APPENDIX C

MATERIALS EVALUATION

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MATERIALS EVALUATION

C.1 INTRODUCTION

Repository ground control design must ensure that the waste emplacement drifts are stable and accessible during the mandated 144-year retrievability period. The stability of subsurface openings is essential for shaft and ramp access, ventilation, emplacement, maintenance, monitoring, and materials handling. The performance of the ground support materials is directly affected by the waste emplacement environment. When studying this environment, the primary considerations are thermal, radiation, and biological factors.

Because organic materials are limited for use as ground support, the primary available materials are steel and concrete (items such as epoxy resin grout, timber blocking, and certain organic additives used in cementitious materials will be excluded from use). During their service life, the steel and concrete components will be exposed to elevated temperatures and radiation flux. Consequently, the effects these factors have on performance characteristics and component behavior must be examined. In addition to thermal and radiation effects, this study addresses concerns regarding the resistance of steel and concrete to bacterially mediated degradation.

The analysis of degradation factors is presented below, beginning with the potential uses of steel and an analysis of its tolerance to the thermal, radiation, and bacterial mechanisms to which it will be exposed. A similar discussion is then presented for concrete. The effect of bacterial degradation on steel and concrete is summarized in this document.

C.2 STEEL

Steel used for repository ground support may be present in various forms including:

- Structural steel sets (also referred to as ring beams and as arch supports)
- Rock bolts (including face plates)
- Welded-wire fabric and chain-link mesh
- Bar, fabric (welded wire), or fiber reinforcement in concrete and shotcrete
- Straps, channel, and lagging.

The following discussion evaluates the effects of temperature (including corrosion), radiation, and biological processes on steel.

C.2.1 Temperature Effects on Steel

Temperature can affect steel's strength, toughness and ductility, and thermal expansion. This section examines these effects and the potential for steel corrosion.

C.2.1.1 Strength

The yield point of structural steel (carbon or low-alloy) generally decreases linearly from its value at 20°C to about 80 percent of that value at 430°C, and to about 70 percent at 540°C (Merritt 1983). By interpolation, the value at 200°C is about 91 percent of that at 20°C. The modulus of elasticity of structural steel decreases from an initial value of 200 GPa at 20°C to about 172 GPa at 480°C, or 86 percent of the room-temperature value (Merritt 1983).

These results are similar to those reported by the American Institute of Steel Construction (AISC 1989). The AISC notes that the tensile strength of elevated-temperature carbon steel at 430°C is approximately 77 percent of room-temperature strength; at 540°C, tensile strength is 63 percent of room temperature strength. In contrast, a report on the elevated-temperature properties of ferritic steels (ASM 1990, p. 930) states that carbon steels are used extensively in pressure vessels up to about 370°C, and given the yield and ultimate strength of carbon steels at the maximum service temperature (370°C), they can be used essentially as they would for design of components at room temperature. Creep is not observed in these steels until temperatures are above 370°C.

Based on the above information, carbon steels at 200°C may experience modest, but insignificant, decreases in strength (about 10 percent) and deformability (about 15 percent) in comparison to these same parameters at 20°C.

C.2.1.2 Toughness and Ductility

Toughness is the ability of a metal to absorb energy and deform plastically before fracturing. A measure of toughness is notch toughness, which is measured (energy in Joules) by impact testing. Toughness decreases as the strength, hardness, and carbon content of steel are increased (ASM 1990, p. 737). At 200°C the notch toughness of a steel with 0.11-percent carbon is about six times that of a steel with 0.80-percent carbon. The 0.80-percent carbon steel exhibits the least ductility of the carbon steels and has the highest transition temperature from brittle to ductile behavior. For maximum toughness and ductility, the carbon content should be kept as low as possible, consistent with strength (ASM 1990, p. 737). The brittle-ductile transition temperature and the carbon content are the principal factors in determining the appropriate toughness and ductility for steel.

Steel set supports for Exploratory Studies Facility design typically have a carbon content of 0.07 percent (Kiewit/PB 1995) and are relatively tough and ductile, with a yield strength of 248 MPa. Rock bolt steel has a carbon content of 0.38 percent (Kiewit/PB 1995) and has moderate ductility and toughness, with a yield strength of about 483 MPa. If a more ductile rock bolt is desired to accommodate higher strain, steel with a lower carbon content may be preferred as an alternative to, for example, changes in fabrication. The trade-off would be a somewhat lower yield strength.

C.2.1.3 Thermal Expansion

Differences in thermal expansion between steel, concrete, and tuff can result in bonding failures between these components and cracking in the concrete materials. (See Appendix A, Section 5, of the *Repository Ground Control Evaluation* report (CRWMS M&O 1995a) for further discussion regarding concrete.)

Carbon steels have a coefficient of thermal expansion that varies from about 11.5 x 10^{-6}/°C at 20°C to 13.8 x 10^{-6}/°C at 200°C (ASM 1990, Figure 58, p. 652). The thermal expansion coefficient for tuff for near-field considerations is shown to vary from about 5 x 10^{-6}/°C at 25°C to 11 x 10^{-6}/°C at 250°C (SNL 1995). Table C-1 lists somewhat different values, ranging from 5.4 x 10^{-6}/°C to 17 x 10^{-6}/°C, for a similar temperature interval. These data show differences in expansion coefficients between tuff and steel of 7 x 10^{-6}/°C at 25°C, decreasing to about 3 x 10^{6}/°C at 200°C. In cases where steel expands at a greater rate than concrete, steel-to-concrete bonds may be broken and concrete cracking induced (for example, in grouted rock-bolt installations and in concrete reinforcing bars).

More severe conditions are indicated by test results reported in the report, *Thermal Goals Reevaluation* (CRWMS M&O 1993), which shows a tuff specimen reaching an expansion coefficient of approximately 12×10^{-6}/°C at 145°C and, after an abrupt increase, values between 25 and 32×10^{-6}/°C in the interval up to 200°C. An increase beyond 200°C gives a value of 53×10^{-6}/°C at 250°C. Additional testing is required to evaluate these results and, if applicable, to determine the limiting temperature at which an abrupt increase in expansion occurs.

Table C-1. Thermal Expansion Coefficient for TSw2 Thermal/Mechanical Unit

Temperature Range (°C)	Thermal Expansion Coefficient (10^{-6}/°C)
25 - 50	5.07
50 - 100	7.30
100 - 150	8.19
150 - 200	8.97
Source: SNL 1995 (average of means of tables 2-10, 2-11, and 2-12)	

C.2.1.4 Corrosion

Rock bolts or other iron-bearing components can corrode. When oxygen is present, rusting can occur. Rusting is an abiotic electrochemical process that requires a flow of electrical current for the chemical corrosion reaction to proceed. For electrochemical (galvanic) corrosion to occur, two dissimilar metals must come into electrical contact in the presence of moisture.

A separate cathodic metal is not required for steel corrosion to occur. An isolated steel bar can spontaneously rust if different areas of the bar develop active sites with different electrochemical potentials (different tendencies for oxidation), thus setting up anode-cathode pairs (or galvanic couples). Corrosion occurs in localized anodic areas. Local anodic and cathodic areas are caused by several conditions including different impurity levels in the steel, different amounts of residual strain, or different concentrations of oxygen or electrolyte in contact with the metal.

The findings of Karhnak (1984) demonstrate that steel corrosion in mines is often caused by the sulfuric acid generated by the oxidation of ore-bearing and pyritic sulfide phases. These sulfuric acid solutions are extremely corrosive to steel. The corrosion potential is enhanced if soluble copper is present in the acid solutions (as copper plates out on the steel), causing the dissolution of iron (for example, corroded train rails in underground copper mines). This type of aggressive corrosion will not occur in the waste emplacement drifts due to the absence of sulfide phases in the host formation. Moreover, it will be shown that production of bacterial sulfide is improbable (Section C.3.3).

C.2.1.4.1 Types of Corrosion

The two types of corrosion are uniform corrosion and pitting corrosion. Pitting corrosion can be further subdivided into three corrosion processes: galvanic, concentration, and crevice. These corrosion types are described below.

Uniform Corrosion occurs at a generally equal rate over the surface. The loss in weight is directly proportional to the time of exposure, and the rate of corrosion is constant. Uniform corrosion is usually associated with acids or waters having a very low pH, for example, the uniform rusting of mild steel in contact with neutral, low calcium, and low-alkalinity salt water.

Pitting Corrosion is non-uniform and more common than uniform corrosion. Pitting corrosion occurs in an environment which offers some, but not complete, protection. The pit develops at a localized anodic point on the surface and continues via a large cathodic area surrounding the anode. Chloride ions are particularly known for their association with this type of steel corrosion. Even stainless steel is subject to pitting corrosion with relatively concentrated chloride-bearing solutions. Pits may be sharp and deep or shallow and broad, and can occur without chlorides. In water that contains dissolved oxygen, the oxide-corrosion products are deposited over the site of the pitting action and form tubercles. Pitting corrosion is formed by three distinct processes:

- *Galvanic Corrosion* – Galvanic corrosion is associated with the contact of two different types of metals or alloys in the same environment. Almost all metals and substances have different solution potentials, whether in the same or in different environments. When two metals come together, the difference in potential results in current flow, and one of the metals becomes anodic and the other cathodic. The anodic metal corrodes and the cathodic metal does not (or if so, at a relatively low rate). The cathodic metal is "protected" at the expense of the anodic metal (for example, the protectiveness zinc metal affords to iron).

- *Concentration-Cell Corrosion* – The most prevalent corrosion, concentrated-cell corrosion, occurs when differences in acidity (pH), metal-ion concentrations, anion concentrations, or dissolved oxygen cause solution differences in the same metal. In water containing dissolved oxygen, the corrosion products are deposited at the anode, and in the subsequent hydrolysis of ferrous ion, hydrogen ions are formed. This greater acidity at the anode results in a hydrogen-ion concentration cell at this point and increases the corrosion rate. In the same instance, dissolved oxygen cannot diffusively penetrate to the anode surface because it first reacts with solubilized ferrous ion, resulting in an absence of oxygen at the anode. But oxygen can diffuse to the cathode area and result in an oxygen-concentration cell, also increasing the corrosion rate. Furthermore, hydroxyl ions accumulate at the cathode, drastically reducing the hydrogen ion concentration, which enhances the concentration cell related to the development of hydrogen ions at the anode.

- *Crevice Corrosion* – Crevice corrosion results when oxygen, because it is spent on corrosion in a crevice, does not diffuse into the crevice depths. The crack, crevice, or the uneven joint between two surfaces of the same metal that are bound together face-to-face behaves as a pit where oxygen can reach the exposed surface but is deficient in the crevice. An oxygen-concentration gradient is created that results in corrosion.

C.2.1.4.2 Corrosion Rates

Based on the theory of corrosion, mathematical models can be developed to predict material corrosion rates under given conditions. Tilman et al. (1989) developed a model that generally predicts the corrosion rate of rock bolts or Split Set® stabilizers in underground mines. To develop the model, non-galvanized (EX-TEN-H60 and KAI-WELL-55) and galvanized Split Set stabilizers were exposed to oxygenated and non-oxygenated mine waters (actual and synthetic) from seven mines. Based on the behavior of the stabilizers when exposed to these waters, corrosion rate equations were derived that quantify (1) the impact of variable dissolved oxygen, chloride, sulfate, and magnesium content on non-galvanized stabilizers and (2) the impact of dissolved oxygen content and temperature on galvanized stabilizers. The derived equations are shown below (corrosion rate reported in thousandths of an inch per year):

- EX-TEN-H60 Steel:
  Ln corrosion rate = 0.303 (O_2 Conc., ppm) - 0.0309 (Cl^- Conc., ppm) + 0.00187 (SO_4^{-2} Conc., ppm) - 0.0435 (Mg^{+2} Conc., ppm)

  $R^2 = 0.96$ [Linear regression coefficient of actual versus predicted corrosion rates.]

- KAI-WELL-55 Steel:
  Ln corrosion rate = 0.352 (O_2 Conc., ppm) - 0.0740 (Cl^- Conc., ppm) + 0.00202 (SO_4^{-2} Conc., ppm) - 0.0415 (Mg^{+2} Conc., ppm)

  $R^2 = 0.96$

- Galvanized Steel
  Ln corrosion rate = (Ln O_2 Conc., ppm) + 2.557 (Ln Temp., °F) - 11.333

  $R^2 = 0.83$

These equations show that non-galvanized steel in contact with a dilute, non-oxygenated water may result in only a slow rate of corrosion, less than 1 thousandth of an inch per year. Conversely, non-galvanized steel in contact with a well-oxygenated, briny solution could have a corrosion rate of 80 thousandths of an inch per year. At this accelerated rate, a 0.092-inch-thick Split Set stabilizer would be penetrated by corrosion in just over a year.

The mathematics of the individual equations can be qualitatively explained based on known geochemical principles:

- Corrosion can occur in the absence of oxygen, as the following chemical reactions demonstrate:
  Anode: $Fe = Fe^{+2} + 2e^-$
  Cathode: $2e^- + 2H_2O = H_2 + 2OH^-$

- When dissolved oxygen is present, the cathode reaction may be represented as:
  $2e^- + H_2O + \frac{1}{2}O_2 = 2OH^-$

  Therefore, with or without dissolved oxygen, the same amount of hydroxide ion is formed at the cathode, and alkaline conditions prevail.

- The effect of dissolved oxygen is reflected at the anode where the following side reaction occurs:
  $2\,Fe^{+2} + H_2O + \frac{1}{2}O_2 = 2Fe^{+3} + 2OH^-$

- Ferric hydroxide can now precipitate generating hydronium ion:
  $Fe^{+3} + 3H_2O = Fe(OH)_3 + 3H^+$

  The resulting acidity increases the solution rate of iron and maintains a high potential difference between the anode and cathode areas.

Under these conditions, the corrosion rate is limited by the supply (typically by diffusion) of dissolved oxygen to the anode corrosion product. The greater the rate of dissolved oxygen diffusion to the anode, the greater the rate of corrosion. This chemical fact is captured in the above equations for non-galvanized steel. The above equations assume a constant pH for the contacting solution and do not directly address acidic attack.

Ferric hydroxides deposited by corrosion can inhibit oxygen diffusion. Beneath the ferric oxide surface within water-filled pipes, anaerobic conditions can develop that, under certain circumstances, can support sulfate-reducing bacteria (SRB). In the absence of the water, oxygen can freely diffuse into this region and prevent SRB activity, as diffusion-based transport calculations will demonstrate. With an absence of water, the source of sulfate ion is also removed, thus suspending SRB activity. This issue is further discussed in Section C.3.3.

An analysis of the corrosion rate equation for galvanized metal shows that temperature changes far outweigh incremental changes in dissolved oxygen content. (Oxygen has a limited solubility in ambient temperature water, a solubility that decreases as temperature increases.) The temperature-dominated equation generally shows that the corrosion rate increases approximately two-fold with each temperature increase of 10°C, which is consistent with the van't Hoff relationship.

It should be noted that the steel composition of rock bolts for ground support of emplacement drifts has not yet been explicitly specified; therefore, the steel corrosion rates predicted by the mathematical models mentioned above are for reference purposes.

C.2.1.4.3 Corrosion Rate and Strength Loss

A corrosion-related strength decay curve can be derived from the tensile and yield strength data of Tilman et al. (1989). Both EX-TEN-H60 and KAI-WELL-55 steel have linear strength-versus-thickness relationships; therefore, loss of material by corrosion also translates into a linear loss in strength, as shown in Table C-2.

By estimating a corrosion rate, the annual strength loss and the residual strength at the end of any given year can be calculated. The above analysis assumes uniform corrosion and does not address isolated pit corrosion.

Table C-3 lists the temperature-dependent corrosion rates predicted for galvanized steel under oxygenated conditions (dissolved oxygen content of 7 ppm).

Table C-2. Relationship Between Corrosion Rate and Strength Loss for Non-Galvanized Steel

Corrosion Rate per Year (thousandths of an inch)	Strength Loss in EX-TEN-H60 Steel per Year (psi)	Residual Strength in EX-TEN-H60 Steel After One Year (psi)	Strength Loss in KAI-WELL-55 Steel per Year (psi)	Residual Strength in KAI-WELL-55 Steel After One Year (psi)
1	290	28,700	298	29,462
10	2,899	26,091	2,976	26,784
20	5,798	23,192	5,952	23,808
40	11,596	17,394	11,904	17,856
80	23,192	5,798	23,808	5,952

Table C-3. Temperature Dependence on the Corrosion Rate of Galvanized Steel Under Oxygenated Conditions

Temperature (°F)	Corrosion Rate per Year (thousandths of an inch)
50	2
100	11
150	31
200	64

The corrosion rate estimates stop at 200°F. Although the emplacement drifts will likely reach higher temperatures, the above relationship is predicated on the presence of liquid water that will not exist at temperatures greater than 212°F. Consequently, another corrosion mechanism will predominate at an unknown rate.

In summary, Tilman et al. (1989) found that (1) deoxygenated water is seven times less aggressive than oxygenated water to non-galvanized steel and (2) galvanized steel is much more resistant to corrosion, with comparatively low corrosion rates even at elevated temperatures. Galvanizing offers two advantages: up to 1/60th the corrosion rate of non-galvanized steel under similar conditions and greater resistance to pitting corrosion. Even when the galvanizing is marred (e.g., during rock bolt emplacement) it acts as a sacrificial anode and provides protection.

Stainless steel is resistant to corrosion over a wide range of water chemistry, exceeding the range even of galvanized bolts (Kaiser et al. 1990). This is particularly important for friction rock bolts. Because of their thin walled construction and large surface area, friction rock bolts are more susceptible to corrosion damage than conventional bolts. Additionally, austenitic stainless steels are more ductile than conventional carbon steels, providing both high strength and ductility. Kaiser et al. (1990) have advocated using stainless steel friction rock bolts to increase the useful life of rock support systems.

Kaiser et al. (1990) also found that in addition to acidic mine waters, elevated humidity and solubilized engine exhaust tend to increase the corrosion rates of carbon steel rock bolts. This is consistent with the understanding of water being a prerequisite for corrosion. Sulfur dioxide in the exhaust can cause accelerated pit corrosion. During their analysis of rock bolt longevity in Canadian underground mines, Kaiser et al. (1990) determined the life spans of forged-head mechanical rock bolts to be 18 to 240 months, averaging 68.7 months, while resin grouted bolts had lifespans of 18 to 60 months, averaging 38 months. Lifespans of Split Set and Swellex friction rock bolts ranged from 3 to 72 months and 3.5 to 120 months, respectively, with both averaging about 25 months.

Mechanisms to further prevent rock bolt corrosion include protectively coating the steel and suppressing the electrochemical process. An example of a protective steel coating is zinc galvanizing. Suppressing the electrochemical corrosion of steel involves cathodic protection. Zinc or cadmium bars are electrically connected to the steel, causing it to act as a cathode and prevent corrosion. High-strength structural steels can be alloyed with copper and other elements to produce high resistance to atmospheric deterioration. These steels develop a tight oxide that inhibits further atmospheric corrosion (Mindess and Young 1980).

Steel can also be protected from the corrosion caused by moisture and temperature changes by embedding it in shotcrete or concrete, as in the case of steel reinforcement bars. For worst-case moisture and temperature conditions, the ACI Building Code (ACI 1989) specifies a minimum concrete cover of about 75 mm for concrete "...cast against and permanently exposed to earth." The minimum cover specified for precast concrete is 38 mm. The ACI Building Code also states that denseness and nonporosity of protecting concrete shall be considered for corrosive environments or other severe exposure conditions. These standard code provisions are not intended to deal with the elevated temperature conditions or exposure durations in the repository environment; they are referenced as a starting point for further analysis beyond the scope of this evaluation.

Degradation of the grout surrounding the rock bolts will be limited because the expected temperatures are below those required to cause serious grout deterioration. (Section C.3.1 examines deterioration mechanisms when grout is exposed to elevated temperature.) The rock bolts will be protected from chloride-related corrosion (due to chloride ions in the grout) by appropriately limiting the use of chloride-based set accelerators. Rock bolt and steel set deterioration should also be limited by the protective coating of shotcrete or grout. Additionally, the dry conditions of the shotcrete or grout environment will limit bacterial activity (further discussed in Section C.2.3).

C.2.2 Radiation Effects on Steel

Radiation hazards from the waste packages will come from different radiation types including alpha-particles, beta-particles, and neutrons and photons (gamma- and x-rays) (CRWMS M&O 1994, Section 6). The primary radiation from the waste package is neutron and gamma because the alpha and beta radiation are stopped by the disposal container (CRWMS M&O 1995b). Neutrons and gamma radiation can produce ionization when they pass through materials because the energy of these particles can eject electrons from the elements they contact. Organic compounds, such as lubricants and electrical insulation, will suffer fragmentation that results in the formation of different material, and integrated circuits in computer systems can be damaged. Metals such as steel are less affected by such irradiation (ASM 1990). Generally, the only type of radiation emanating from the high-level waste packages that may affect steel is the neutron field. The remainder, namely beta, gamma, and alpha radiation, have no known significant effect upon the structural properties of steel.

Irradiation is described in terms of (1) the flux of neutrons striking the material, measured as the number of neutrons per square meter per second ($n/[m^2 \cdot s]$) and (2) the fluence, which is flux integrated over time or the number of neutrons per square meter (n/m^2). Based on a 100-year service life for the underground facilities, the neutron fluence for a waste package has been conservatively estimated to not exceed $2.2 \times 10^{20}\ n/m^2$ (CRWMS M&O 1995b). This value is about $3.2 \times 10^{20} n/m^2$ for a 144-year service life, which includes retrievability preparation time and closure operations (YMP 1994, Section 6.2).

Radiation effects from the waste packages are not expected to be a design concern for steel materials used in the emplacement drift, as reported in report title (CRWMS M&O 1995b):

> Irradiation effects on steels include swelling, hardening, and embrittlement. Swelling is not detectable at neutron fluences of less than 1×10^{26} n/m² even in austenitic steel (ASM 1990, p. 655, Figure 2), and ferritic steels, such as those expected to be used in the repository, are much more resistant to swelling (ASM 1990, p. 656, column 3). Increases in hardness, and thus strength, are not harmful. For a manganese-molybdenum low-alloy steel (ASTM A 302, grade B), measurable embrittlement occurs at neutron fluences as low as 1×10^{22} n/m². For fluences up to about 3×10^{22} n/m², the effect appears to be approximately proportional to the fluence. The increase in the ductile-brittle transition temperature, as measured by a 41 J Charpy V-notch impact test, is approximately 25×10^{-22} K·m² F, where F is the neutron fluence (ASM 1990, p. 659, Fig. 7). Because the neutron fluence over the service life of the underground facilities is less than 2.2×10^{20} n/m² (considering a 100-year service life), the expected increase in the ductile-brittle transition temperature is not more than 0.6 K (0.8 K for a 144-year service life).

In summary, the neutron radiation field expected from any single waste package is not expected to exceed 2.2×10^{20} n/m² for 100 years (or 2.2×10^{18} n/[m²·yr]) based upon estimated values from bare fuel assemblies. This value is very conservative because in practice the radiation field would be expected to be several orders of magnitude lower due to shielding from the waste package walls, decay of radioactivity, and geometric divergence. Therefore, radiation effects are believed to be insignificant and not expected to degrade the steel properties.

C.2.3 Biological Effects on Steel

In aqueous, oxygen-free, reduced environments, the lifetime of steel and iron material is diminished by SRB. Although the deleterious effects of SRB have been demonstrated in both laboratory and natural settings, special conditions that do not exist at the Yucca Mountain repository are required for SRB to corrode steel. In addition to the anaerobic, aqueous environment, these conditions require the availability of sulfate, an electron acceptor, and a carbon source.

Steel biodegradation occurs when SRB consume hydrogen during sulfate reduction. Iron immersed in water releases Fe^{++}-cations, and the metal surface becomes negatively charged by the remaining electrons. The dissolving process continues only if the electrons are removed, for example by an oxidizing agent. Under aerobic conditions, oxygen acts as an electron acceptor and rust is formed. Under anaerobic conditions, the electrons left on the metal surface reduce protons, from the dissociation of water, to hydrogen, which forms a protective layer over the submerged iron surface. SRB oxidize the elemental hydrogen with sulfate as the electron acceptor. Removal of the hydrogen protons by SRB disrupts the natural equilibrium and causes cathodic depolarization of the iron surface (Cord-Ruwisch and Widdel 1986). The presence of liquid-phase water is critical to this process. Elevated temperatures in the emplacement drifts will ultimately eliminate liquid water. Concrete will be formulated with a sufficiently low water-to-cement ratio to prevent free water in the pore spaces.

In the laboratory setting, *Desulfovibrio* (a hydrogenase-positive SRB) did not break down steel and produce sulfide unless a favorable organic energy source, such as lactate, was present. Experimental results indicate that the availability of organic electron donors may be an important factor influencing the removal of cathodic hydrogen from iron surfaces; and anoxic aqueous environments that are rich in anaerobically degradable organic matter should be more corrosive than environments that are mainly inorganic. In the natural environment, biodegradation of steel has been demonstrated in off-shore oil pipes, sewage pipes, and oil tanks (Cord-Ruwisch and Widdel 1986) which meet the above bacterial requirements. These requirements are absent within the waste emplacement drifts, thus eliminating SRB activity.

SRB may penetrate the concrete and come into contact with the steel. The presence of oxygen, excessively high temperatures, and inadequate sources of sulfate and carbon create an environment hostile to SRB. In the absence of the specialized environment required for SRB metabolism, corrosion of steel by SRB is expected to be limited.

C.3 CONCRETE

Concrete for ground support may be used in the following forms:

- Shotcrete – Full-circle structural lining, 100 to 150 mm thick; or to secure fractured rock, less than 100 mm.

- Concrete lining – Pre-cast segments, cast-in-place, with or without reinforcement such as steel bars, mesh, or fibers.

- Grout – typically to encapsulate and secure rock bolts, but also to consolidate and strengthen the rock mass.

Additionally, concrete may be used for invert fill and waste package pedestals. Both of these applications and most of those listed above were considered in the materials review documented in Appendix A, Concrete Stability at Elevated Temperatures, of *Repository Ground Control Evaluation* (CRWMS M&O 1995a). Conclusions from this literature review are summarized below.

Ground control measures typically emphasize rigid confinement of the supported rocks. Previous thermomechanical modeling results have suggested that a ground support that provides light to moderate confinement, yet still prevents rock loosening and fallouts, may be preferable. Rather than design to resist a thermally induced stress, ground support components can be fabricated for ductility and structural flexibility. An example of this type of component is fiber-reinforced concrete (described below). The relatively low tensile strength of concrete is well known. In fact, tensile stresses are expected to be carried entirely by the steel reinforcing bars (Mindess and Young 1980).

