.2
Megalonaias nervosa	34	166.23	124.6	190.8	115.10	87.2	130.2	60.06	52.4	71.4
Obliquaria reflexa	99	55.12	36.5	69.5	43.32	24.1	52.4	33.63	21.6	45.1
Plethobasus cyphyus	4	90.90	88.6	94.3	63.33	59.4	66.3	46.63	43.6	50.3
Pleurobema cordatum	1628	96.06	54.9	160.2	75.48	44.7	134.9	46.52	25.2	79.9
Pleurobema oviforme	9	71.04	63.5	76.1	55.01	48.6	60.8	39.66	33.0	41.7
Pleurobema plenum	4	65.73	51.3	84.6	59.63	49.4	70.2	43.75	36.4	50.6
Pleurobema rubrum	4	88.05	80.7	92.8	70.05	64.3	74.8	48.10	44.5	51.4
Potamilus alatus	407	141.46	46.9	187.7	98.42	56.7	134.5	40.60	21.5	139.8
Ptychobranchus fasciolaris	2	105.60	94.4	116.8	59.05	56.7	61.4	39.75	34.8	44.7
Quadrula metanevra	122	78.24	46.9	100.7	61.48	42.2	84.2	43.73	26.2	55.3
Quadrula pustulosa	827	57.18	36.1	82.8	53.87	32.1	98.4	34.39	20.2	49.9
Tritogonia verrucosa	116	112.77	76.7	148.8	58.92	40.6	76.3	36.59	19.7	60.4

Enclosure 2

List of Regulatory Commitments

Tennessee Valley Authority
Watts Bar Nuclear Plant - Unit 2, Docket No. 50-391

<table>
<tr><td colspan="2">TVA will provide a response to the following Request for Additional Information on or before April 23, 2010:</td></tr>
<tr><td><i>H-16</i></td><td><i>The figure included in Appendix B of the 2007 TVA EIS shows water flow rates for plant systems with one unit in operation. Provide an update of this figure showing the flow rates for the system with WNB Unit 1 and 2 in operation. Provide an update to the table on page 3-3 of 1978 EIS to include values that include the flow rates needed for both units in operation.</i></td></tr>
</table>

<table>
<tr><td colspan="2">The first two buildings are in the Unit 1 FSAR; TVA will include all three buildings (the Old Steam Generator Storage Facility, Radwaste Pad, and Decon Building) in one of the next updates to the Unit 2 FSAR.</td></tr>
<tr><td><i>RP-1o</i></td><td><i>Identify (preferably on a diagram) and provide a reference for principal release points for gaseous and liquid radioactive materials to the environment.</i>
<i>Identify and provide a reference for direct radiation sources within or onsite out-of-plant as solid waste (e.g., independent fuel storage)..</i></td></tr>
</table>