One development that improves the tensile strength of concrete is the use of fiber-reinforcing additives. Mindess and Young (1980) define fiber-reinforced concrete as concrete made from Portland cement which incorporates discrete fibers. Fibers suitable for reinforcing concrete include steel, organic polymers, ceramics, and asbestos. These fibers differ in both performance characteristics and costs and are briefly described below.

- Steel fibers may be produced either by cutting wire, shearing sheets, or from a hot-melt extract; they may be smooth or deformed in a variety of ways to improve the bond. Steel fibers will rust at the concrete surface but appear to be very durable within the concrete mass.

- Using iron as an admixture to function as either a fiber reinforcement or as an agent to increase grout density is in contrast with using iron filings as a grout expanding agent, which is not being proposed.

- Glass fibers are generally available as "chopped strand," where each strand may consist of 100 to 4,000 separate filaments. Ordinary glass is not suitable for use because the highly alkaline environment will attack and rapidly reduce the fiber strength. Glass fibers are manufactured with significant amounts of ZrO_2 which is highly alkali resistant.

- Naturally occurring asbestos fibers have long been used with cement and water to manufacture pipe and other building components. However, there are significant health hazards associated with the production and handling of asbestos fiber.

- Most polymeric fibers, such as nylon and polypropylene, have lower elastic moduli than concrete. Therefore, these fibers cannot increase the strength of the composite material and may reduce the strength. They are effective in increasing the impact and shatter resistance of the concrete.

- Kevlar, which is an aromatic polyamide, has both a high tensile strength and a high modulus of elasticity and shows considerable promise as a reinforcement media, but is very expensive.

- Carbon fibers also have a very high elastic modulus, tensile strength, and cost. Like organic fibers, they are not attacked chemically by the cement.

- Natural organic fibers, such as sisal and jute, are cellulosic compounds and may not be suitable for use. They have low tensile strengths and elastic moduli and tend to deteriorate in damp or alkaline environments. Additionally, their ability to potentially support bacterial activity prevents their usage.

- Typical properties of these fibers are shown in Table C-4.

The direct tensile strength of concrete can be increased considerably by the addition of appropriate fibers. The increase is dependent on the aspect ratio of the fibers. The effects on flexural strength are less clear. Some investigators (Mindess and Young 1980) have found both an increase in the first crack strength and in the ultimate strength, the latter being up to three times the strength of plain concrete. A real advantage of fiber-reinforced concrete is that a certain amount of flexural strength can be relied upon, even after some cracking of the matrix occurs.

A limitation of the information database is the behavior of fiber-reinforced concrete under elevated temperatures and radiation flux. Arguably, little impact may be measured for a steel-reinforced concrete. The behavior of other materials, including organic-based compounds, may be less resilient under the high temperature and radiation environment of the waste emplacement drifts, as discussed below.

Table C-4. Typical Properties of Fibers and Cement Matrix

Fiber	Diameter (Thousandths of an inch)	Specific Gravity	Modulus of Elasticity (GPa)	Tensile Strength (GPA)	Elongation at Break (%)
Asbestos	0.02 - 20	2.55	165	3 - 4.5	2 - 3
Glass	9 - 15	2.60	70 - 80	2 - 4	2 - 3.5
Graphite	8 - 9	1.90	240 - 415	1.5 - 2.6	0.5 - 1.0
Steel	5 - 500	7.84	200	0.5 - 2.0	0.5 - 3.5
Poly-propylene	20 - 200	0.91	5 - 77	0.5 - 0.75	20
Kevlar	10	1.45	65 - 133	3.6	2.1 - 4.0
Sisal	10 - 50	1.50	—	0.8	3.0
Cement matrix	—	2.50	10 - 45	$3 - 7 \times 10^{-3}$	0.02

C.3.1 Temperature Effects on Concrete

The review of temperature effects on concrete in Appendix A of *Repository Ground Control Evaluation* (CRWMS M&O 1995a) found that:

> At temperatures below 300°C, Portland cement does not lose enough strength (unconfined compressive strength) to necessitate the substitution of a more thermally resistant material. Consequently, Portland cement-based concrete with "standard" aggregate should be adequate for all concrete used for ground support.

The *Repository Ground Control Evaluation* (CRWMS M&O 1995a) also reported that strength loss of concrete at temperatures below 300°C is only about 10 to 15 percent. This lower strength level is expected for the repository preclosure lifetime if the concrete is shown to be durable during the initial months after exposure to elevated temperatures. The finding that concrete degradation occurs within the first few months following waste disposal (or at least after significant temperature rise) suggests that a testing program to determine concrete performance could be carried out relatively early in the program.

In regard to blast cooling of emplacement drifts, a cycle of heating and cooling (from about 200°C to 50°C in a matter of hours) is expected to result in a maximum strength loss of about 25 percent, indicating that (even though the results are conservative for repository conditions) repeated cycles of cooling and heating should be avoided.

If it is necessary or desirable to increase the strength and durability of concrete beyond the level currently estimated to be acceptable for repository emplacement drifts, the following approaches can be considered:

- Using a low water-to-cement ratio
- Adding reactive silica (for example, silica fume or rice hull ash)
- Using organic water-reducing admixtures
- Using high-alumina cement (for temperatures exceeding 300°C).

A Portland cement/fly ash waste-disposal form has been developed for low-level radioactive materials. This product has mechanical, thermal, and radiation stability and relatively low actinide and fission leachability (CRWMS M&O 1995a, Appendix A, Section 3.6).

C.3.2 Radiation Effects on Concrete

Although the exposure of concrete to elevated gamma and neutron fluxes can lead to measurable deterioration, numerous studies have defined the radiation exposure limits of concrete that do not result in significant loss in, for example, compressive strength. These limits are below the reasonably predicted radiation exposures for concrete within the waste emplacement drifts during the retrieval period.

Nuclear radiation can result in lattice defects within crystalline material, causing an increase in brittleness. Formation of additional cross linking can also lead to embrittlement in polymers. Ionized radiation may cause the loss of free or bonded water decreasing the hydraulic bonding strength. Finally, radiation may lead to the breakdown of atomic bonds. Attenuation of the radiation by the material often causes its internal temperature to increase. As previously discussed and as documented within the studies cited below, elevated temperature caused by radiative heating may be an important mechanism causing a loss in concrete strength, perhaps the predominant strength-loss mechanism.

Granata and Montagnini (1972) showed that Portland cement-based concrete with a limestone aggregate was resistant to integrated neutron fluxes of the order of 10^{19} n * cm^{-2}. These specimens displayed limited loss in compressive strength after exposure and concomitant heating to 125°C. Samples that were exposed to an integrated neutron flux of 10^{20} n * cm^{-2} were essentially destroyed.

Elleuch et al. (1972) also measured the effects of neutron flux on the properties of high-alumina cement-based concretes. They subjected serpentine aggregate-bearing concretes to integrated irradiation fluxes (or fluence) of 2×10^{19} to 20^{20} n * cm^{2} at energies above 1 Mev and at temperatures on the order of 200°C. Compressive strengths were shown to be the same or only slightly diminished relative to those that experienced only thermal cycling in the absence of irradiation. Although not directly a part of their study, these researchers also simultaneously exposed the same concrete specimens to a gamma flux exceeding 1×10^{11} rads, resulting in no measured deterioration of compressive strengths.

Hilsdorf et al. (1976) summarized the results of several gamma and neutron irradiation concrete exposure studies and concluded that most concretes are resistant to deterioration by neutron fluxes of less than 10^{19} n * cm^{2}. They report that Houben (1969) recommends the following maximum irradiation fluxes for prestressed-concrete reactor vessels for a 30-year life:

- Thermal neutrons: 6×10^{19} n * cm^{-2}
- Fast neutrons: 2 to 3×10^{18} n *cm^{-2}
- Gamma radiation: 1×10^{11} rads.

Importantly, Hilsdorf et al. (1976) document that various aggregates that enhance the shielding capacity of concrete (to protect workers) also enhance the concrete's resistance to radiation mediated deterioration. Aggregates used in concrete are selected to attenuate either gamma or neutron radiation. Increasing the density of a concrete of a given thickness increases the attenuation of gamma radiation. Consequently, dense (or high specific-gravity) aggregates are selected. High specific-gravity aggregates that may be used include barite, magnetite, ilmenite, hematite, ferrophosphorus, ferrosilicon, and iron or steel shot or punchings. Use of these materials is not without operational considerations. For example, the difference in the density between these materials and the rest of the concrete can lead to segregation upon placement. Ferrophosphorus also tends to generate hydrogen gas upon reaction with the Portland cement, an issue that would have to be addressed during design and operations.

Neutrons are attenuated by hydrogen-bearing compounds. Water is an effective attenuating component of neutrons; however, concrete frequently does not contain sufficient water to result in neutron capture. Consequently, appropriate aggregates are needed. Neutron-attenuating aggregates that contain hydroxyl groups to aid in neutron capture include limonite, goethite, bauxite, and serpentine. When hydrogen absorbs thermal neutrons, high-energy gamma radiation is released, which also must be attenuated. Boron is an effective absorber of neutrons and also results in the production of relatively lower energy gamma rays. Thus, various boron-containing compounds may be used to develop neutron-shielding concrete. These boron-containing forms include boron glass, borocalcite, colemenite, ferroboron, boron carbide, and boron frit. Water-soluble boron compounds can act as a strong set inhibitor to cementitious reactions, a problem that would have to be addressed (for example, by using a set accelerator). Descriptions of radiation-shielding aggregates and their standard specifications are presented in ASTM C638-84 and C637-84, respectively.

Gamma radiation field strength at concrete surfaces within the waste emplacement drifts is conservatively estimated at 10 (R/hr) (rems per hour) from a typical package. Based on an integrated exposure over 144 years (YMP 1994, Section 6.2) and assuming no decay, this results in an integrated exposure of 1.23×10^{7} R at the concrete surface. This exposure is four orders of magnitude below an approximate threshold of 1×10^{11} R, above which, the measurable degradation of concrete is predicted.

Radiolysis can occur upon elevated exposure of water to gamma radiation. Elleuch et al. (1972) measured 6,362 cm^3 of gas per kilogram of irradiated concrete. Hilsdorf et al. (1976) report that the gas evolved from irradiated concrete consists of hydrogen, oxygen, nitrogen, carbon monoxide, and carbon dioxide. They report that this gas development has minimal effect on concrete properties.

This discussion has emphasized that sulfate-reducing bacteria are obligate anaerobes and that free oxygen is lethal to their existence. The findings of Cember (1983) document that the production of free radicals and oxygen (and oxygenated) compounds due to gamma radiation may impede this type of bacterial development. This is in addition to the potentially lethal irradiated environment of the waste emplacement.

When pure water is irradiated the following reaction occurs:

$H_2O = H_2O^+ + e^-$, with the positive ion immediately dissociating according to the equation:

$H_2O^+ = H^+ + OH$, while the electron is picked up by a neutral water molecule:

$H_2O + e^- = H_2O^-$, which dissociates immediately by the following reaction:

$H_2O^- = H + OH^-$

The free radicals H and OH may combine with like radicals, or they may react with other molecules in solution. For example, the OH free radicals may combine together to form hydrogen peroxide:

$OH + OH = H_2O_2$

Whereas the above reactions produce free radicals with half lives on the order of a microsecond, hydrogen peroxide, being a relatively stable compound, persists long enough to diffuse to points remote from its point of origin. The hydrogen peroxide, which is a powerful oxidizing agent, can thus affect molecules or cells that did not suffer direct radiation damage. If the irradiated water contains dissolved oxygen, the free hydrogen radical may combine with oxygen to form the hydroperoxyl radical, $H + O_2 = HO_2$, which is not as reactive, and therefore has a longer lifetime, than the free OH radical. This greater stability allows the hydroperoxyl radical to combine with a free hydrogen radical to form hydrogen peroxide, thereby further enhancing the toxicity of the radiation. The dissociation of hydrogen peroxide by the reaction, $2H_2O_2 = 2H_2O + O_2$, results in a strongly oxygenated solution lethal to SRB.

C.3.3 Biological Effects on Concrete

A concern has been expressed regarding the potential for bacterially mediated attack of sulfuric acid on the concrete components used for ground support. The basis for this concern seems to stem from the attack by sulfuric acid on a concrete cooling tower located in a New Zealand geothermal field. Sulfuric acid is generated from the bacterially mediated oxidation of reduced sulfur species, presumably primarily hydrogen sulfide gas. Hydrogen sulfide gas may be derived from the geothermal brines. Sulfuric acid corrosion of concrete components is also well established in the crowns of concrete sewer tile. Bacterially produced hydrogen sulfide gas emanating from the stagnant sewage collects in the moisture along the crown of the tile. There the hydrogen sulfide gas is oxidized to sulfate ion along with the production of acid. Severe corrosion of the concrete can result in this situation.

The predominant dissolved phase of sulfide ion will depend on the pH condition of the aqueous solvent. At pH conditions less than about 7, hydrogen sulfide (H_2S) will be the predominate dissolved form of sulfide ion. At pH conditions from 7 to 14, bisulfide ion (HS^-) will be the predominant dissolved sulfide phase. However, *hydrogen sulfide*, as used in this text, will denote total sulfide concentration (or thermodynamic activity of sulfide ion), partially for readability of this text but also because the specific pH conditions that may exist at any given moment or location are uncertain.

Eglinton (1987) emphasizes that oxygen must be deleted to promote sulfuric acid chemical deterioration of concrete. Loss of oxygen is required for the initiation of bacterial sulfate reduction. Even within the organic-enriched sewer environment, diffusion of atmospheric oxygen can prevent the production of bacterially mediated hydrogen sulfide, preventing potential sulfuric acid damage to the concrete.

Attack of concrete by sulfuric acid is only documented in cases where anaerobic sewer conditions prevail or where concrete is in direct contact with sulfidic soils or rock (Mindess and Young 1980; Eglinton 1987). The literature does not describe any cases where concrete is attacked by oxidized hydrogen sulfide in the absence of organic wastes, extrinsic hydrogen sulfide, or pre-existing sulfide minerals.

Literature describing bacterial degradation beyond that within stagnant sewers is lacking, which suggests that bacterially mediated deterioration of concrete is isolated. Concrete is often exposed to warm, organic-rich conditions. In spite of these favorable conditions, measurable bacterial degradation is not recognized. Under certain inorganic chemical conditions, organic acids can cause concrete deterioration. However, Portland cement-based concrete is also often resistant to attack by various organic acids. For example, Eglinton (1987) reports that Portland-cement concrete tanks have a reasonable life when used to store fermentation products that contain butyric, lactic, and acetic acids (among others). These acids are present in fodder silage, and the precast concrete staves used in the construction of the silos are generally made with ordinary Portland cement. Similarly, tanks made with ordinary Portland- cement concretes are used to distill residues containing lactic, acetic, and other acids. Presumably, bacterial activity should be maximized in these warm, organic-rich conditions, yet no reports of serious bacterially mediated attacks are documented.

Portland-cement concrete is also successfully used in manure trenches, such as those in barns, without bacterially mediated deterioration. The absence of severe bacterial attack under these warm, wet, organic-rich conditions further argues that bacterial deterioration of concrete is not a widespread process nor is it inevitable.

The potential for sulfuric acid attack of concrete can be evaluated by examining plausible sulfur cycles and assessing the applicability to the waste repository. The following analysis will show that sulfuric acid attack is very unlikely to occur because (1) the conditions at the site are not conducive to hydrogen sulfide production and (2) empirical evidence demonstrates that hydrogen sulfide production does not occur within saturated concrete.

The sulfuric acid attack discussed herein is differentiated from the more typical sulfate deterioration that may occur when Portland cement-based products encounter unacceptably elevated sulfate concentrations. The distinguishing factor between these two degradation mechanisms is that sulfuric-acid attack, in addition to potentially resulting in sulfate deterioration of the concrete, is characterized by acid dissolution of the cementitious calcium silicates, aluminate, and ferrite phases. Expansive ettringite attack may also simultaneously occur with the sulfuric acid dissolution of the concrete. Expansive ettringite attack can also occur under neutral or even alkaline conditions. Ettringite attack can be mitigated by using the appropriate type of sulfate-resistant Portland cement and a low water-to-cement ratio in the concrete formulation.

Sulfuric acid attack requires the presence of a reduced sulfur phase (having a valance less than S^{+6}), for example, hydrogen sulfide. Hydrogen sulfide can be abiotically or biotically produced. Abiotic production requires elevated temperatures, such as in geothermal systems. Elevated temperatures are required for abiotic reduction of sulfate ion to the sulfide form, due to the kinetic inhibition of sulfate ion from participating in the oxidation/reduction reaction at temperatures below about 250°C (a temperature above the maximum predicted for the waste emplacement drifts). Production of sulfide ion from a sulfate source requires bacterial production at temperatures less than 250°C due to the kinetic limitation of sulfate ion. Because most bacteria are rendered inactive at temperature above about 80°C and are killed above 121°C, limited sulfide production occurs within the temperature range of about 80°C to 250°C.

Because biotic sulfide production requires anaerobic conditions, oxygen that is present must be eliminated by rapid metabolic activity or limiting its transport or both. Rapid metabolic activity uses substantial amounts of readily metabolizable organic carbon or carbon dioxide and other required nutrients. Transport of oxygen in the subsurface (for example, through sediment or rock) is inhibited by saturated water conditions. Oxygen diffusion is slowed by a factor of 10,000 times by saturated or even near-saturated conditions in the subsurface relative to its diffusion in the atmosphere due to the formation of water-filled pore connections. Consequently, it follows that bacterial sulfide production is maximized in high-organic, saturated environments. A further requirement is a large or renewable sulfate reservoir. Without a large or renewable sulfate reservoir, sulfide production slows and ultimately ceases as the sulfate ion is consumed.

The conditions that promote sulfide-ion production were examined to assess the likelihood that sulfuric acid will be generated in the waste emplacement drifts. The waste emplacement drifts and surrounding area are not saturated. Additionally, organic carbon concentrations are low or nonexistent, depriving SRB of its necessary carbon source. Because the fundamental requirements for bacterially mediated sulfide production do not exist in the host formation, it is extremely unlikely that sulfur-metabolizing bacteria will colonize the area. Consequently, only the potential for sulfide generation within the waste emplacement drifts must be evaluated.

The waste emplacement drifts lack significant metabolizable organic carbon. Organic carbon-based components are specifically limited in use to minimize this potential. Additionally, minimal water is anticipated within the waste emplacement drifts, which will prevent large volumes of saturated material from developing.

Assuming that saturated conditions do develop within a concrete invert, empirical evidence suggests that hydrogen sulfide is still unlikely to form. Portland cement does contain a small amount of sulfate; gypsum is added to the components during the manufacturing process to regulate the cement's setting characteristics. However, despite the presence of sulfate ion and possible saturated conditions in the concrete, intrinsic hydrogen sulfide production is unknown in concrete. This is the case even for submerged concrete. Oxidized conditions are maintained in concrete, even under saturated conditions, because sulfidization or corrosion of reinforcement steel does not occur. This reinforcement steel commonly .retains an oxide coating when encased within the concrete, documenting both oxidizing conditions and the absence of hydrogen sulfide (or a dissolved sulfide ion form) which would quickly react with the ferric oxide to form a iron sulfide phase (such as mackinawite or greigite and ultimately transforming into pyrite) (Berner 1972).

An intrinsic sulfide source in the concrete will be prevented by limiting the sulfide content of the aggregate used in the formulation of the concrete, a standard industry practice (Eglinton 1987).

To combat the effect of bacteria on concrete, numerous bacteriocidal admixtures have been developed (Ramachandran 1984). Materials that are the most effective in imparting bacteriocidal properties include polyhalogenated phenols, sodium benzoate, benzalkonium chloride, and copper compounds. Addition rates range from 0.75 to 10 percent, by weight, of cement. An elevated concentration of copper is required to kill SRB because hydrogen sulfide precipitates otherwise toxic soluble copper as insoluble and less-toxic copper sulfides. Ramachandran (1984) reports that these compounds result in the destruction of microorganisms both on the concrete surface and within the matrix. The admixture's effectiveness is dependent on the method of incorporation into the mix. For example, polyhalogenated phenols should be incorporated into the cement prior to blending into the concrete mixture to ensure long-term effectiveness. Use of phenol-based compounds do not adversely impact the strength development of the concrete (Ramachandran 1984).

The primary method of preventing bacterial attack by sulfide oxidation is to prevent the initial bacterial production of hydrogen sulfide, which is best accomplished by continuously maintaining oxidizing conditions within the drift. This process will be facilitated by preventing readily metabolizable organic materials from depositing in the drift and minimizing the development of free-standing water. These preventive activities are planned and will produce reducing conditions. The development of free radicals by radiolysis and the subsequent production of hydrogen peroxide will also limit the development of anaerobic conditions. Bacterial sulfate reduction is not observed to occur in or on concrete in the absence of elevated concentrations of organic matter. Even with elevated organic and carbon concentrations (for example, manure trenches), sulfate reduction may not occur on or within concrete.

If a large amount of Portland cement-based concrete is used in the waste emplacement drifts, the drifts' geochemical and biogeochemical conditions will be impacted. Not only should the potential effect of various bacteria on the concrete be assessed, but also the effect the concrete has on the bacteria that may attempt to inhabit the concrete surface or matrix. Because certain bacteria are sensitive to their environment's pH conditions, the pH-controlling processes that develop within Portland cement-based concrete should be examined.

The hydration of Portland cement results in the sustained production of calcium hydroxide that is available for reaction with pozzolanic materials (Mindess and Young 1980; Popovics 1992). This reaction develops a three-dimensional cementitious framework which gives Portland cement-based concretes their strength. Unreacted calcium hydroxide typically remains in the Portland cement-based concretes. Calcium hydroxide and other alkaline components, including sodium and potassium hydroxides and the aluminosilicates, contribute to Portland cement's residual alkalinity. Portland cement may contain up to 0.5-percent, by weight, free lime in the form of nonchemically combined calcium hydroxide (although this level is not specifically constrained by an ASTM specification) (Mindess and Young 1980). Solutions with weak buffering capacity or that lack extreme acidity and initially come into contact with previously unleached concrete often develop a pH of about 12. High solubility of calcium hydroxide in aqueous solutions also contributes a high ionic strength to the contacting solution. These conditions are not conducive to the growth of certain bacteria.

Although, under certain extreme conditions, bacteria can survive on or perhaps within concrete, a major modification resulting in an acceptable microenvironment is necessary. This modification typically requires the presence of an external source of gaseous hydrogen sulfide or the presence of anomalous amounts of organic carbon, neither of which have been shown to be probable. This fact further argues that deleterious bacterial activity on or within the concrete is unlikely.

Although presently not proposed, various inorganic oxidants are available as admixtures to increase the oxidation capacity of the concrete and to prevent locally reducing conditions from developing. These oxidants would augment the hydrogen peroxide and free radicals produced by radiolysis and the oxidizing capacity of atmospheric oxygen.

The use of strong oxidants or the production of free radicals or hydrogen peroxide would not cause the concrete or reinforcing steel to deteriorate (Elleuch et al. 1972). Concrete is composed of non-electroactive components, with the exception of iron which has a protective oxide coating that is already in its thermodynamically stable oxidized form. The ferric oxide is stable in the presence of hydrogen peroxide and, consequently, would not react with this compound.

As noted earlier, sulfate reduction can develop, under certain conditions, under a ferric hydroxide coating in a water-filled pipe. Using Fick's Law of Diffusion equation-based calculations, boundary conditions for sulfate reduction under a ferric hydroxide mass can be established for a ferric hydroxide coating exposed to the atmosphere under a thin water film. These calculations can quantify the limits of oxygen diffusion and the minimum hydrogen-sulfide production rate. From this information, the bacterial metabolic rate and the associated requirements can be defined.

Because SRB are obligate anaerobes, the complete oxygen consumption by reaction with hydrogen sulfide is required to protect the bacteria. Since oxygen transport is limited by diffusion through a ferric hydroxide layer, a one-dimensional diffusion limited transport model can be used.

From Fick's First Law of Diffusion:

$$J = K\, \partial C/\partial x$$

Where: J = Flux Rate of Diffused Oxygen (In terms of unit mass per unit area per unit time)
K = Effective Diffusion Coefficient (assumed to 1×10^{-6} cm^2/s)
∂C = Change in Concentration of Oxygen (Diffusion Gradient, assumed to be 7 ppm, the solubility of O_2 in 25 °C water)
∂x = Distance of Diffusion (assumed to be 0.3 cm)

Assuming a 1-cm^2 area of ferric hydroxide:

$$J = 1 \times 10^{-6}\, [7 \mu g/cm^3/0.3\ cm]$$
$$J = 2.33 \times 10^{-5}\ \mu g/cm^2/s \text{ or } 2.33 \times 10^{-11}\ g/cm^2/s$$

which translates into 1.46×10^{-12} moles O_2/cm^2/s. Consequently, bacteria must produce at least this rate of hydrogen sulfide to survive. This oxygen diffusion rate through the ferric hydroxide layer is very high, in fact, it is too high to allow the sustained activity of obligate anaerobes, to whom oxygen is poisonous. The production of hydrogen sulfide in nearshore marine sediments, which represent an ideal environment with very high organic content and an abundant sulfate supply, has been measured at 1.8×10^{-14} moles S/cm^3/s (Berner 1972), or two orders of magnitude below that required in the above scenario (assuming a thin sulfate reduction zone) to sustain anaerobic life. The absence of either sulfate or organic carbon within the ferric hydroxide coating would prevent such an accelerated hydrogen-sulfide production rate (as measured in the nearshore marine sediments) from being established or maintained. Even in the unusual event that such a rate could develop, it would be two orders of magnitude too slow to quantitatively consume the available oxygen, thus killing the anaerobes.

In summary, the waste emplacement drifts will ultimately be a hostile environment for sulfate reducing, anaerobic bacteria. Radiation will develop immediately after waste emplacement, followed by lethal heating of the drift. The combined radiation and heat will pose lethal challenges to all bacteria. The heat will dry the drifts, eliminating a water source for the bacteria. Even the most thermophilic bacteria cannot withstand 160°C temperatures. Temperatures exceeding 80°C will develop in the drifts within nominally 25 years after waste emplacement, preventing any bacterial activity for the remainder of the waste retrieval period. Autoclaving, a method of sterilizing laboratory and hospital equipment by super heating it to 121°C for 15 minutes, eliminates bacteria regardless of their metabolic state (Rechart, R., Ph.D., personal communication with Laura Jantz, Morrison-Knudsen, 9 November 1995). Consequently, even in an improbable worst-case condition, bacterial degradation can only occur for a short time immediately after waste emplacement.

C.3.4 Potential Longevity of Concrete

Past research indicates that the waste emplacement drifts will be very hot and radioactive. Recent research has also demonstrated that the predicted heat and radioactivity will not lead to accelerated deterioration of the concrete. Consequently, concrete should not have a shortened performance lifetime.

Concrete and concrete-like products have been used successfully since antiquity (Mindess and Young 1980; Eglinton 1987). Gypsum and lime were the first calcareous materials to be used as mortar cements. The Egyptians used gypsum mortars (by calcining impure gypsum) in the construction of the Pyramid of Cheops (about 3,000 B.C.). Lime mortars were later used in Egypt during the time of the Romans (about 2,000 years ago). The Romans and the Greeks also produced hydraulic limes by calcining limestone that contained argillaceous (clayey) impurities. They also knew that certain volcanic deposits, when finely ground and mixed with lime and sand, yielded mortars that were not only stronger than ordinary lime mortars but also were water resistant. The Roman-constructed Pantheon, perhaps the best preserved building of the ancient world (dating from the second century A.D.), was built primarily of concrete

The quality of cementing materials gradually declined during the Middle Ages; high-quality cementing materials did not reappear until the after the fourteenth century. In 1756, John Smeaton, who was commissioned to rebuild the Eddystone Lighthouse off the coast of Cornwall, England, determined that the best limestones for mortar contained a large proportion of clayey materials. The mortar developed from these limestone allowed the lighthouse to stand for 126 years before it was replaced with a more modern structure. After this discovery, Portland cement developed rapidly through the nineteenth and twentieth centuries, and many structures completed during the nineteenth century are still standing.

The examples given above document that concrete can successfully perform for extended periods of time under a variety of environmental conditions. Direct extrapolation of concrete under any specific set of conditions to the waste emplacement drift environment must be done with caution. For example, an inappropriate analogy of deterioration would be a concrete cooling tower that conveys hydrogen sulfide-bearing gases. The above examples do show that under certain circumstances and lacking known degradation processes, concrete can last for extended periods of time on the order required for the retrievability period.

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APPENDIX D
SURFACE DESIGN

BOUND SEPARATELY

Appendix D contains figures and drawings describing the repository surface design. The figures support the descriptions provided in Section 7 of this volume. For ease of understanding the data, all of the figures that appear in Section 7 are duplicated in this appendix along with design diagrams such as general arrangements (i.e., floor plans, sections, and elevations), flow diagrams, heating, ventilation, and air conditioning zone diagrams, and mechanical equipment details.

The listing that begins below is organized according to the section the figures support. The figures and drawings are listed by number, title, and page number, except for the figures associated with Section 7.2.7. The listing for these figures is categorized by site map reference and includes additional information.

Section 7.1 Overview

Section 7.2 North Portal Area Overview

Section 7.2.2 Waste Handling Building

General WHB Figures

System Flow Figures

Section 7.2.3 Cask Maintenance Facility

General CMF Figures

System Flow Figures

Process Flow Diagrams

General Arrangements

HVAC Flow Diagrams

Section 7.2.5 Carrier Staging Shed

General CSS Figures

System Flow Figure

Mechanical Flow Diagrams

General Arrangements

Section 7.2.6 Transporter Maintenance Building

General TMB Figures

General Arrangements

Section 7.2.7 North Portal Support Structures

Site Map Ref.	Title	Drawing Number	Source
220-5B	Food Service Facility Section	SK-228-A-160	SCP-CDR .. D-188
220-5C	Training Center	Included under 220-5A, Administration Building	
220-1B	Medical Center	None Available	
220-2	Fire Station Floor Plan	SK-228-A-300	SCP-CDR .. D-189
220-2	Fire Station Section	SK-228-A-320	SCP-CDR .. D-190
220-22	Computer Center Plan, Elevations, Section	SK-225-A-201	SCP-CDR .. D-191
220-7	Central Warehouse	None Available	
220-4A	Central Shops Floor Plan	SK-226-A-100	SCP-CDR .. D-192
220-4A	Central Shops Section	SK-226-A-120	SCP-CDR .. D-193
220-4B	Motor Pool and Facility Service Station	None Available	
220-6	Mockup Building Floor Plan and Sections	SK-225-A-400	SCP-CDR .. D-194
N221-2	Utility Building	None Available	
N221-3	Visitors Center Plans, Section and Elev.	4.2.2.21-G1	MRS/MPC . D-195

Section 7.2.8 North Portal Site Support Systems

Section 7.3 South Portal Development Operations

Section 7.4 Emplacement Shaft Surface Operations

Section 7.5 Development Shaft Surface Operations

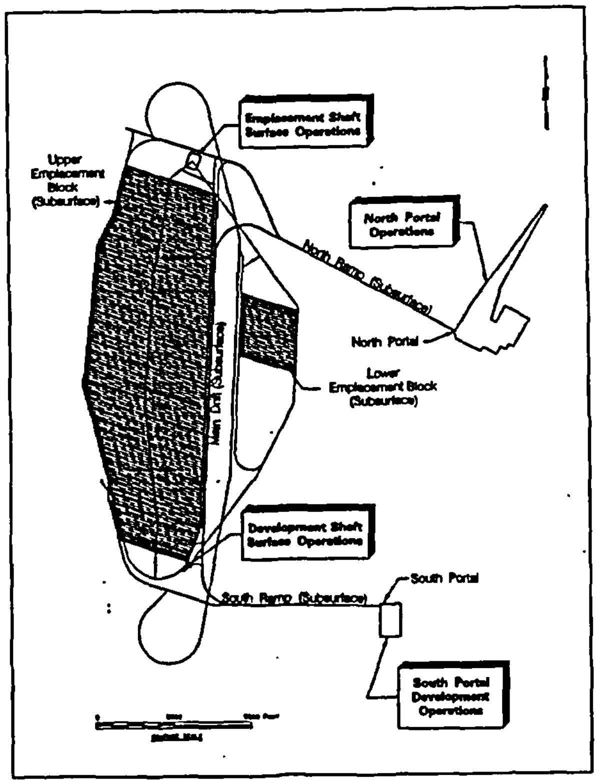

Figure 7.1.1-1. Overall Repository Site Map

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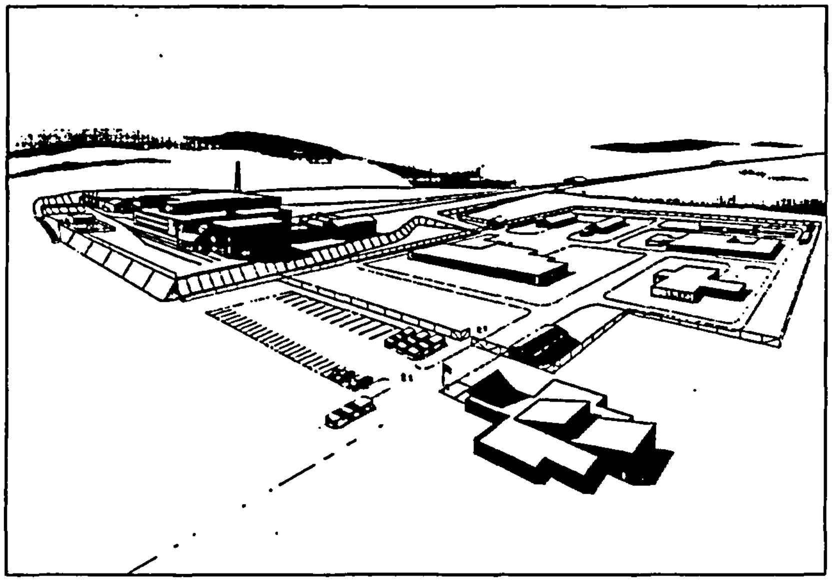

Figure 7.2.1-1. Conceptual Illustration of the North Portal Operations Area.

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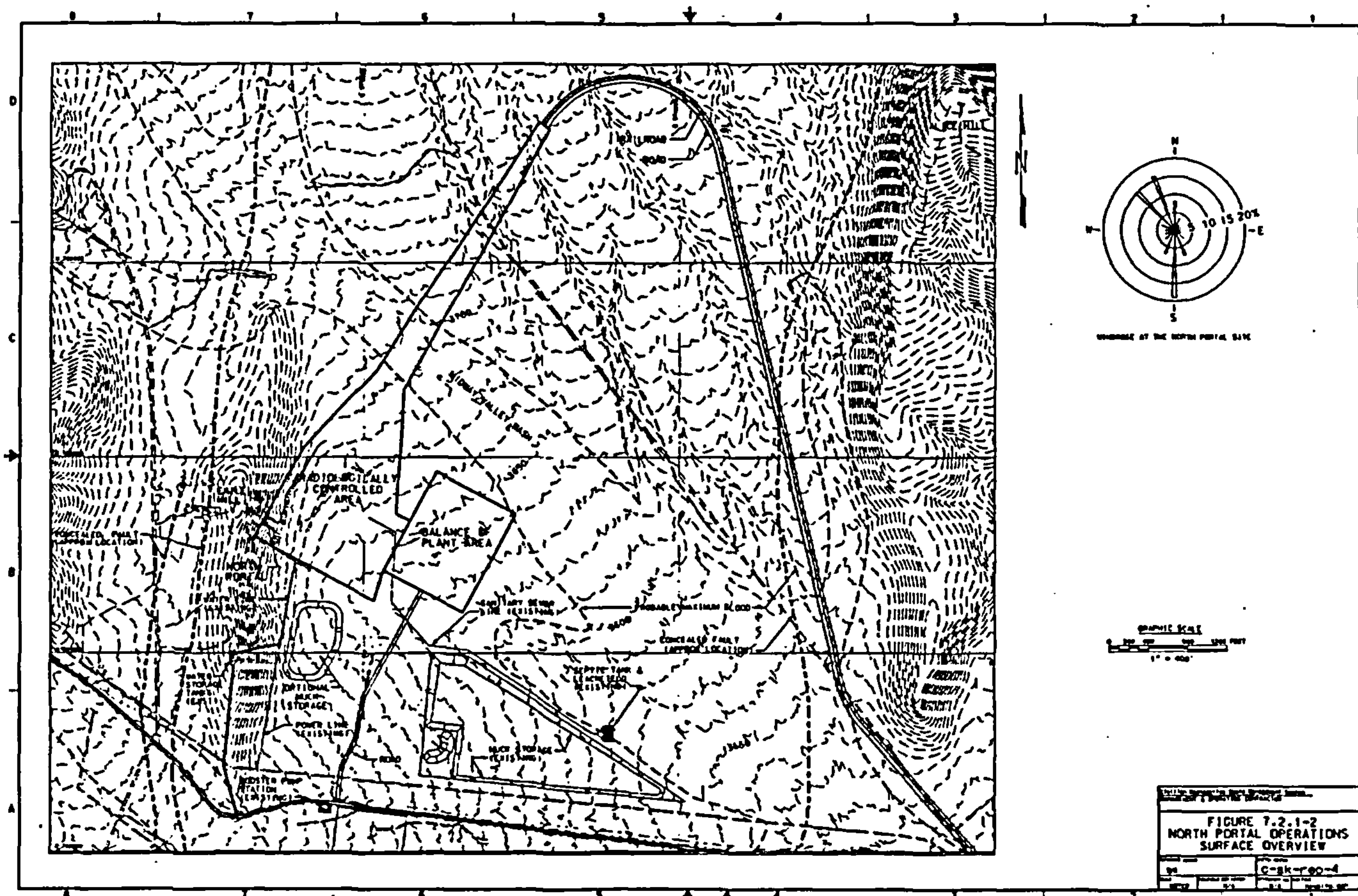

FIGURE 7.2.1-2
NORTH PORTAL OPERATIONS
SURFACE OVERVIEW

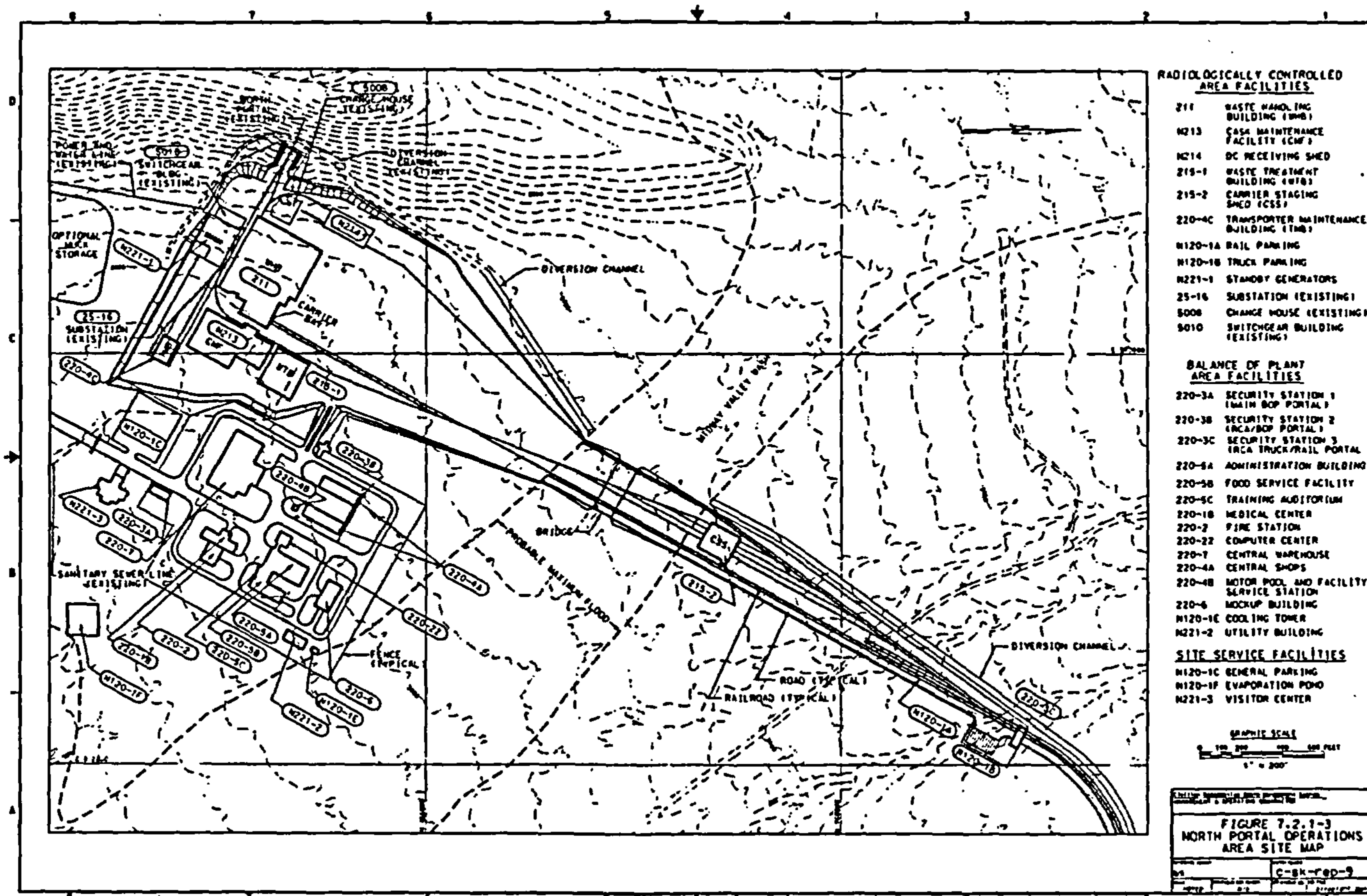

FIGURE 7.2.1-3
NORTH PORTAL OPERATIONS AREA SITE MAP

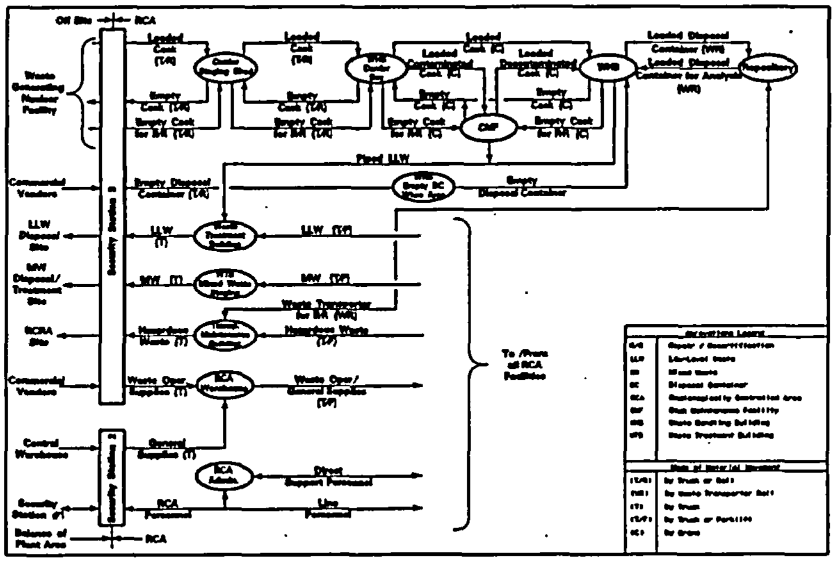

Figure 7.2.1-4. North Portal Operations – RCA Operations Flow

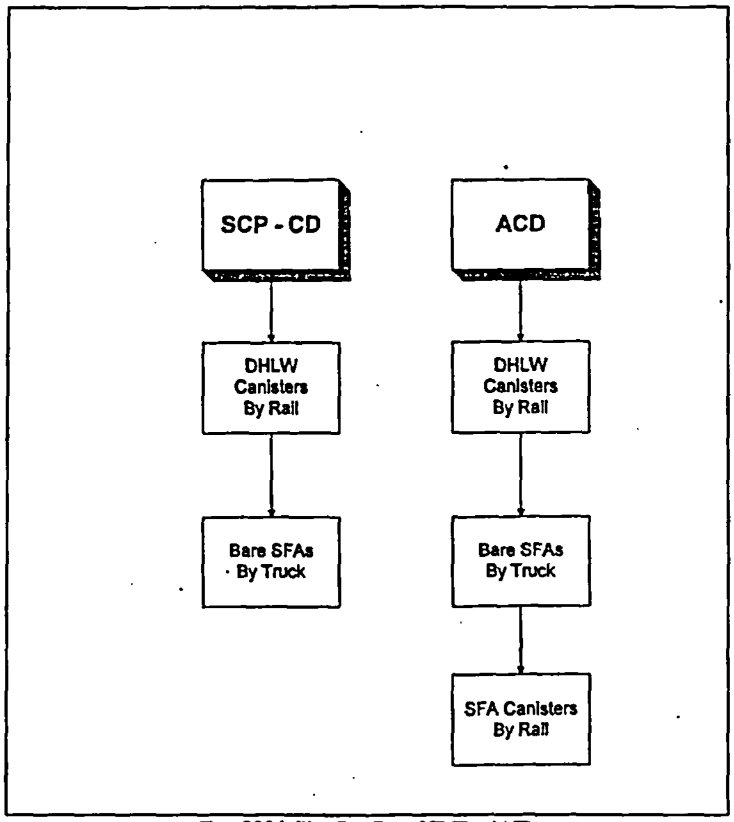

Figure 7.2.2-1. Waste Form Types: SCP-CD and ACD

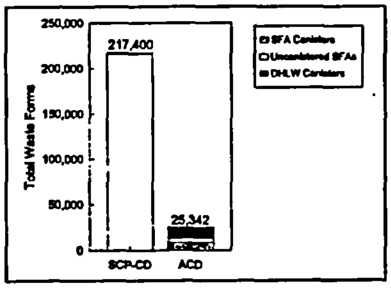

Figure 7.2.2-2. Waste Forms: SCP-CD and ACD

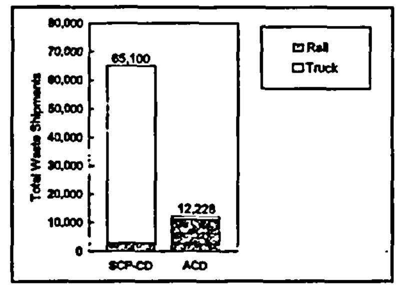

Figure 7.2.2-3. Mode of Transportation: SCP-CD and ACD

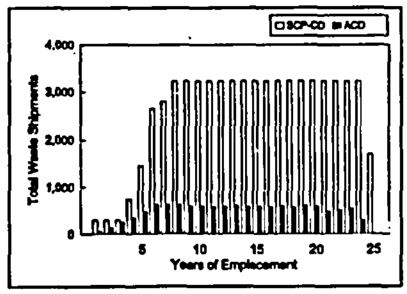

Figure 7.2.2-4. Number of Shipments: SCP-CD and ACD

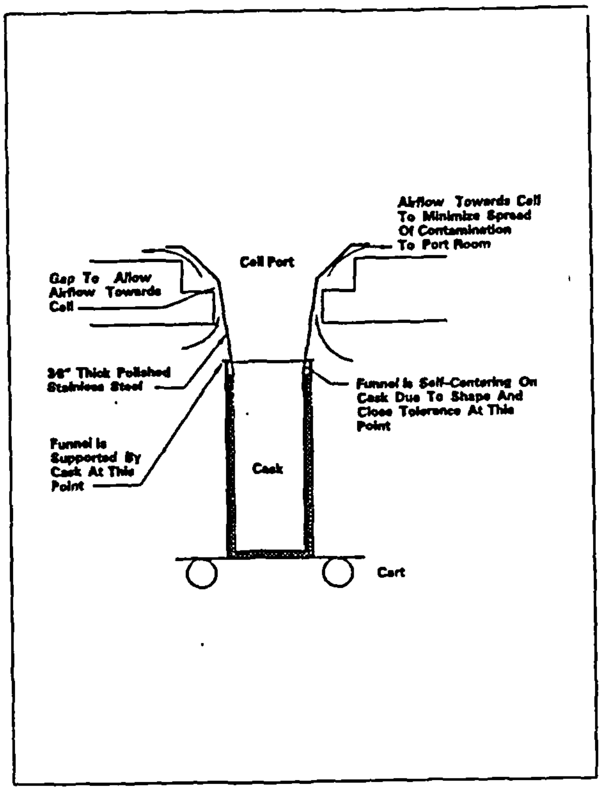

Figure 7.2.2-5 Cask-Cell DC-Cell Interface Method

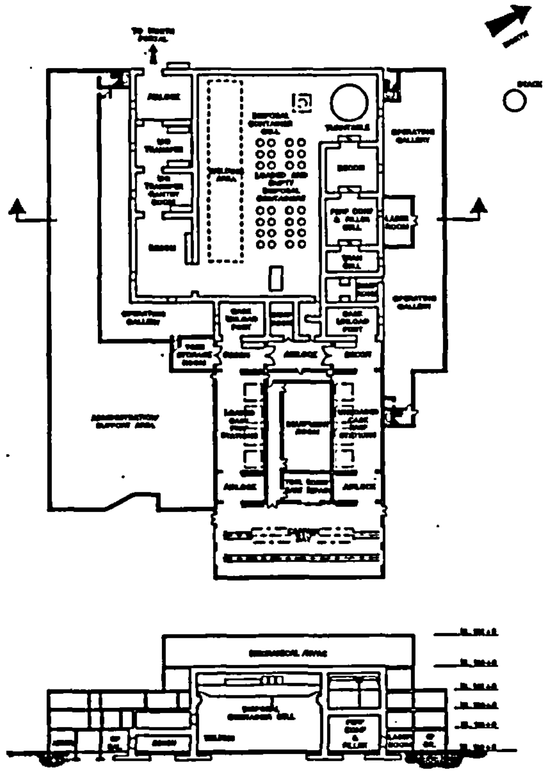

Figure 7.2.2-6. Waste Handling Building (Floor Plan and Building Section)

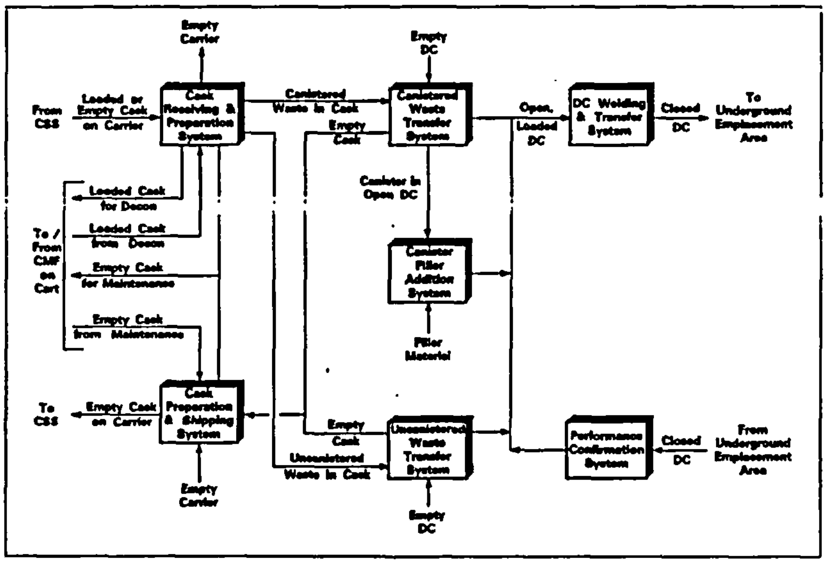

Figure 7.2.2-7. Waste Handling Systems Overview

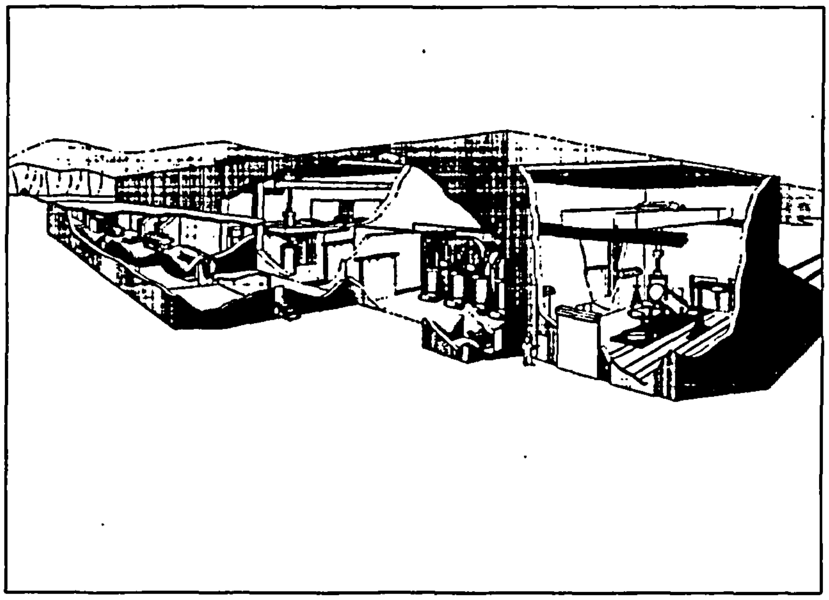

Figure 7.2.2.-8. Cask Receipt and Waste Canister Unloading

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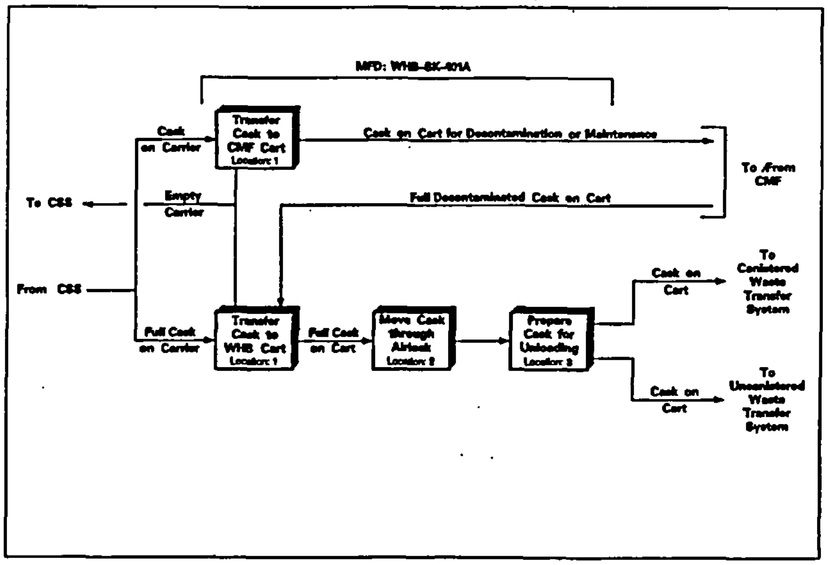

Figure 7.2.2-9. Cask Receiving & Preparation System

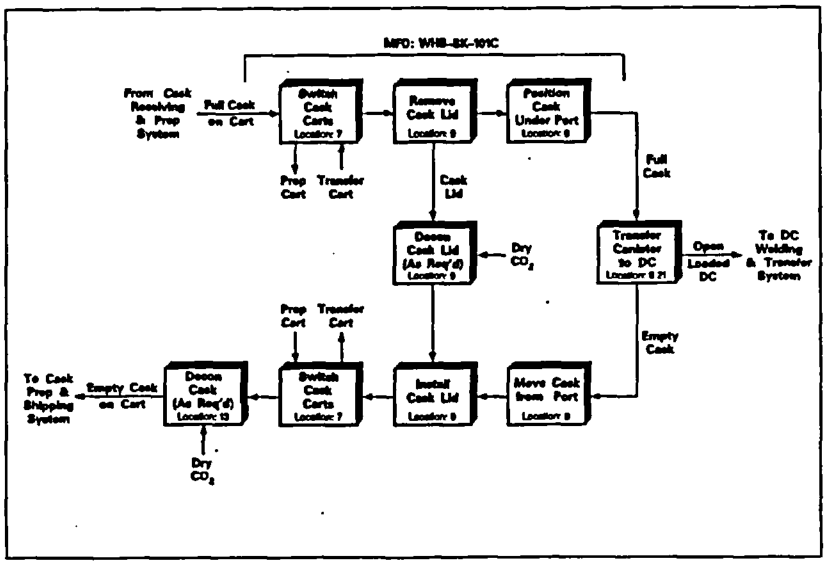

Figure 7.2.2-10. Canistered Waste Transfer System

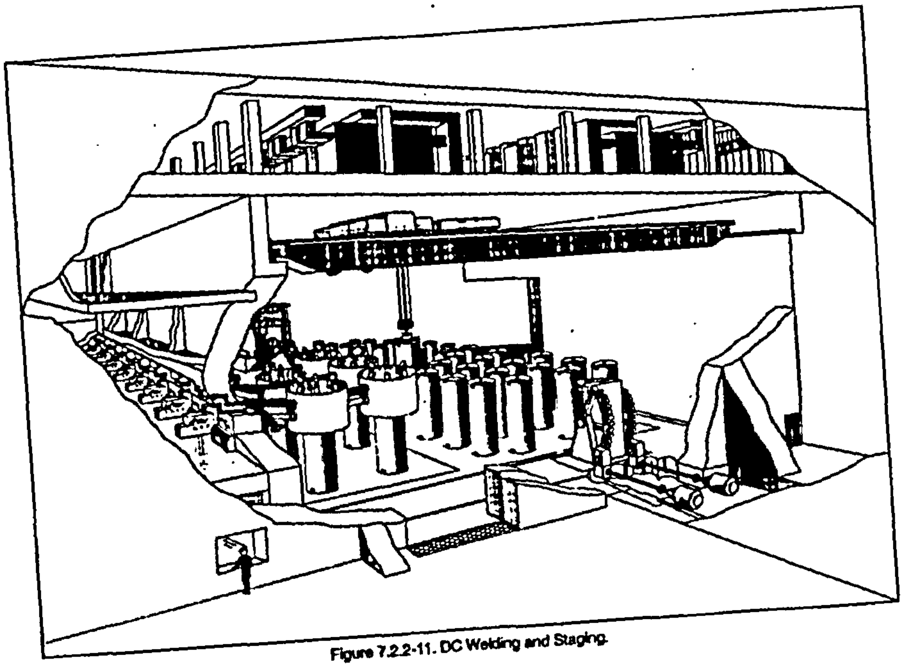

Figure 7.2.2-11. DC Welding and Staging.

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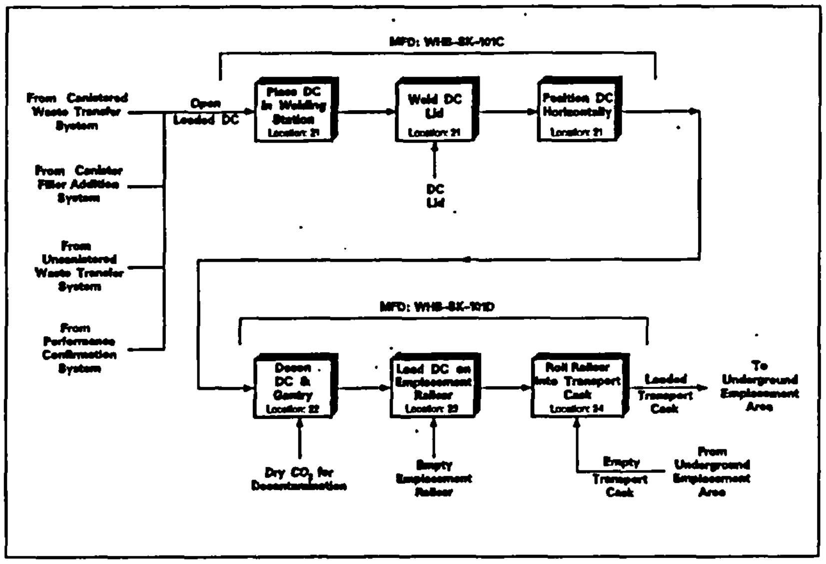

Figure 7.2.2-12. DC Welding & Transfer Systems

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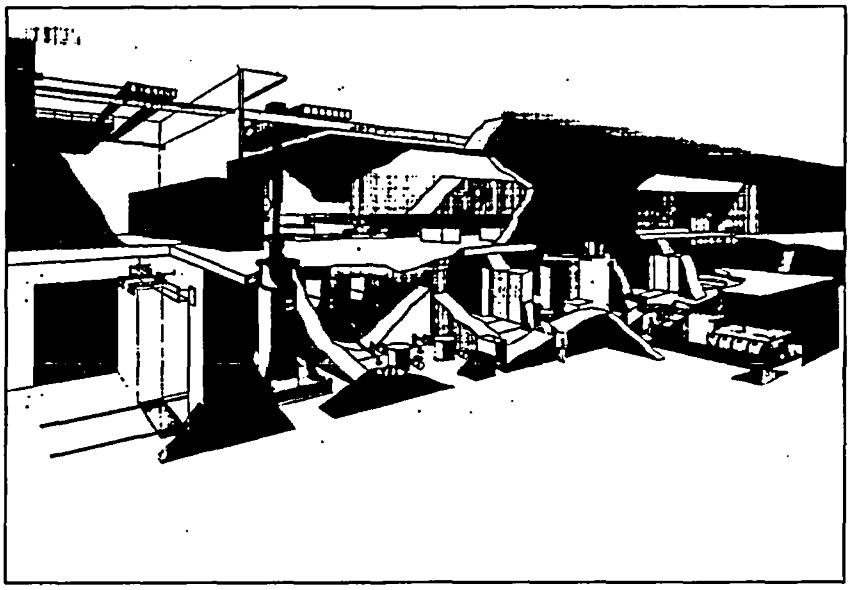

Figure 7.2.2-13. SFA Unloading, Canister Filling and Performance Confirmation.

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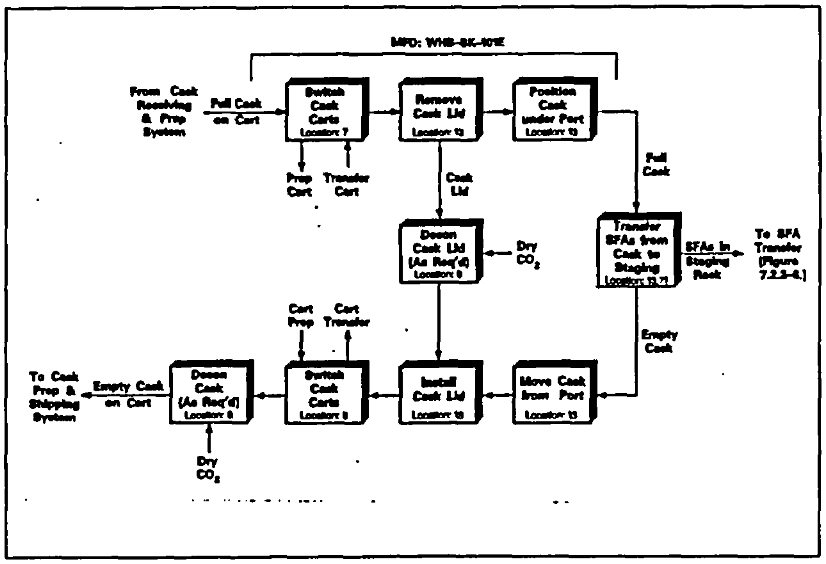

Figure 7.2.2-14. Uncanistered Waste Transfer System (page 1 of 2)

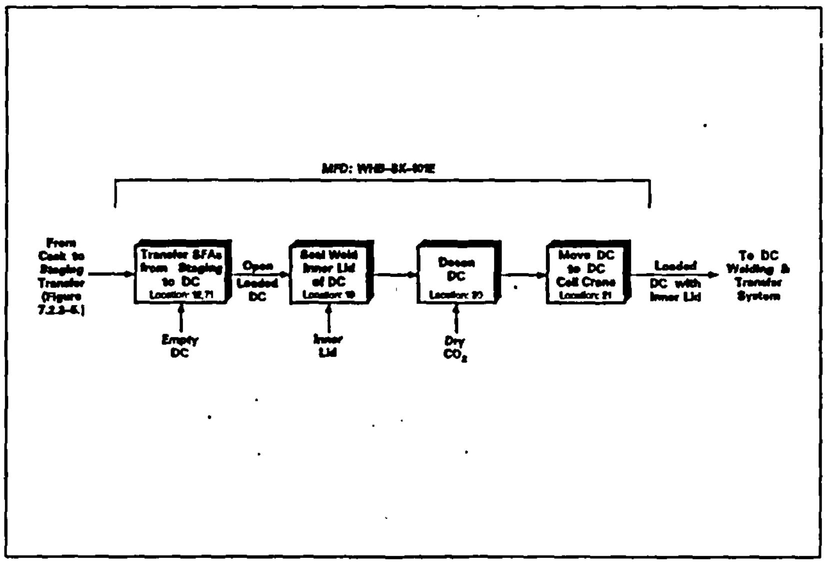

Figure 7.2.2-15. Uncanistered Waste Transfer System (page 2 of 2)

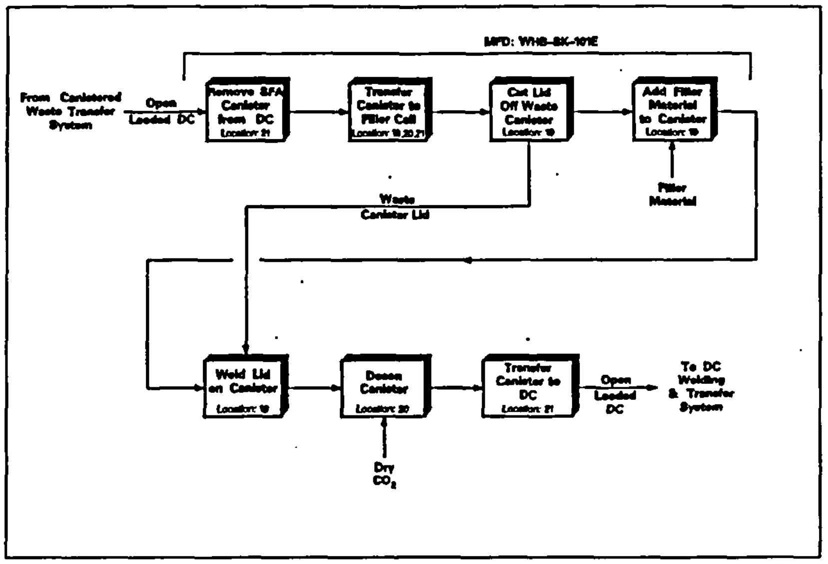

Figure 7.2.2-16. Canister Filler Addition System

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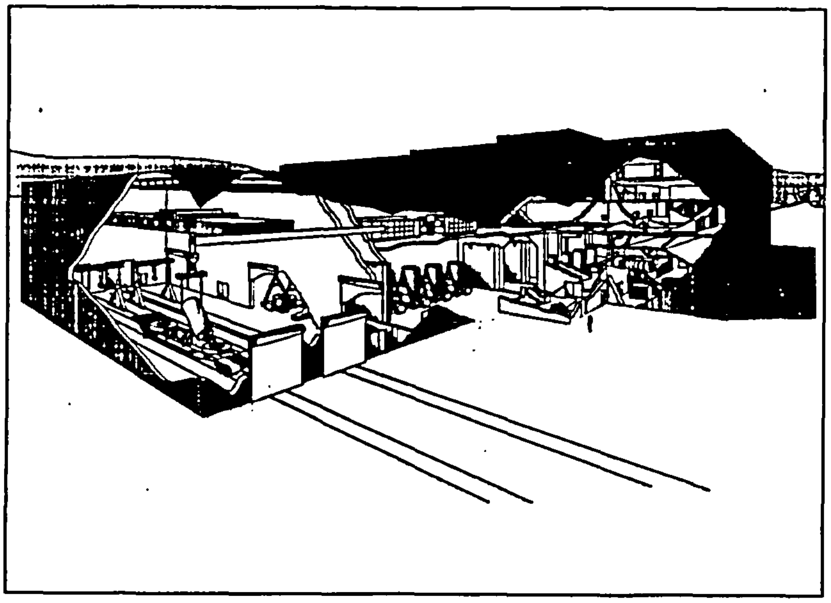

Figure 7.2.2-17. Cask Preparation and Shipping.

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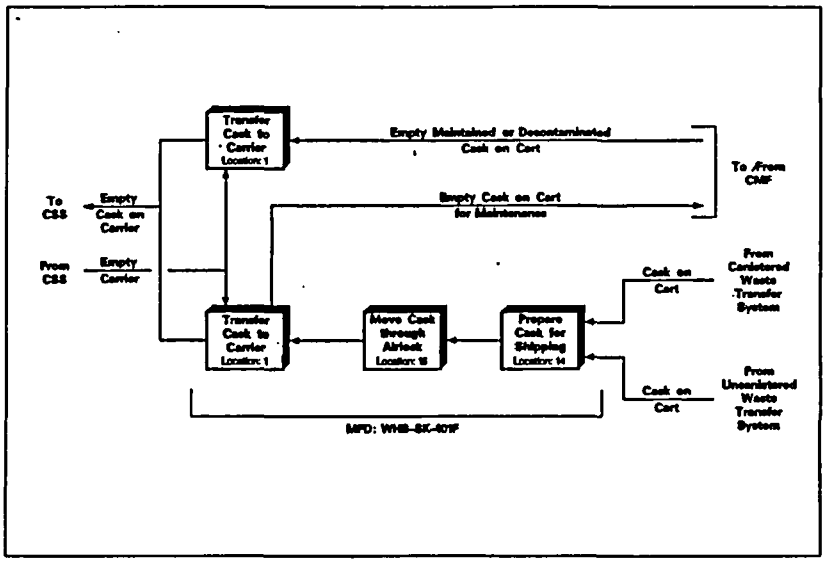
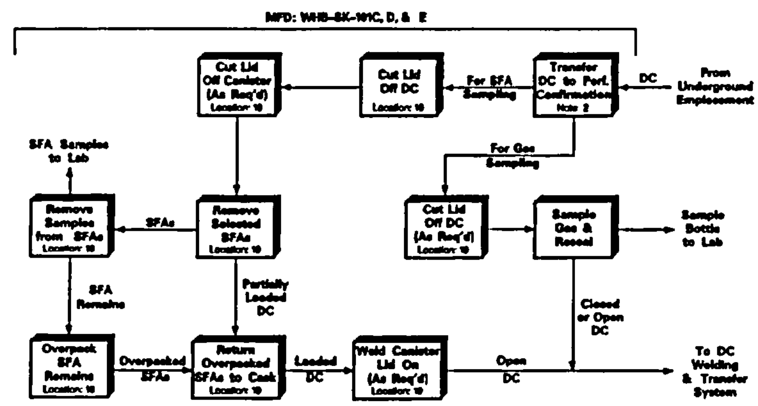


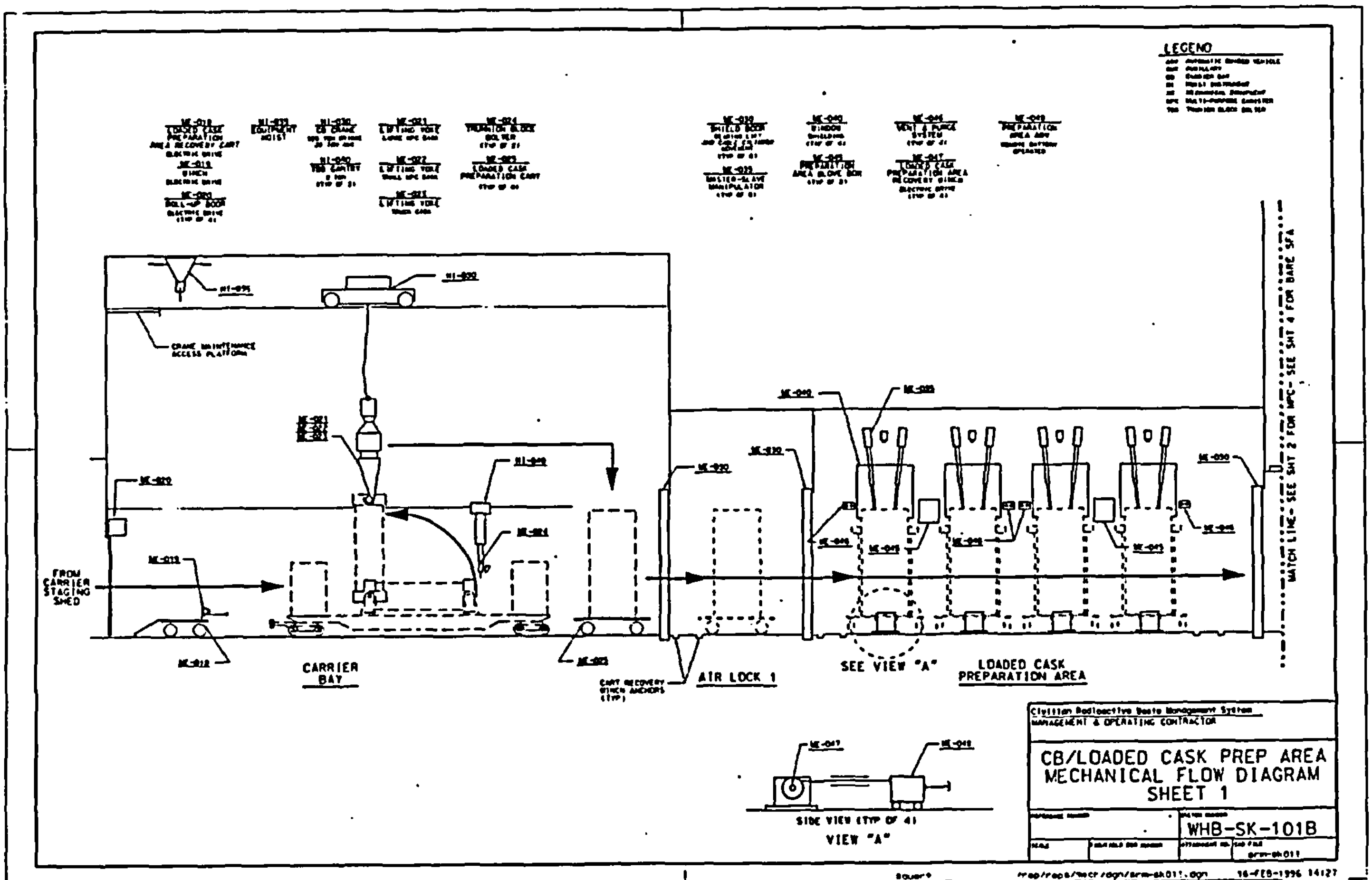
Figure 7.2.2-18. Cask Preparation & Shipping System

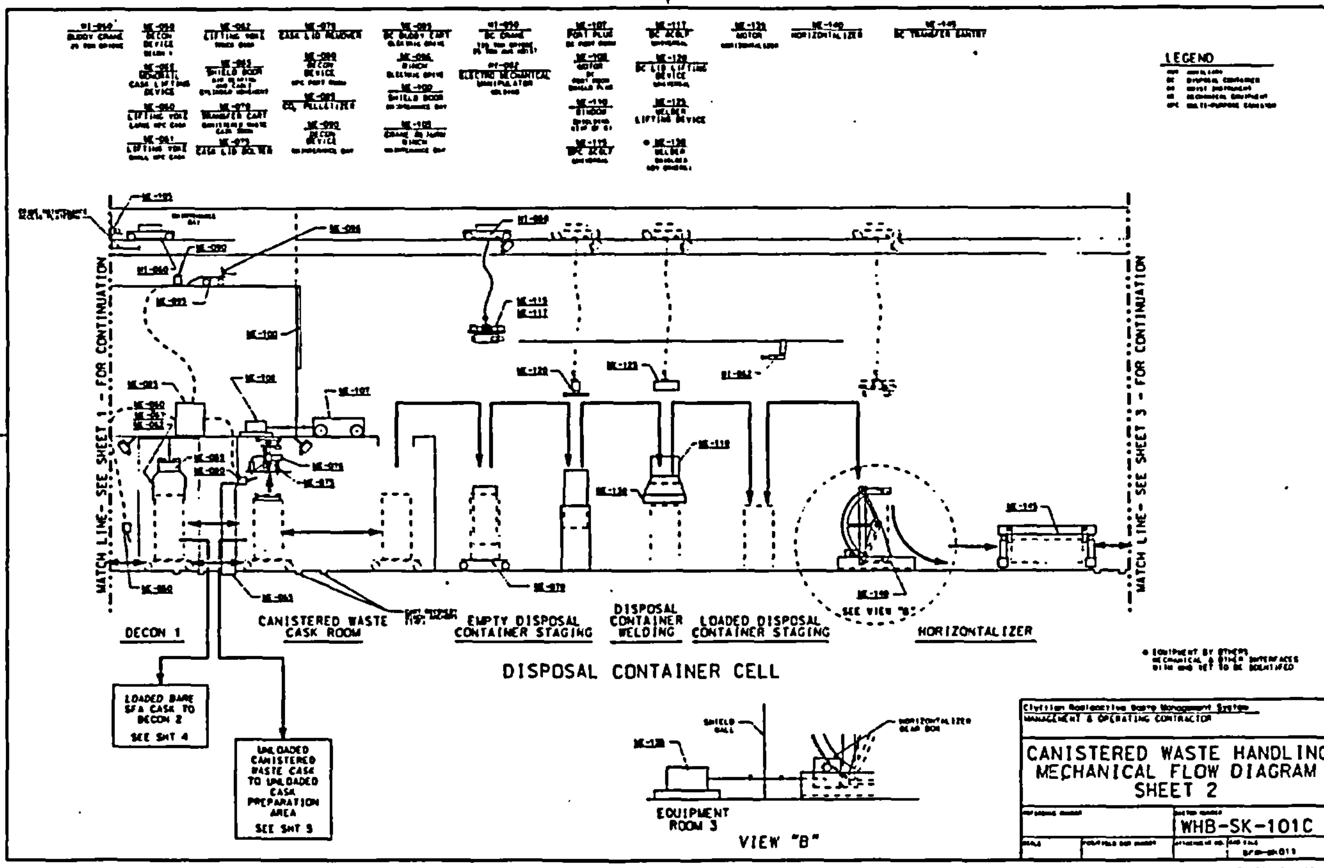


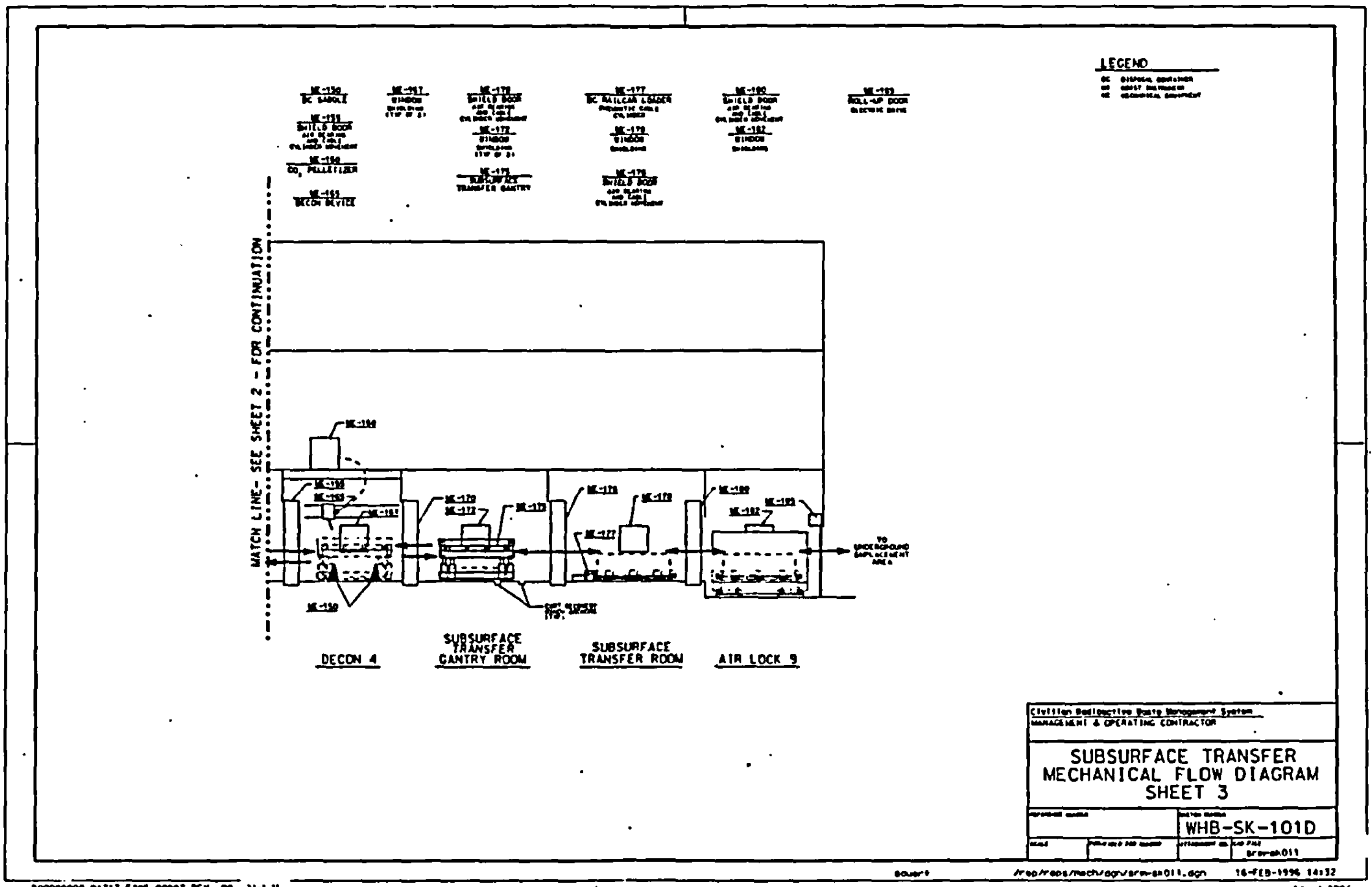
Notes: 1. Nondestructive evaluation measurements will be taken at various stages of DC disassembly.

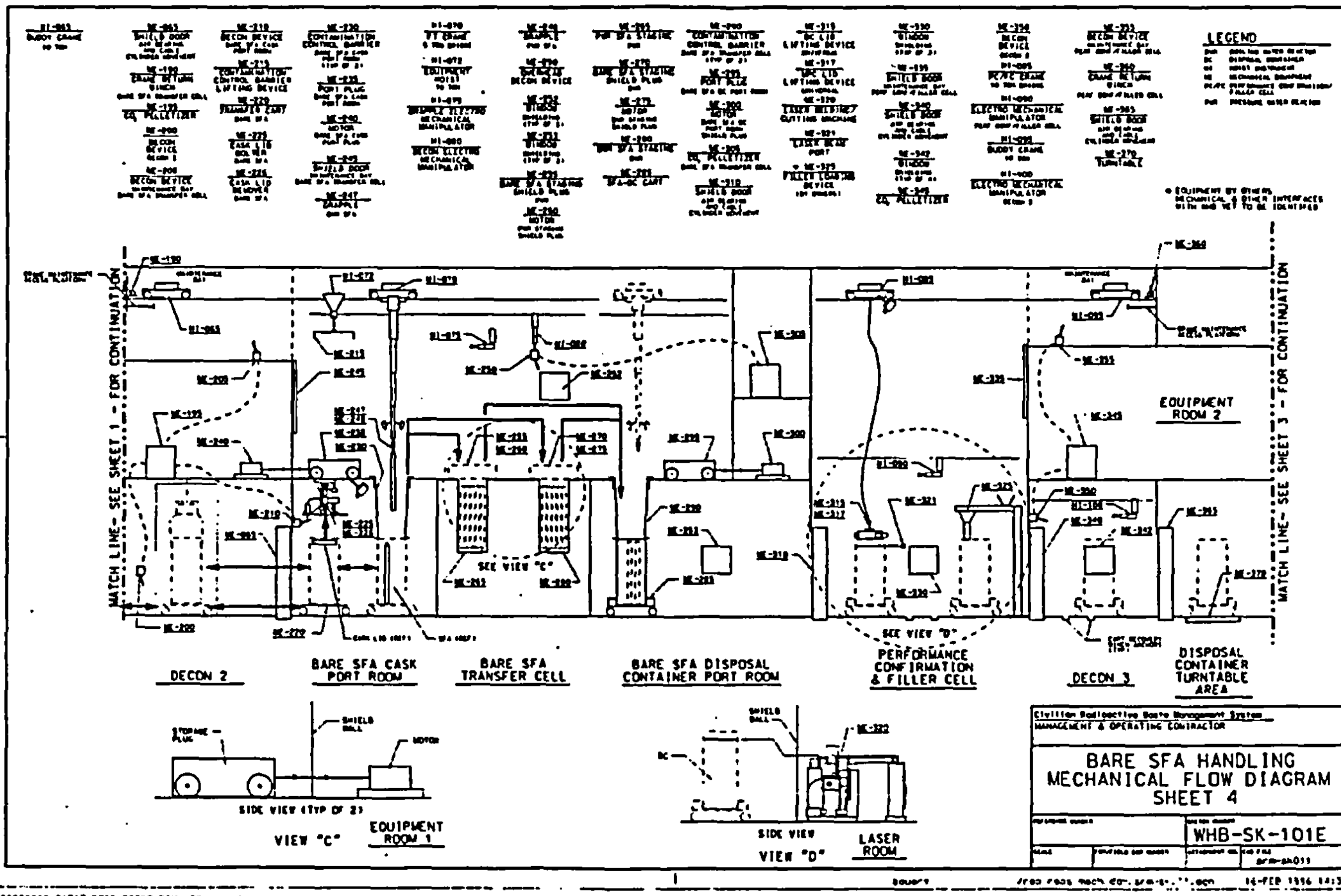
2. Transfer from underground emplacement to performance confirmation cell passes through locations: 19,20,21,22,23,24, & 67.

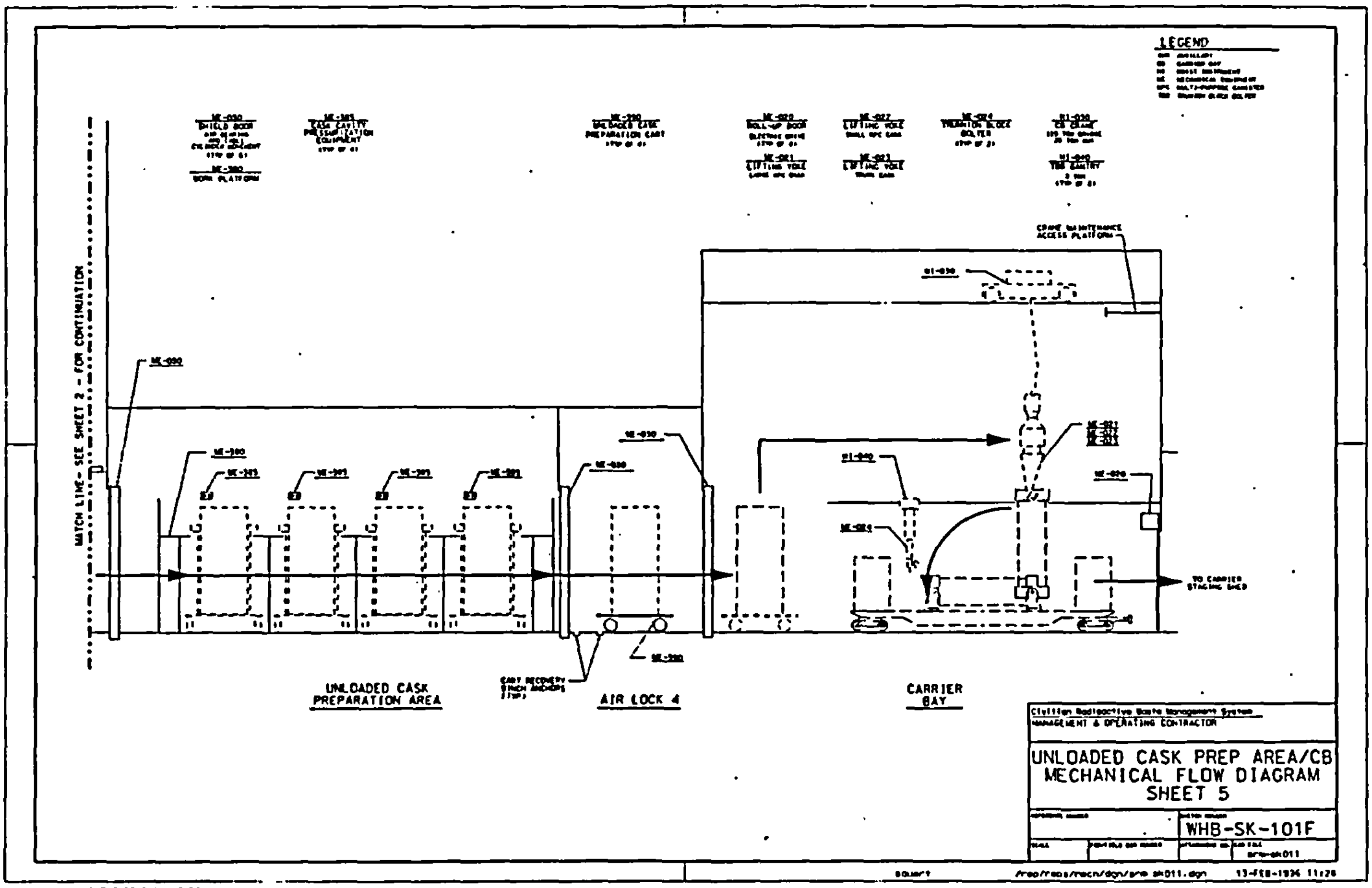
Figure 7.2.2-19. Performance Confirmation System

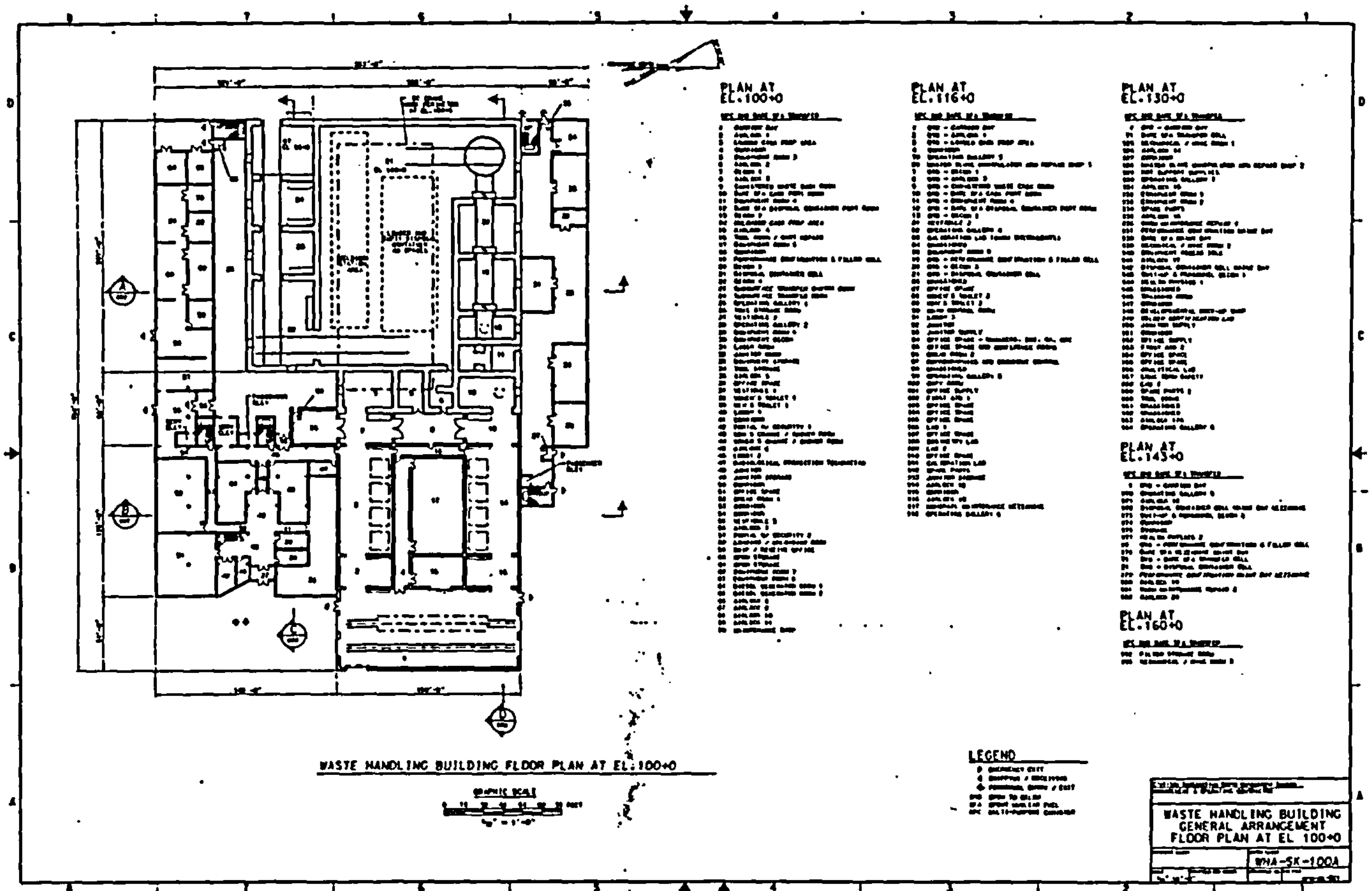

LEGEND
FROM CARRIER STAGING SHED
CARRIER BAY
AIR LOCK 1
SEE VIEW "A"
LOADED CASK PREPARATION AREA
CRANE MAINTENANCE ACCESS PLATFORM
CART RECOVERY WINCH ANCHORS (TYP)
MATCH LINE- SEE SHT 2 FOR MPC- SEE SHT 4 FOR BARE SFA
SIDE VIEW (TYP OF 4)
VIEW "A"
Civilian Radioactive Waste Management System
MANAGEMENT & OPERATING CONTRACTOR
CB/LOADED CASK PREP AREA
MECHANICAL FLOW DIAGRAM
SHEET 1
WHB-SK-101B
16-FEB-1996

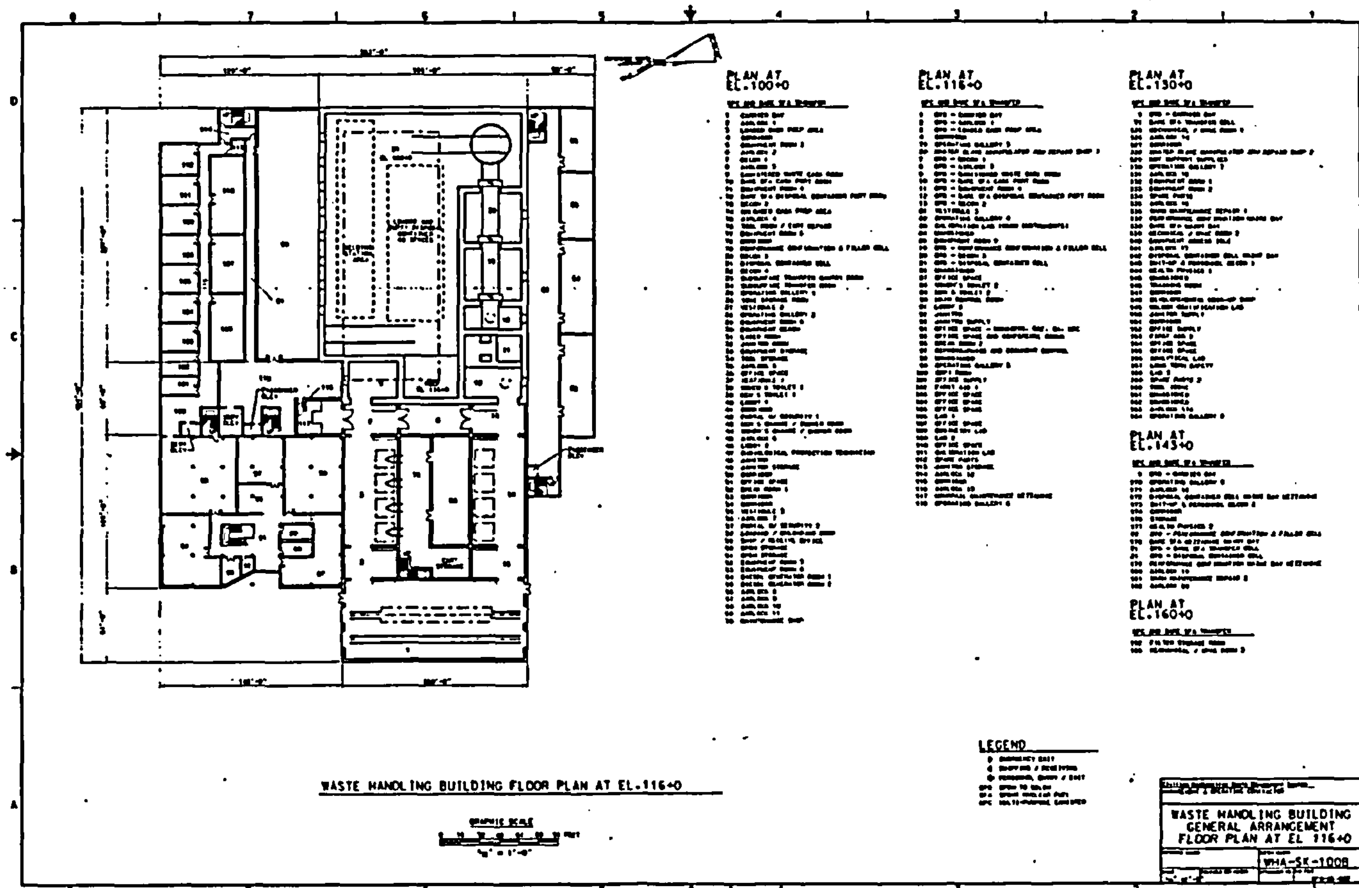

LEGEND
DECON 1
CANISTERED WASTE CASK ROOM
EMPTY DISPOSAL CONTAINER STAGING
DISPOSAL CONTAINER WELDING
LOADED DISPOSAL CONTAINER STAGING
HORIZONTALIZER
DISPOSAL CONTAINER CELL
MATCH LINE - SEE SHEET 1 - FOR CONTINUATION
MATCH LINE - SEE SHEET 3 - FOR CONTINUATION
LOADED BARE SFA CASK TO DECON 2 SEE SHT 4
UNLOADED CANISTERED WASTE CASK TO UNLOADED CASK PREPARATION AREA SEE SHT 5
EQUIPMENT ROOM 3
VIEW "B"
SEE VIEW "B"
CANISTERED WASTE HANDLING MECHANICAL FLOW DIAGRAM SHEET 2
WHB-SK-101C


LEGEND
MATCH LINE- SEE SHEET 2 - FOR CONTINUATION
DECON 4
SUBSURFACE TRANSFER GANTRY ROOM
SUBSURFACE TRANSFER ROOM
AIR LOCK 9
Civilian Radioactive Waste Management System
MANAGEMENT & OPERATING CONTRACTOR
SUBSURFACE TRANSFER
MECHANICAL FLOW DIAGRAM
SHEET 3
WHB-SK-101D
/rep/reps/mech/dgn/arm-sk011.dgn
16-FEB-1996 14:32


DECON 2
BARE SFA CASK PORT ROOM
BARE SFA TRANSFER CELL
BARE SFA DISPOSAL CONTAINER PORT ROOM
PERFORMANCE CONFIRMATION & FILLER CELL
DECON 3
DISPOSAL CONTAINER TURNTABLE AREA
EQUIPMENT ROOM 2
MATCH LINE - SEE SHEET 1 - FOR CONTINUATION
MATCH LINE - SEE SHEET 3 - FOR CONTINUATION
LEGEND
SIDE VIEW (TYP OF 2)
VIEW "C"
EQUIPMENT ROOM 1
SIDE VIEW
VIEW "D"
LASER ROOM
Civilian Radioactive Waste Management System
MANAGEMENT & OPERATING CONTRACTOR
BARE SFA HANDLING MECHANICAL FLOW DIAGRAM SHEET 4
WHB-SK-101E


LEGEND
MATCH LINE- SEE SHEET 2 - FOR CONTINUATION
UNLOADED CASK PREPARATION AREA
AIR LOCK 4
CARRIER BAY
Civilian Radioactive Waste Management System
MANAGEMENT & OPERATING CONTRACTOR
UNLOADED CASK PREP AREA/CB
MECHANICAL FLOW DIAGRAM
SHEET 5
WHB-SK-101F
13-FEB-1996 11:28


PLAN AT EL. 100+0
PLAN AT EL. 116+0
PLAN AT EL. 130+0
PLAN AT EL. 145+0
PLAN AT EL. 160+0
WASTE HANDLING BUILDING FLOOR PLAN AT EL. 100+0
GRAPHIC SCALE
LEGEND
WASTE HANDLING BUILDING GENERAL ARRANGEMENT FLOOR PLAN AT EL 100+0
WHA-SK-100A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PLAN AT EL.145+0
PLAN AT EL.160+0
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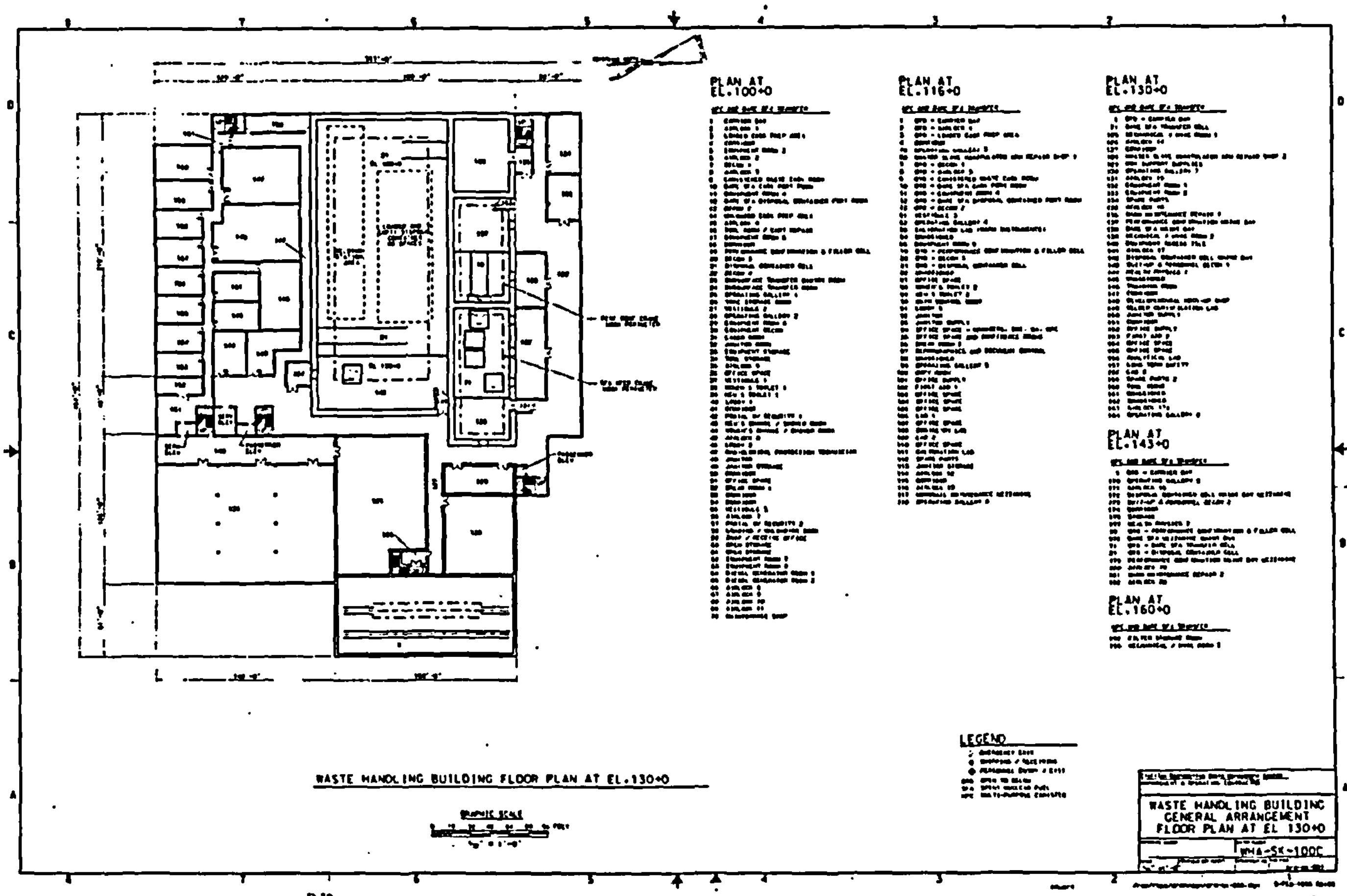
WASTE HANDLING BUILDING
GENERAL ARRANGEMENT
FLOOR PLAN AT EL 116+0
WHA-SK-1008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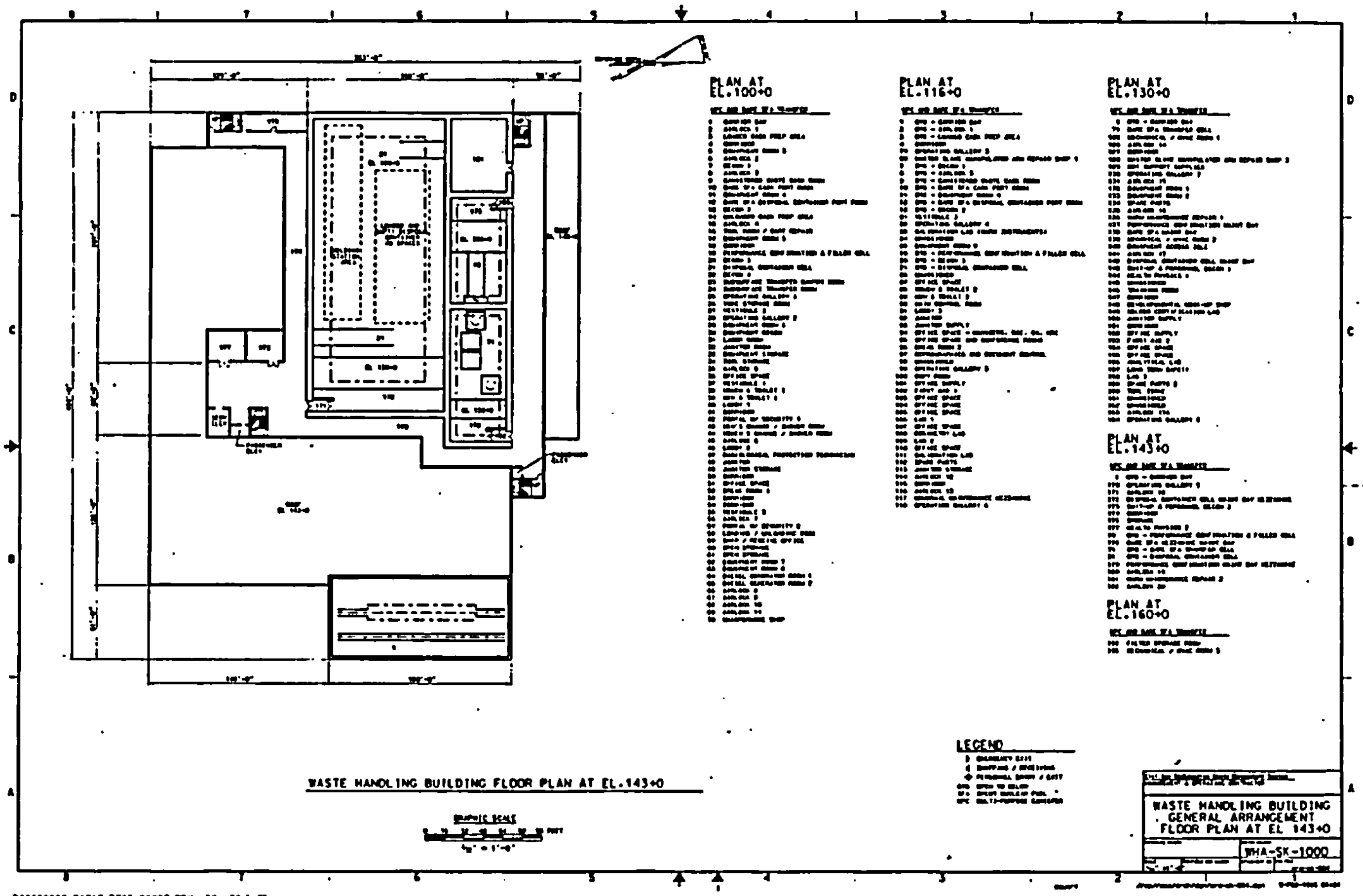
PLAN AT EL.116+0
PLAN AT EL.130+0
PLAN AT EL.143+0
PLAN AT EL.160+0
LEGEND
WASTE HANDLING BUILDING FLOOR PLAN AT EL. 130+0
GRAPHIC SCALE
WASTE HANDLING BUILDING
GENERAL ARRANGEMENT
FLOOR PLAN AT EL 130+0
WHA-SK-100C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PLAN AT EL.116+0
PLAN AT EL.130+0
PLAN AT EL.143+0
PLAN AT EL.160+0
LEGEND
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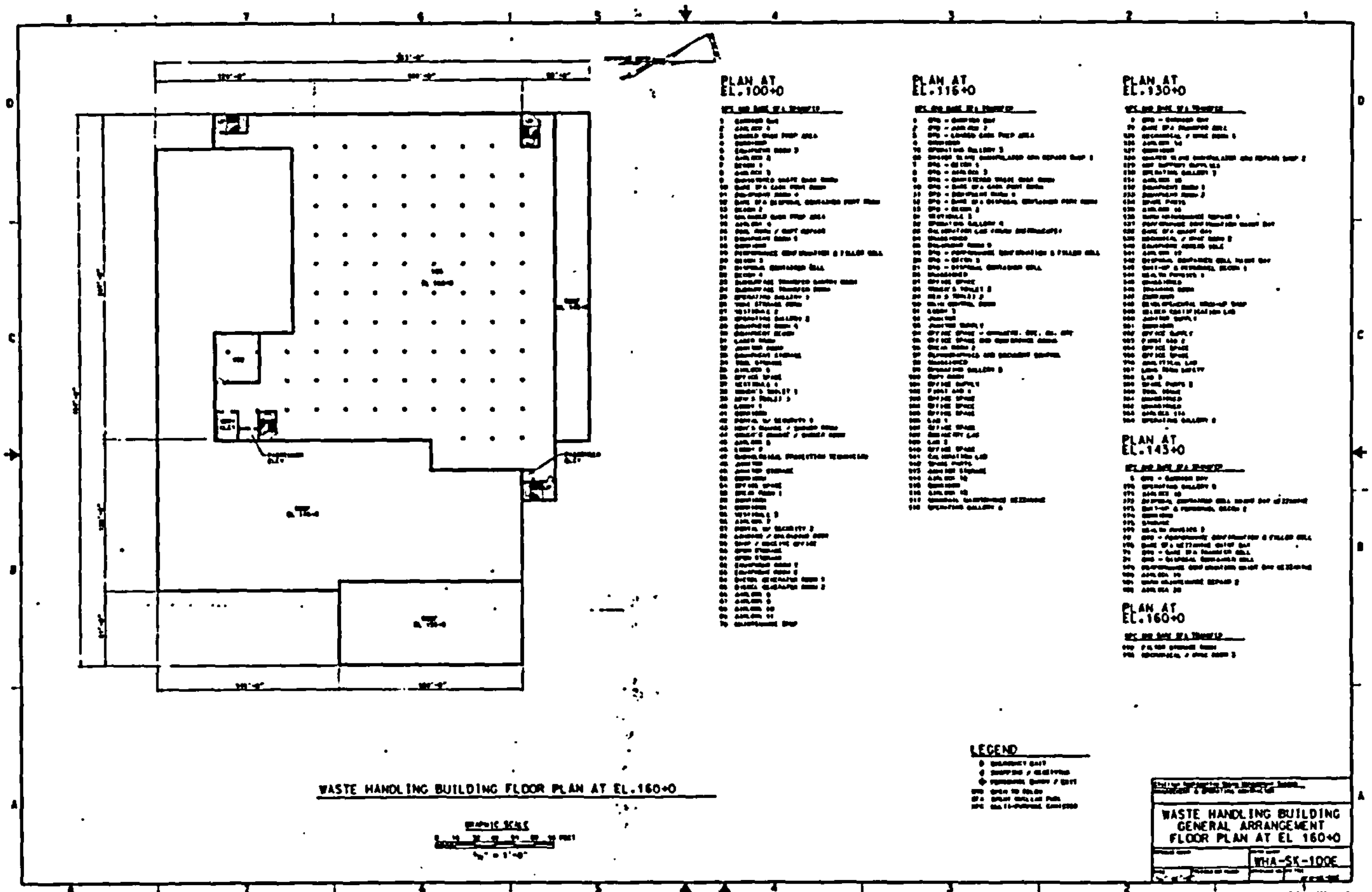
WASTE HANDLING BUILDING
GENERAL ARRANGEMENT
FLOOR PLAN AT EL 143+0
WHA-SK-1000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PLAN AT EL. 116+0
PLAN AT EL. 130+0
PLAN AT EL. 145+0
PLAN AT EL. 160+0
LEGEND
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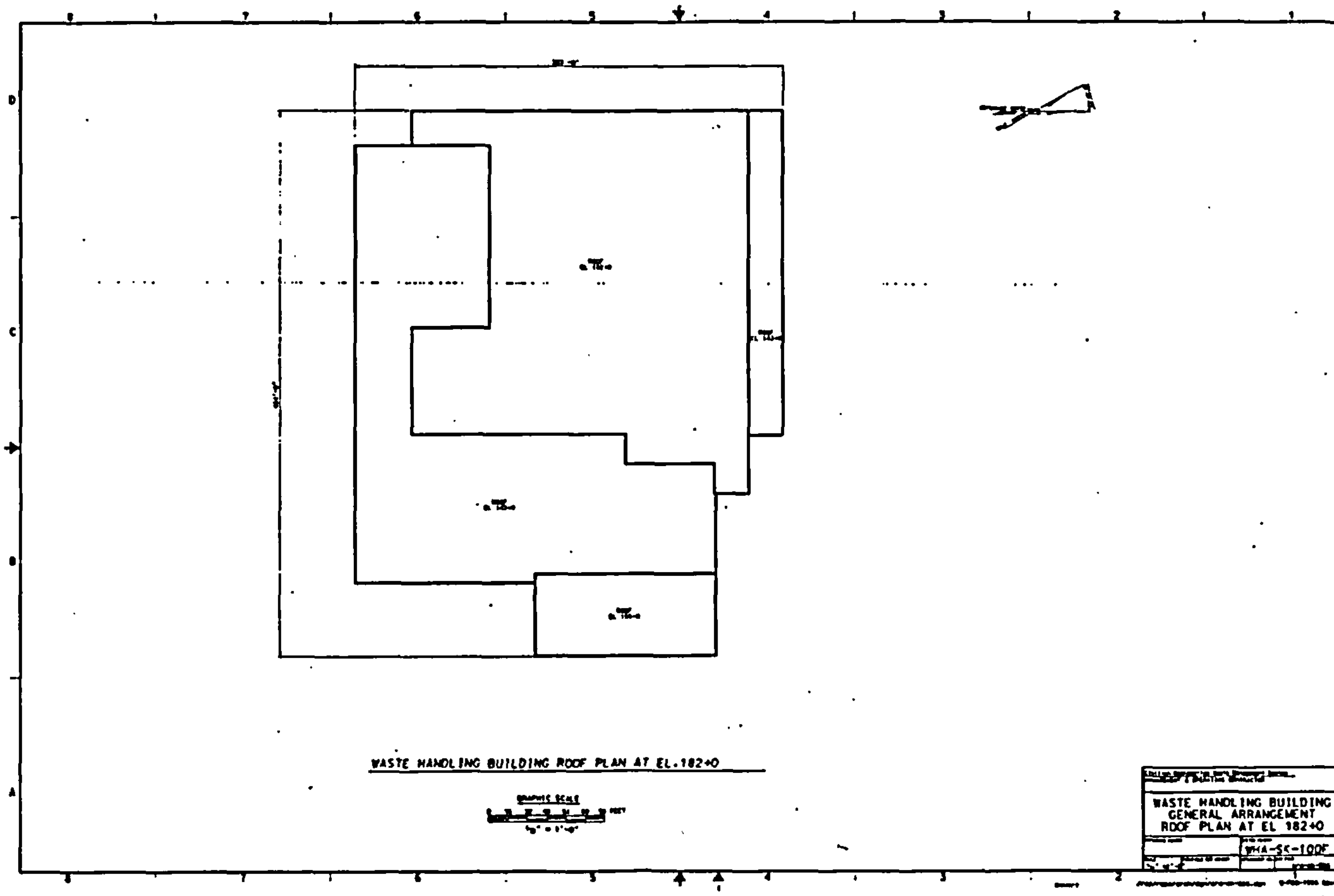
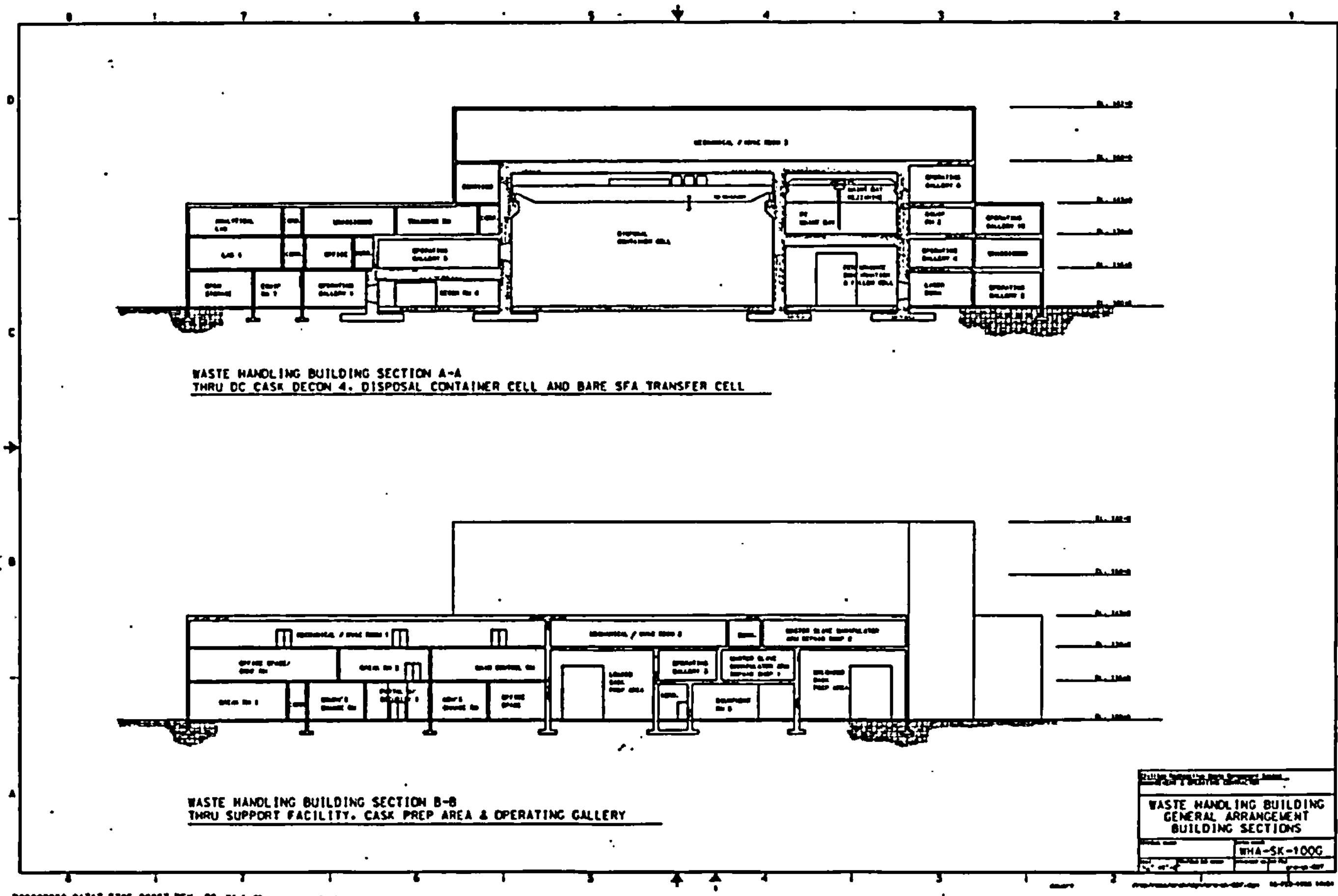
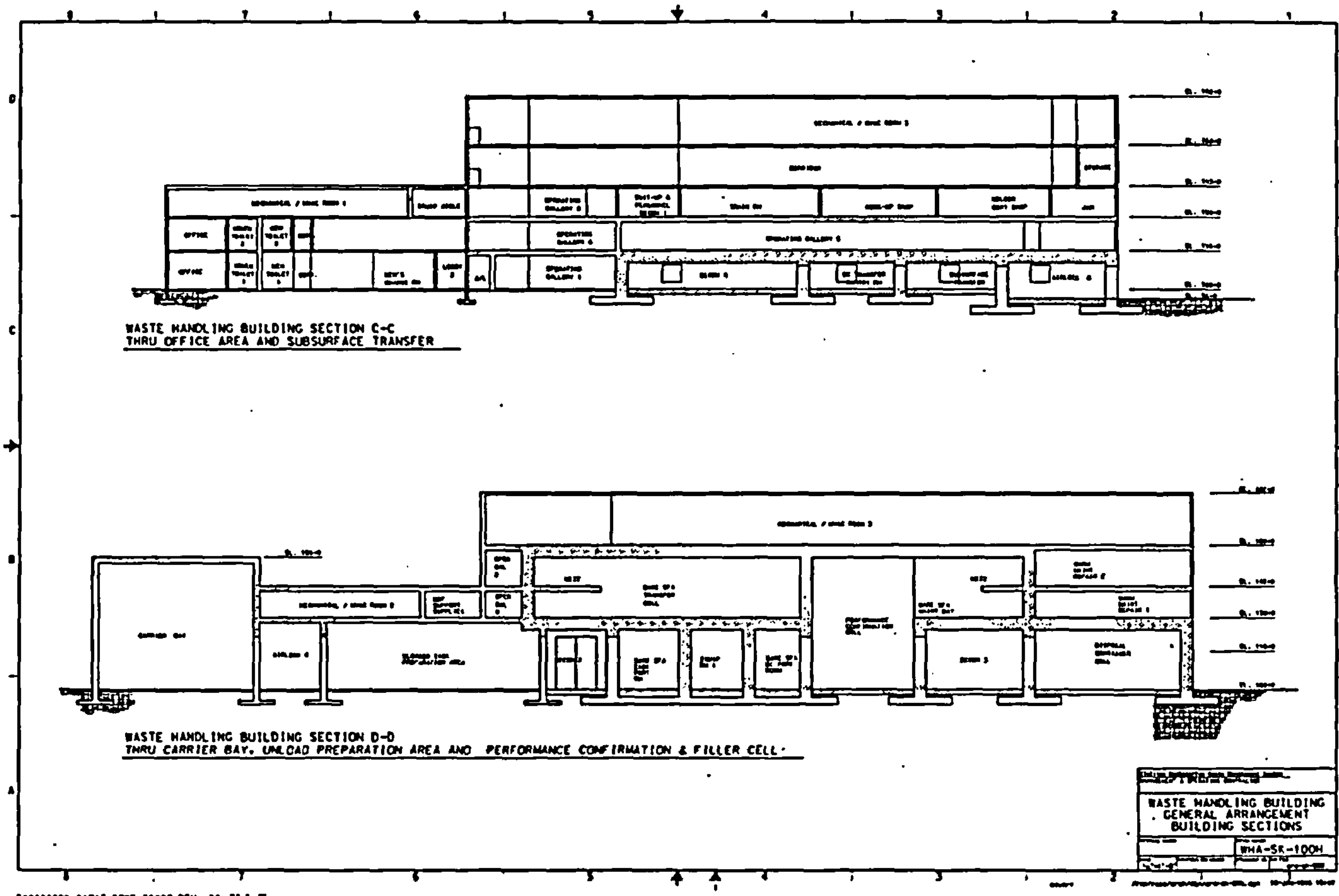
WASTE HANDLING BUILDING
GENERAL ARRANGEMENT
FLOOR PLAN AT EL 160+0
WHA-SK-100E



WASTE HANDLING BUILDING ROOF PLAN AT EL. 182+0
GRAPHIC SCALE
WASTE HANDLING BUILDING
GENERAL ARRANGEMENT
ROOF PLAN AT EL 182+0
WHA-SK-100F


WASTE HANDLING BUILDING SECTION A-A
THRU DC CASK DECON 4, DISPOSAL CONTAINER CELL AND BARE SFA TRANSFER CELL
WASTE HANDLING BUILDING SECTION B-B
THRU SUPPORT FACILITY, CASK PREP AREA & OPERATING GALLERY
WASTE HANDLING BUILDING
GENERAL ARRANGEMENT
BUILDING SECTIONS
WHA-SK-100G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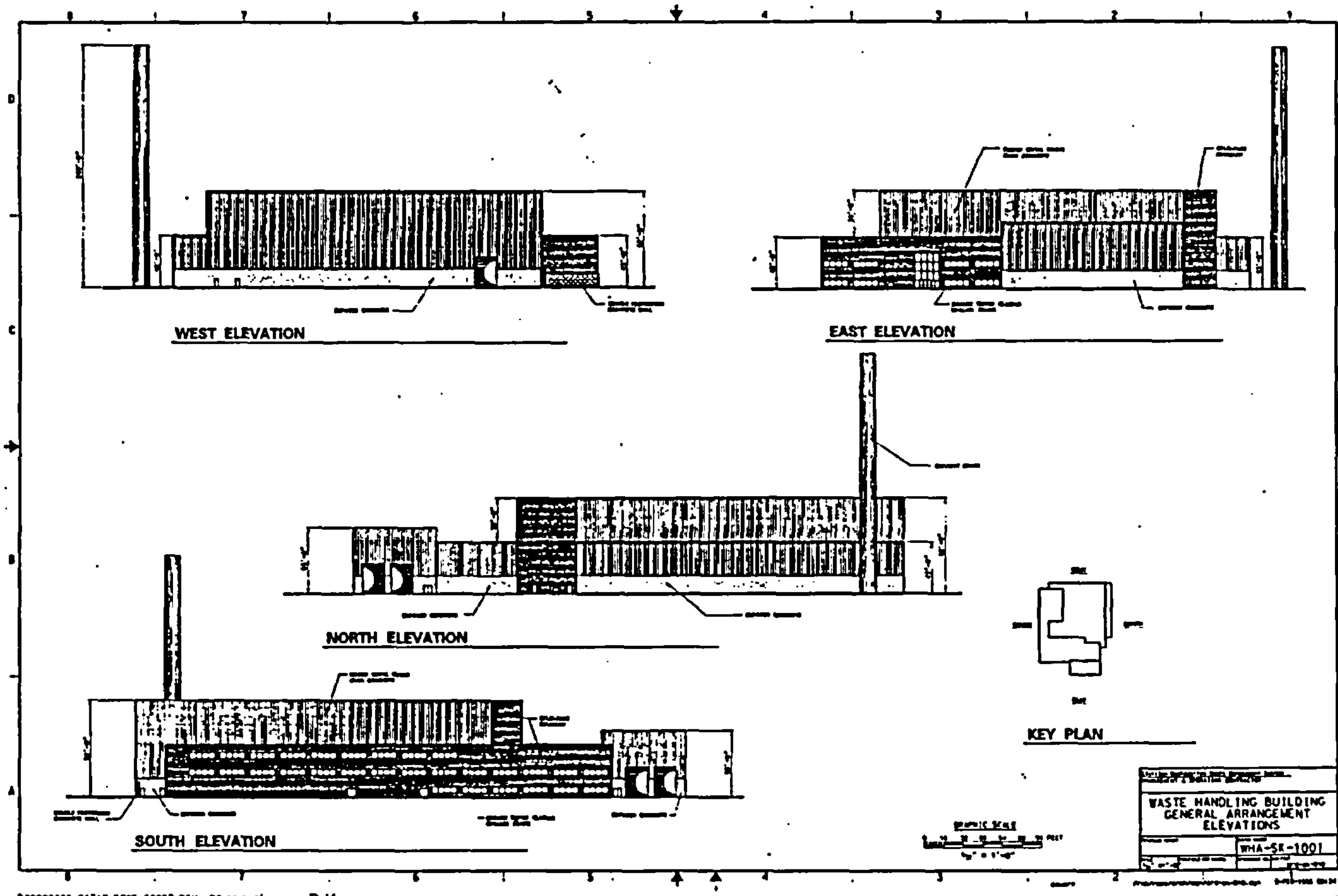
THRU OFFICE AREA AND SUBSURFACE TRANSFER
WASTE HANDLING BUILDING SECTION D-D
THRU CARRIER BAY, UNLOAD PREPARATION AREA AND PERFORMANCE CONFIRMATION & FILLER CELL
WASTE HANDLING BUILDING
GENERAL ARRANGEMENT
BUILDING SECTIONS
WHA-SK-100H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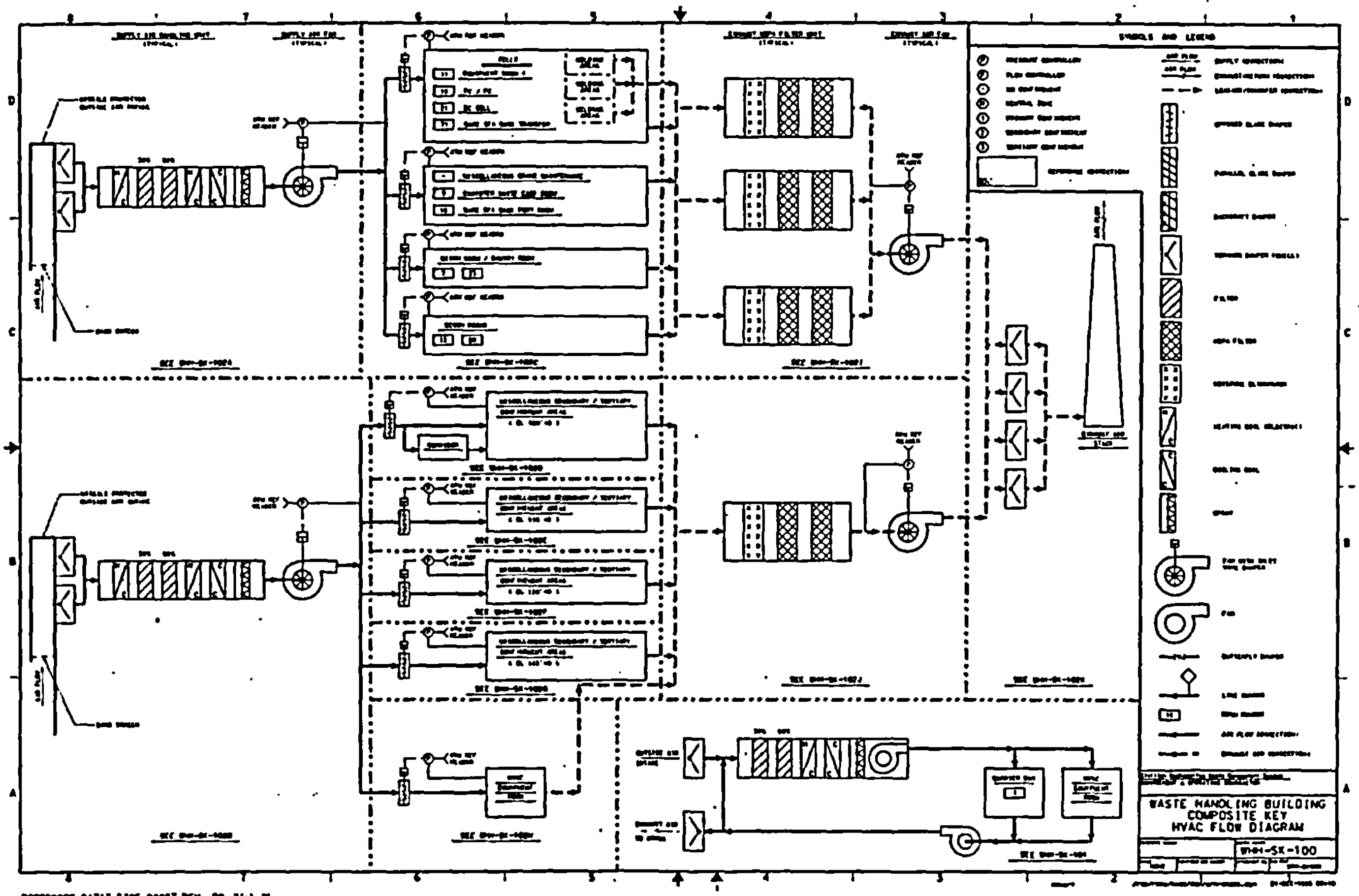
EAST ELEVATION
NORTH ELEVATION
SOUTH ELEVATION
KEY PLAN
WASTE HANDLING BUILDING
GENERAL ARRANGEMENT
ELEVATIONS
WHA-SK-1001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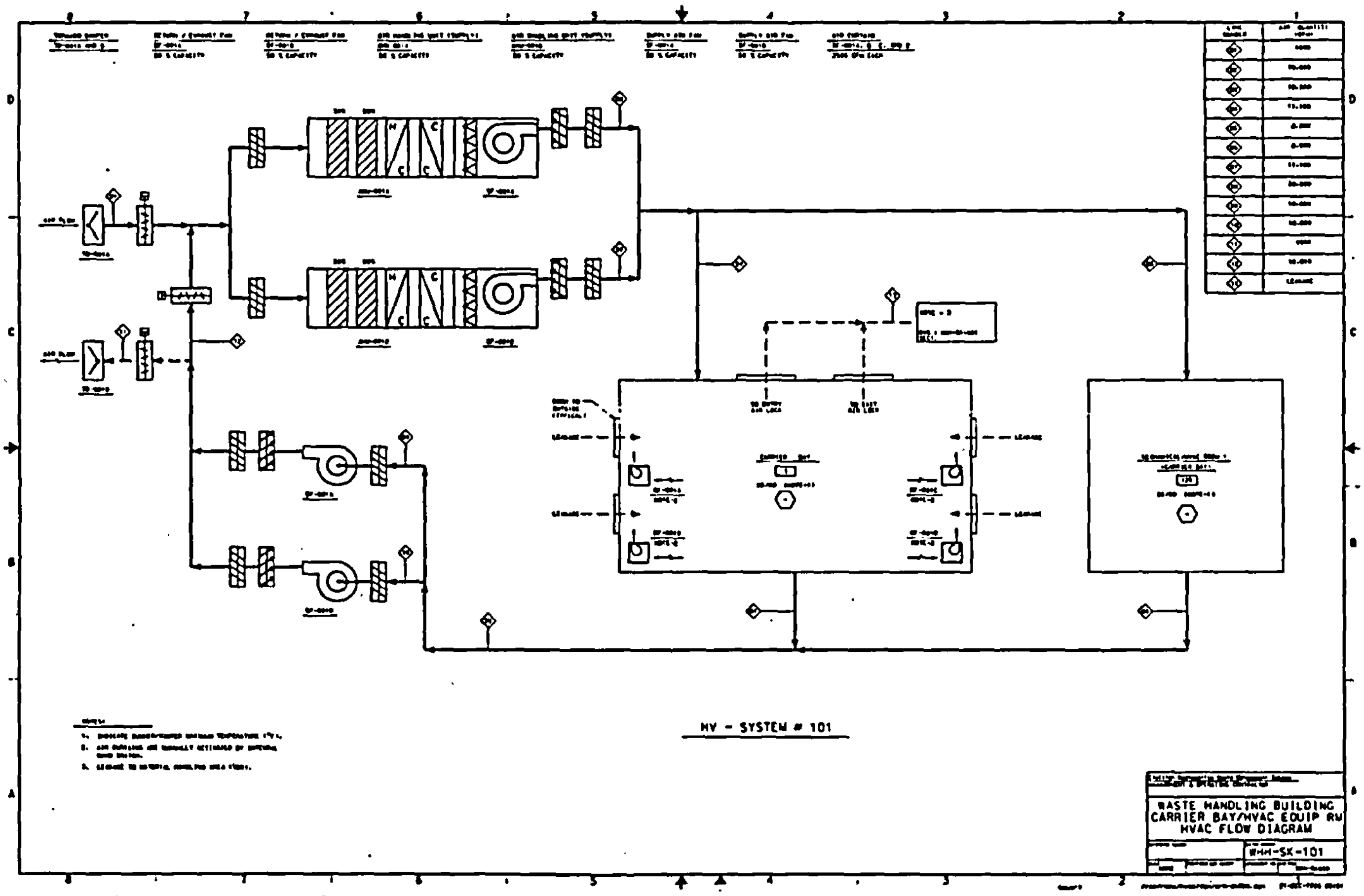
COMPOSITE KEY
HVAC FLOW DIAGRAM
WHM-SK-100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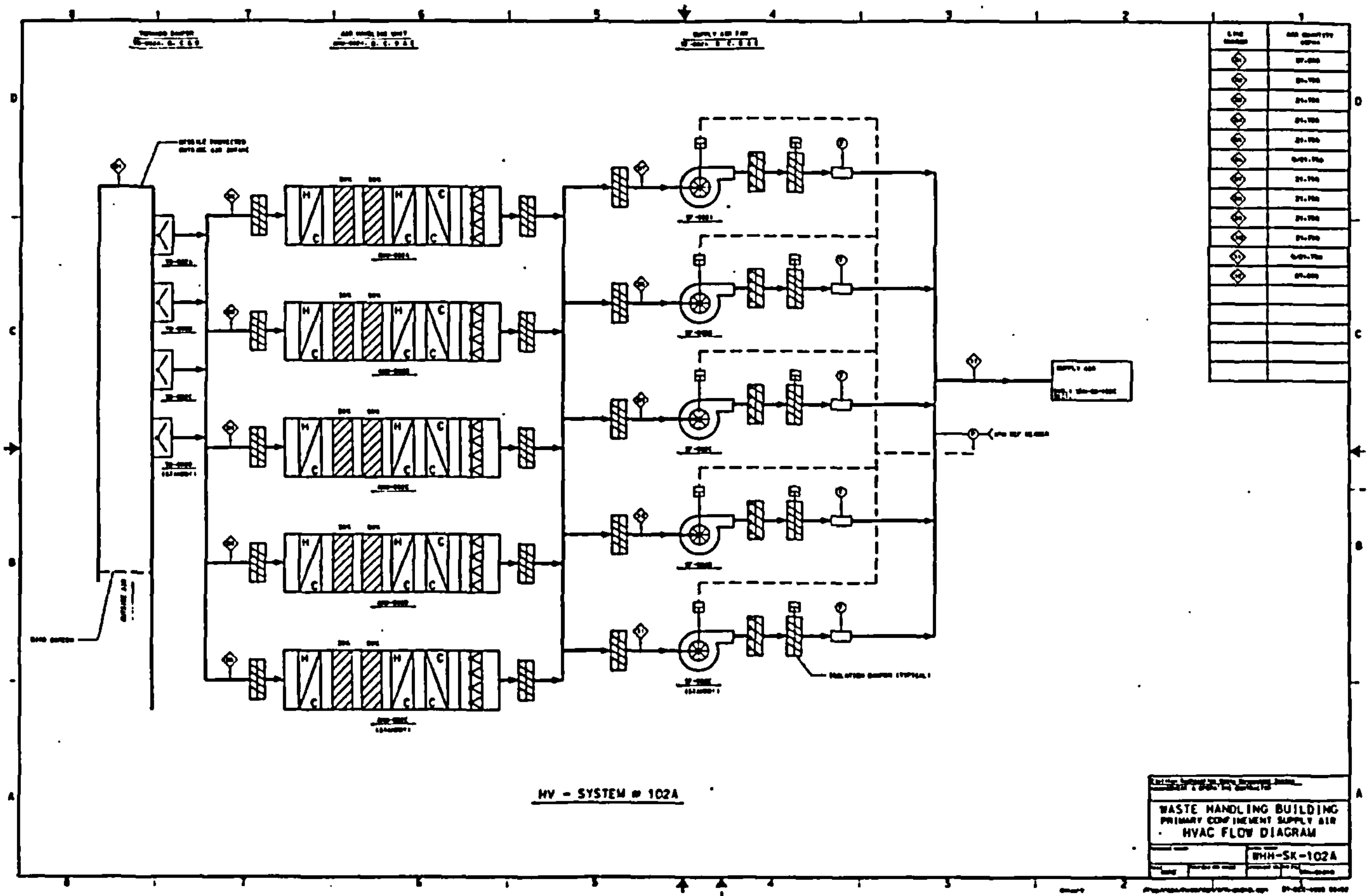
CARRIER BAY/HVAC EQUIP RM
HVAC FLOW DIAGRAM
WHH-SK-101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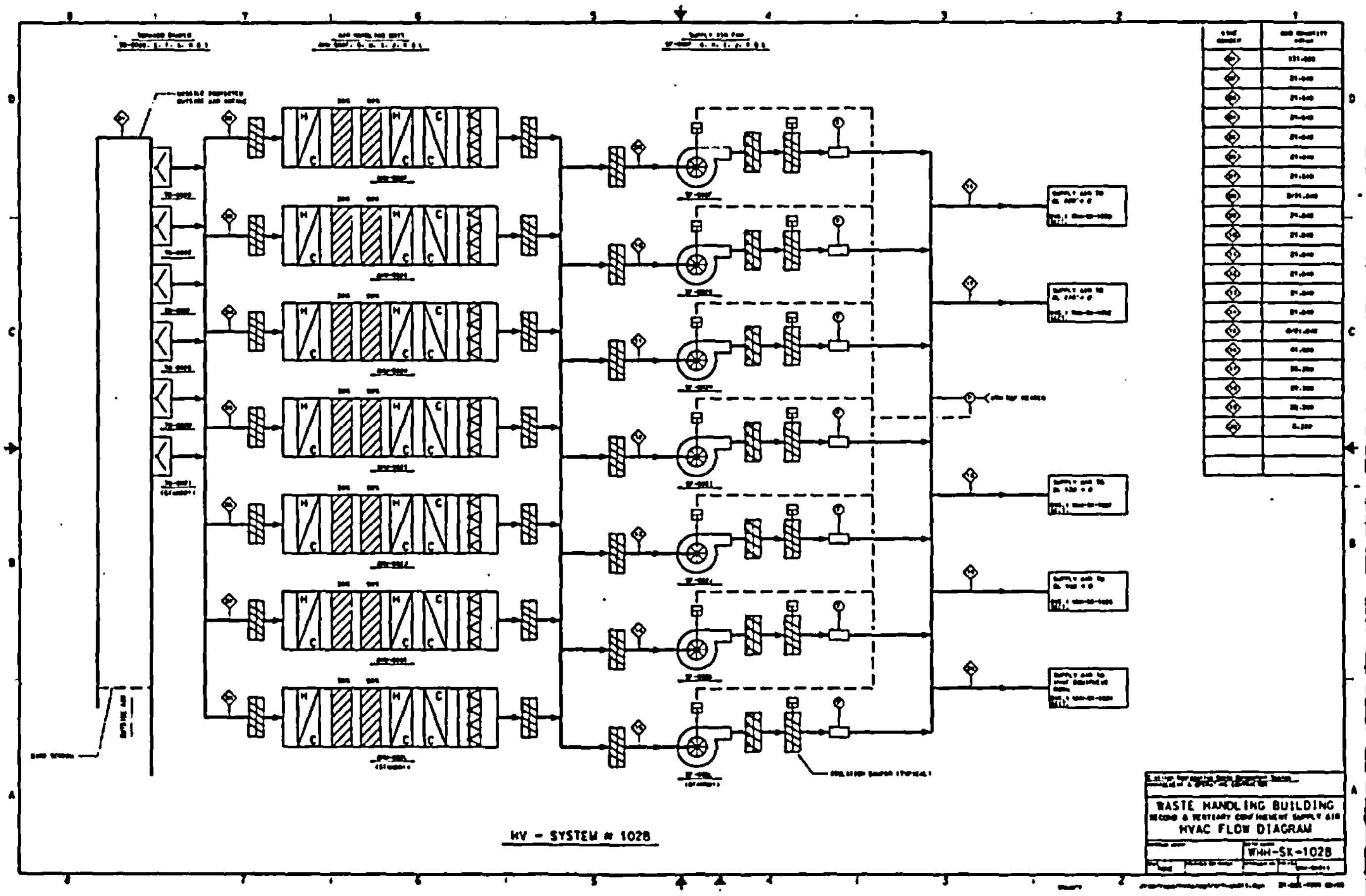
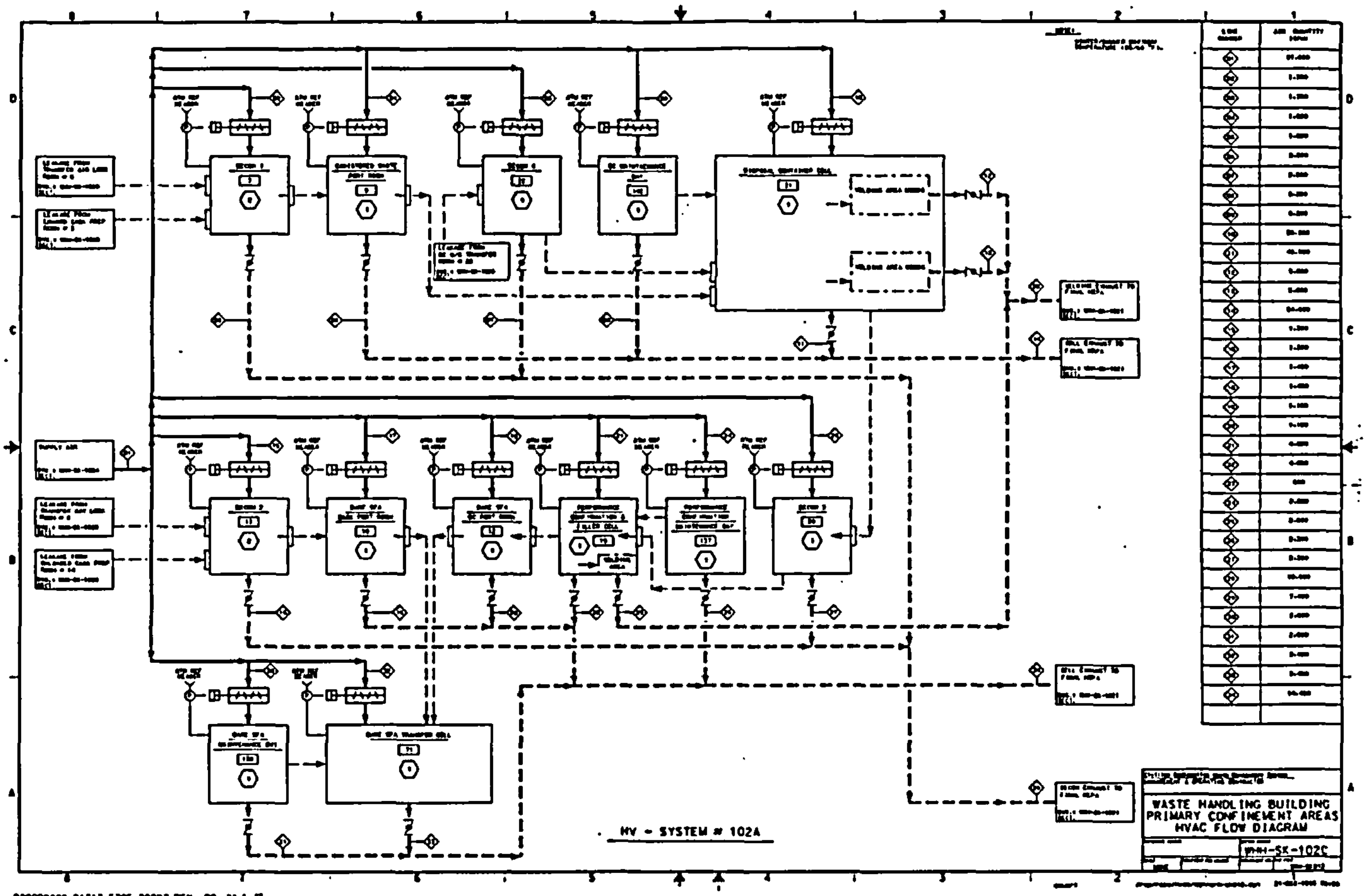
HVAC FLOW DIAGRAM
WHH-SK-102A


HV - SYSTEM # 1028
WASTE HANDLING BUILDING
SECOND & TERTIARY CONFINEMENT SUPPLY AIR
HVAC FLOW DIAGRAM
WHH-SK-1028


WASTE HANDLING BUILDING
PRIMARY CONFINEMENT AREAS
HVAC FLOW DIAGRAM
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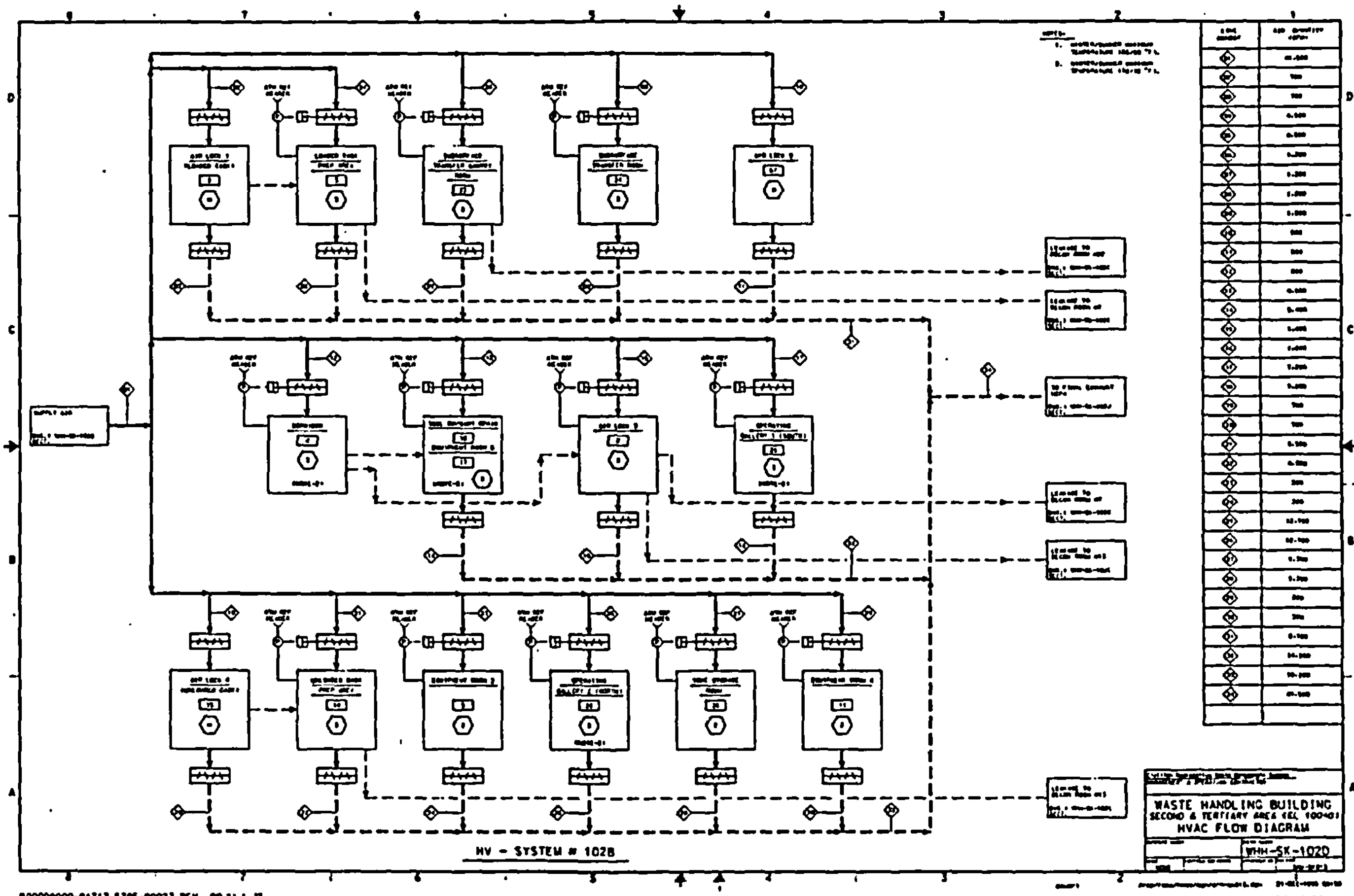
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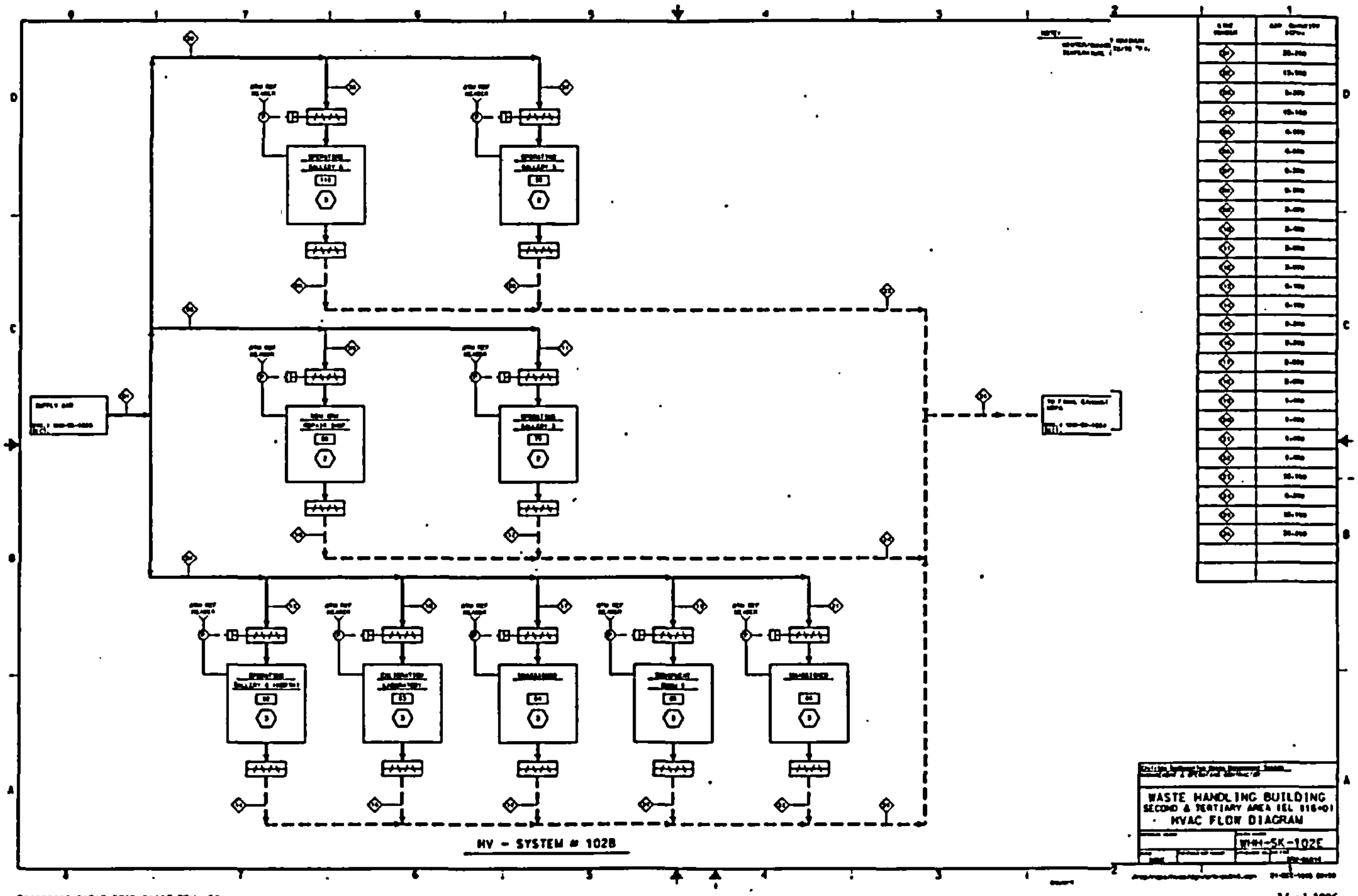
HVAC FLOW DIAGRAM
WHH-SK-1020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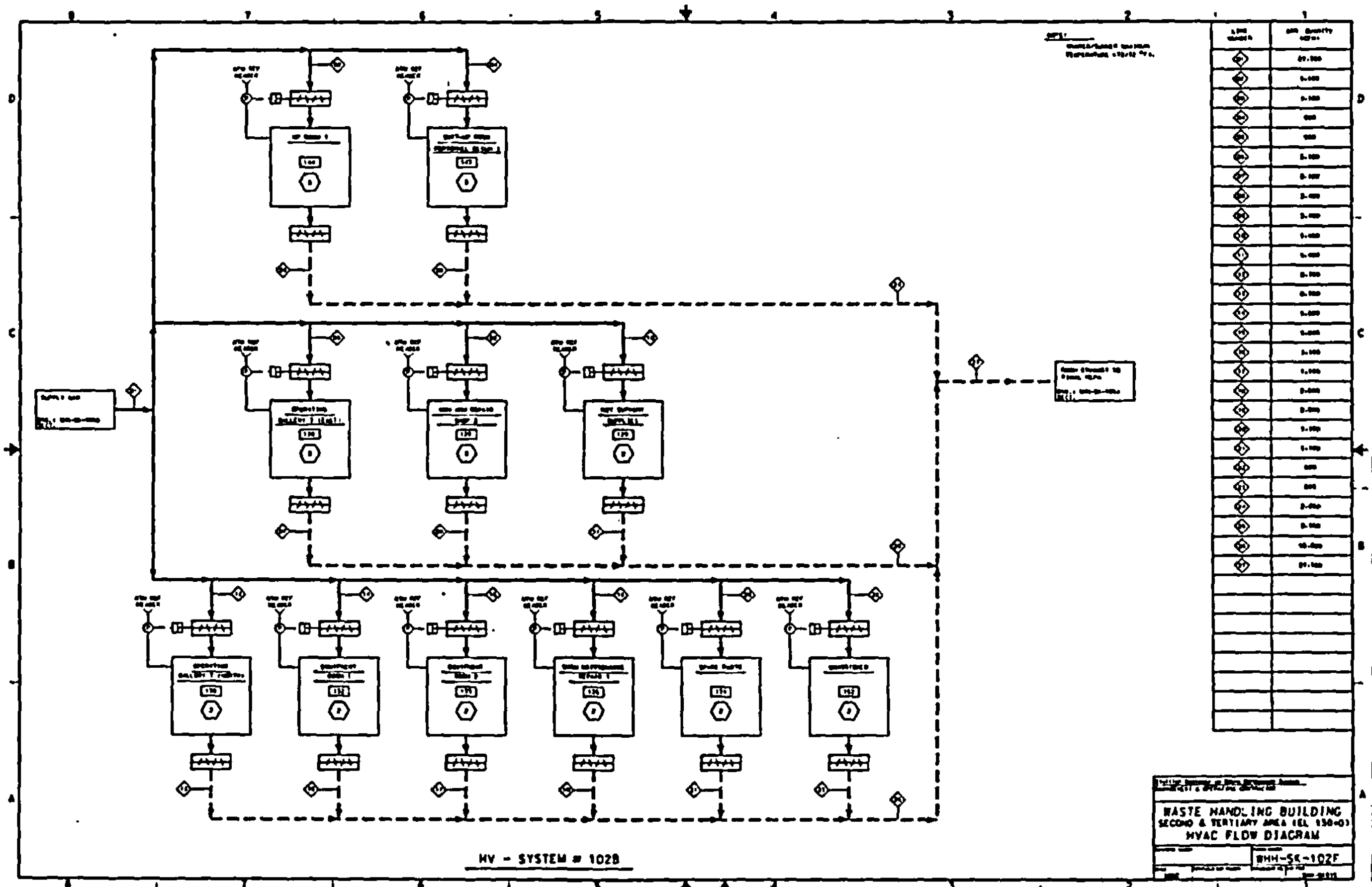
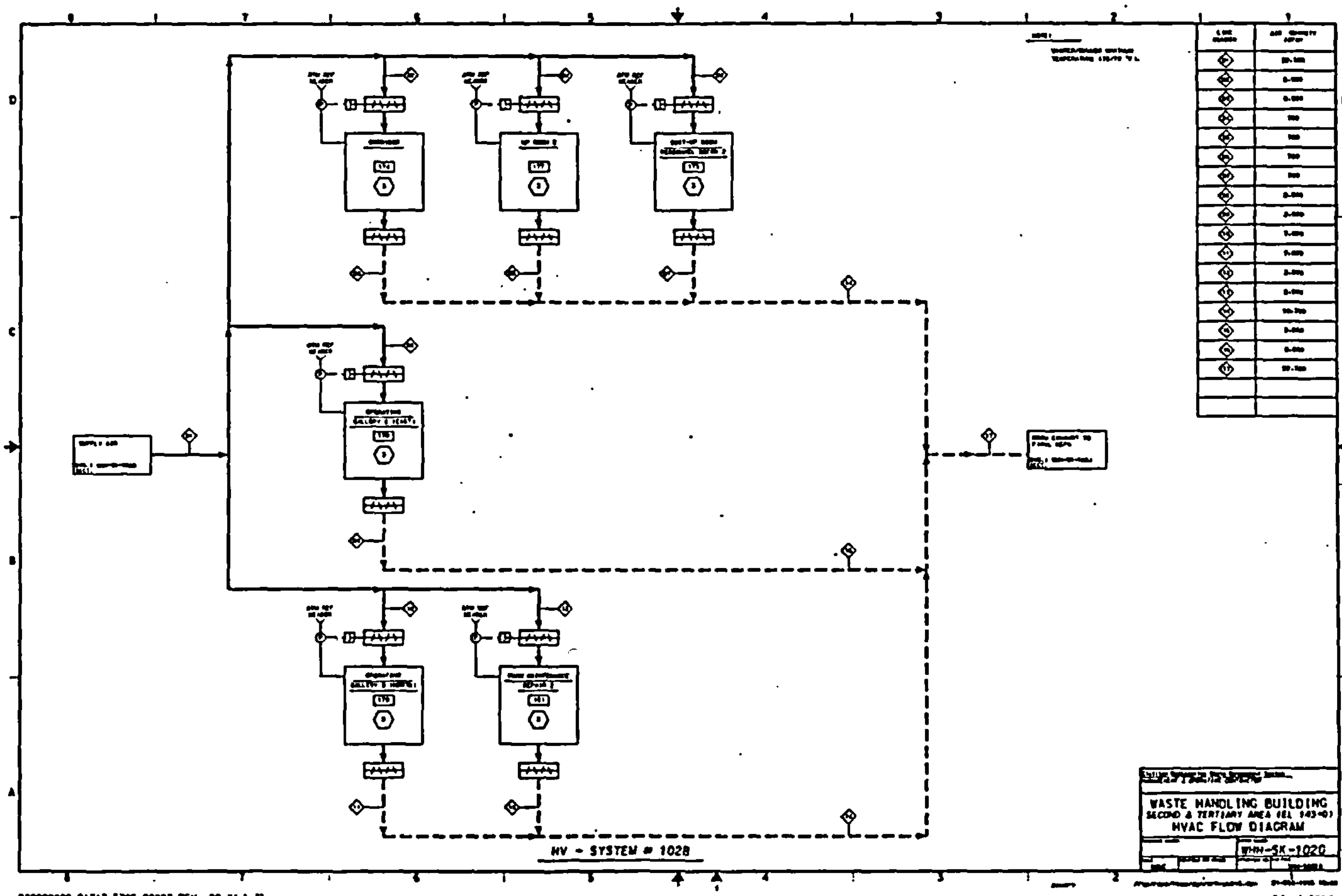
WASTE HANDLING BUILDING
HVAC FLOW DIAGRAM
WHH-SK-102E



WASTE HANDLING BUILDING
SECOND & TERTIARY AREA (EL 130+0)
HVAC FLOW DIAGRAM
WHH-SK-102F
HV - SYSTEM # 102B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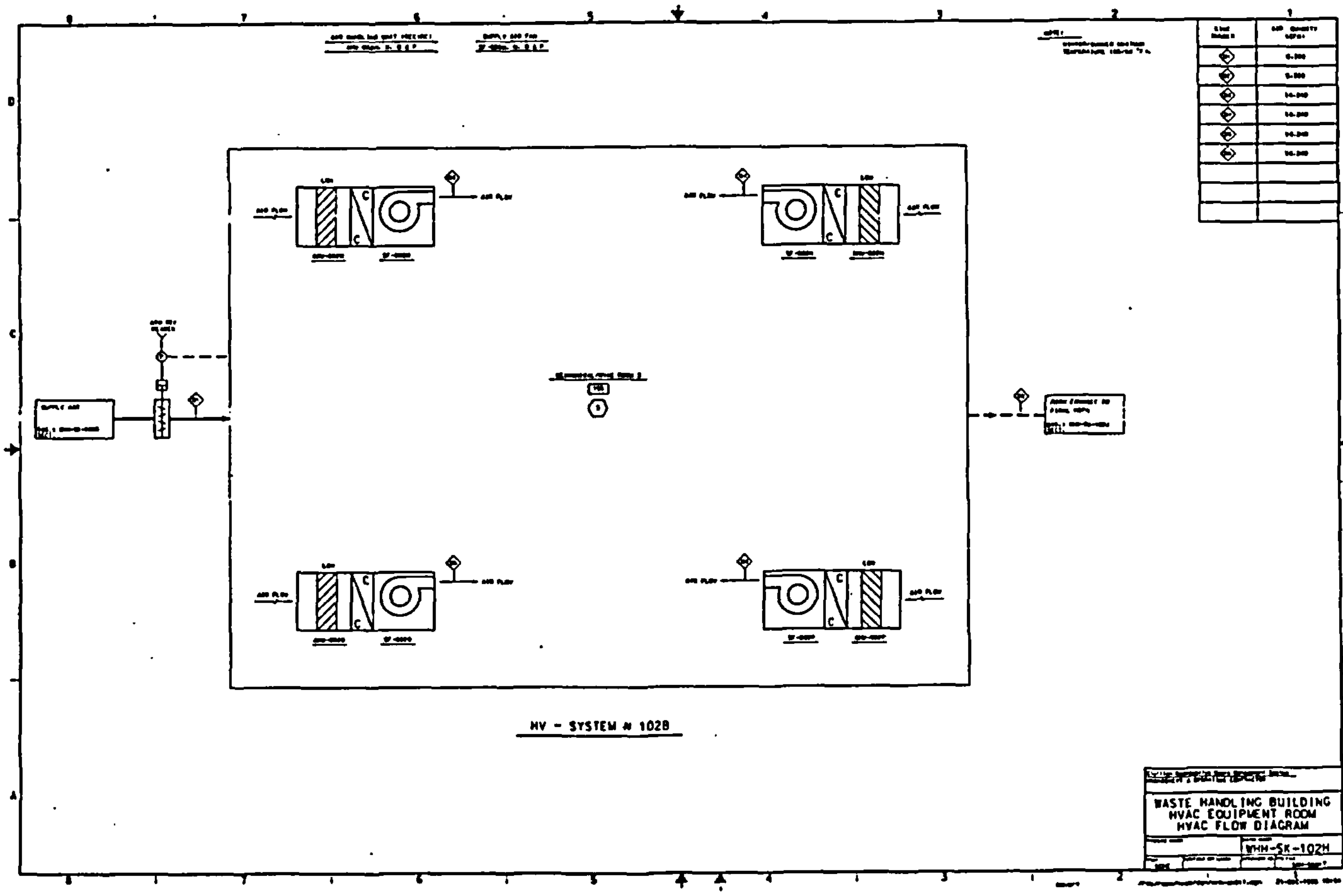
WASTE HANDLING BUILDING
SECOND & TERTIARY AREA (EL 143-0)
HVAC FLOW DIAGRAM
WHN-SK-1020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WASTE HANDLING BUILDING
HVAC EQUIPMENT ROOM
HVAC FLOW DIAGRAM
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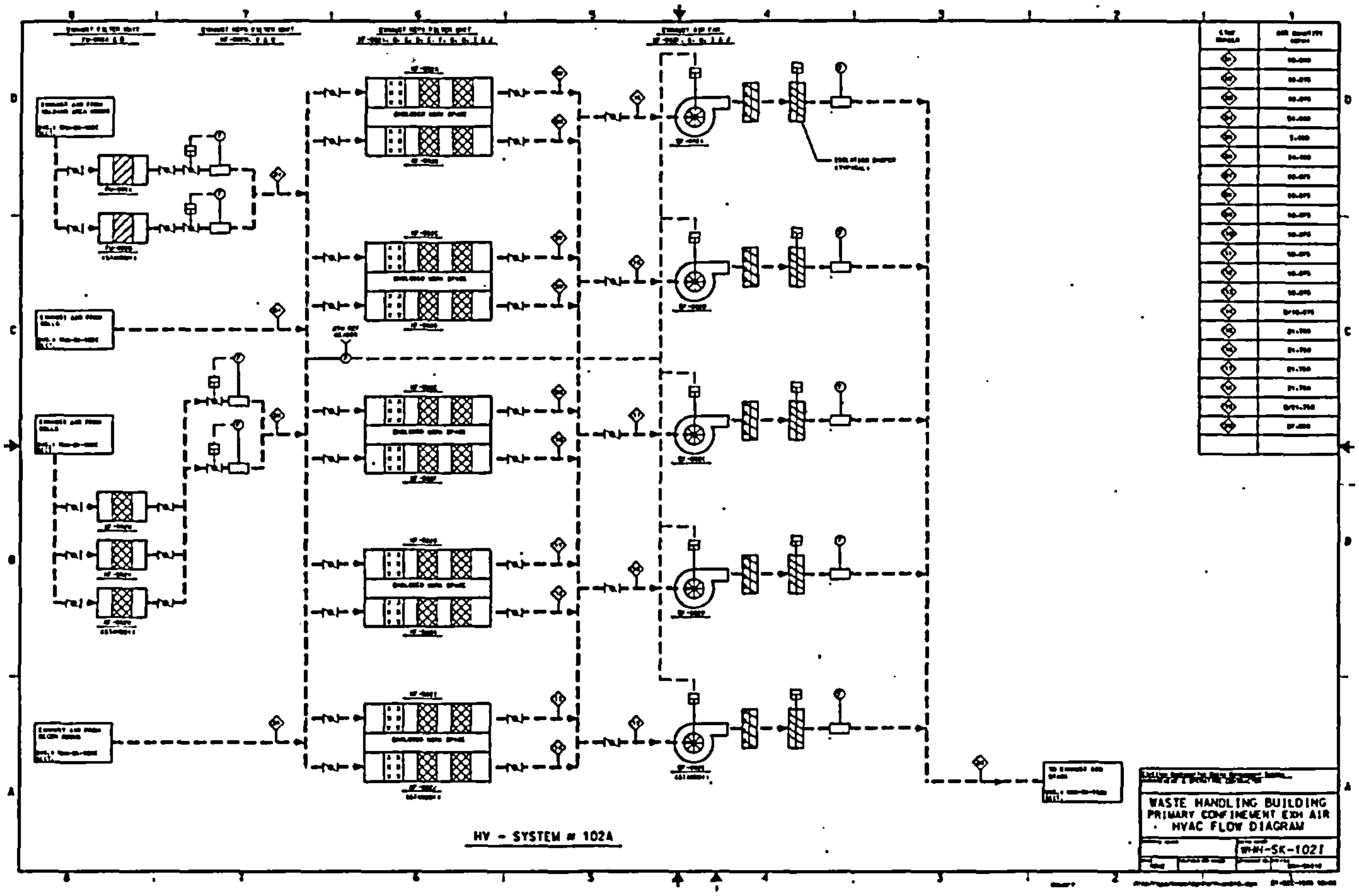
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PRIMARY CONFINEMENT EXH AIR
HVAC FLOW DIAGRAM
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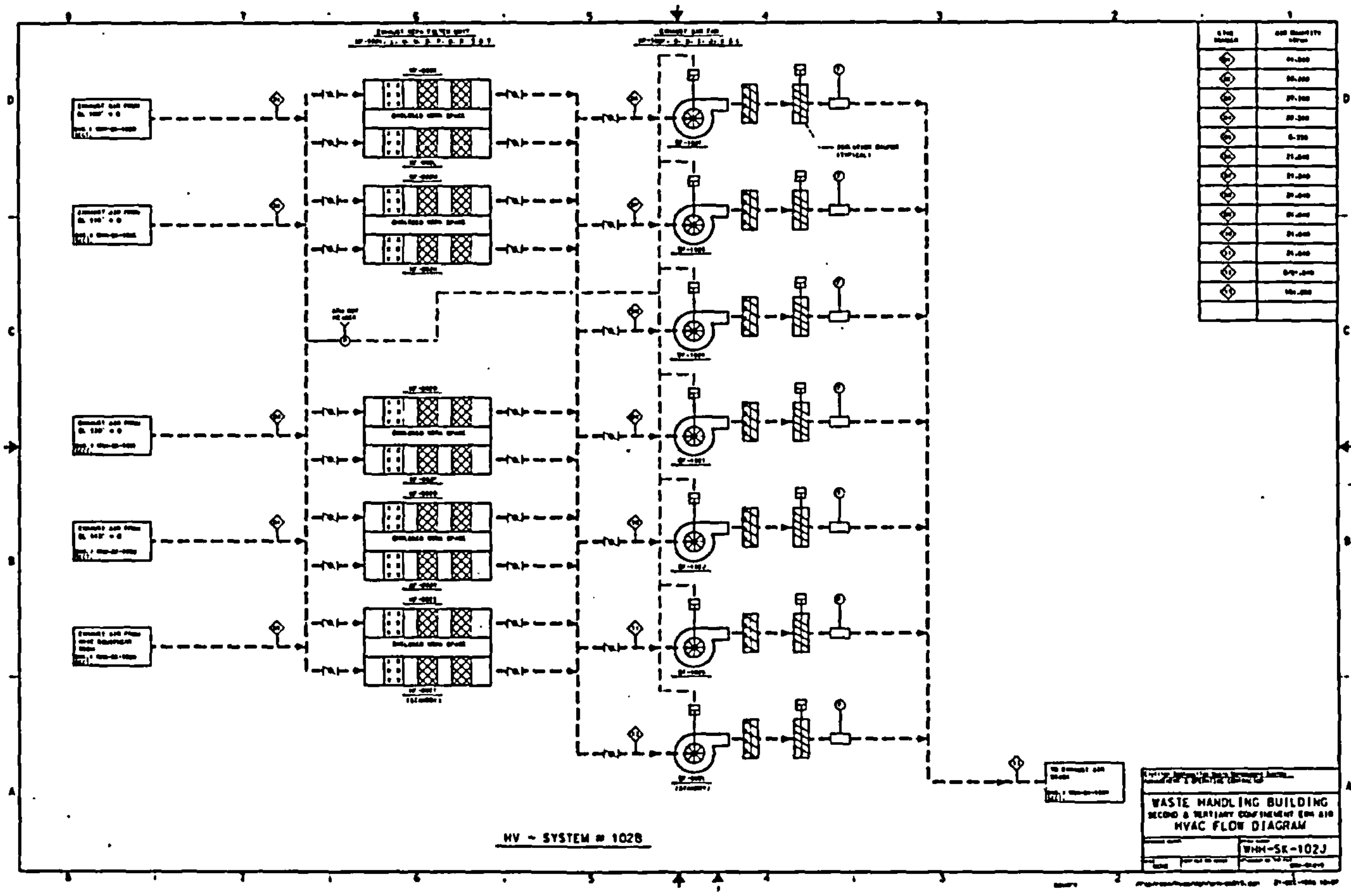
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HVAC FLOW DIAGRAM
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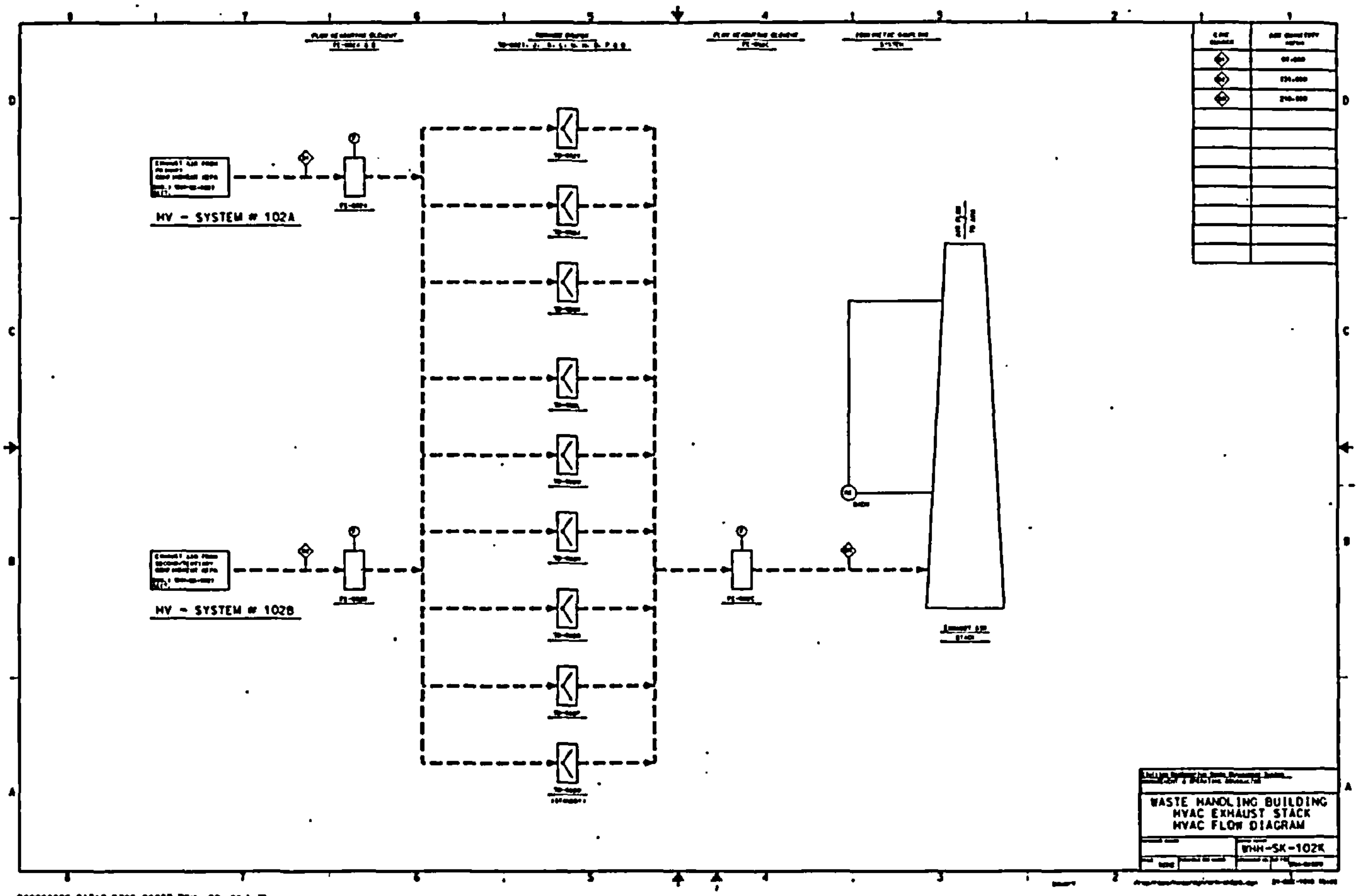
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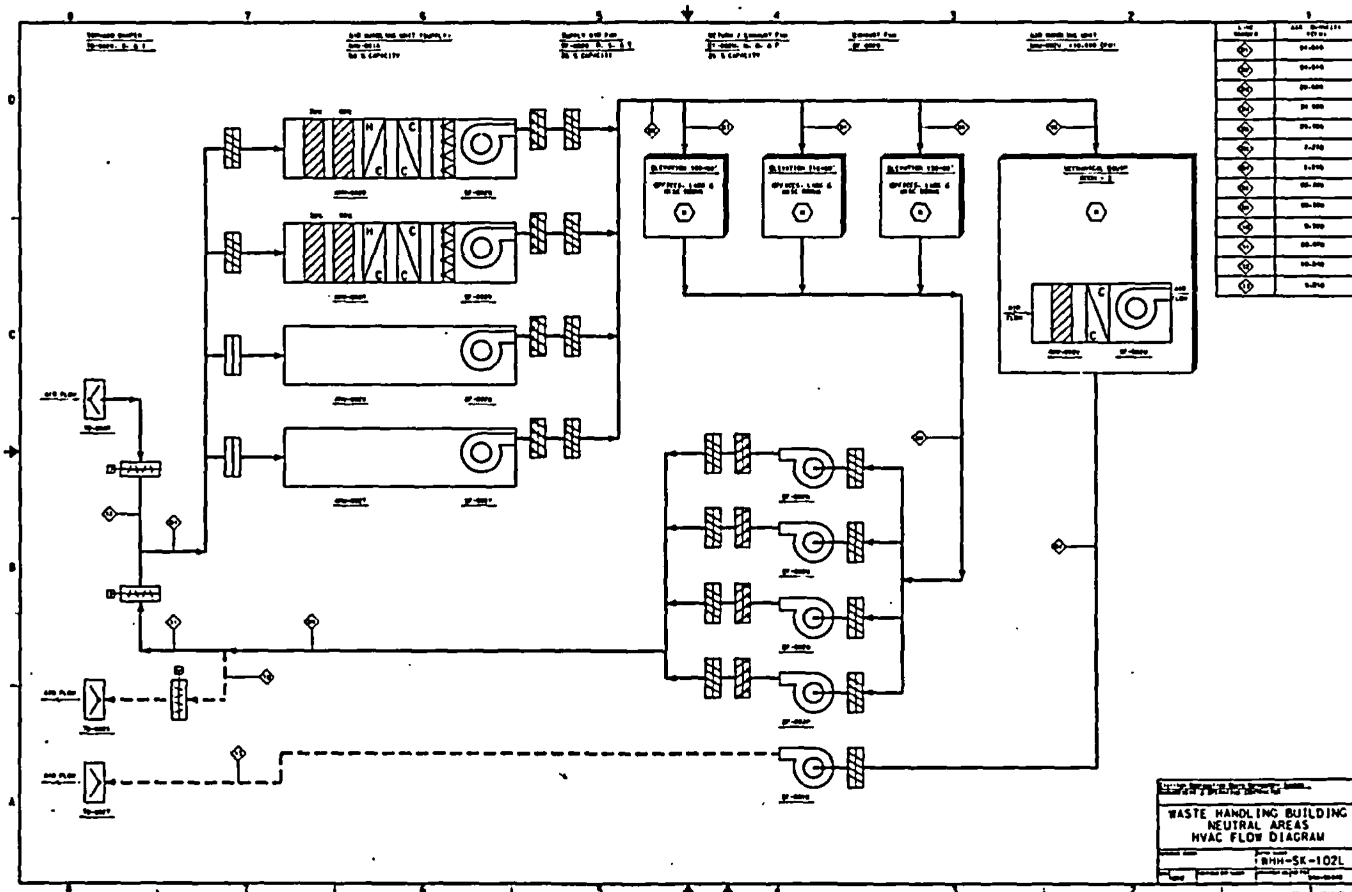
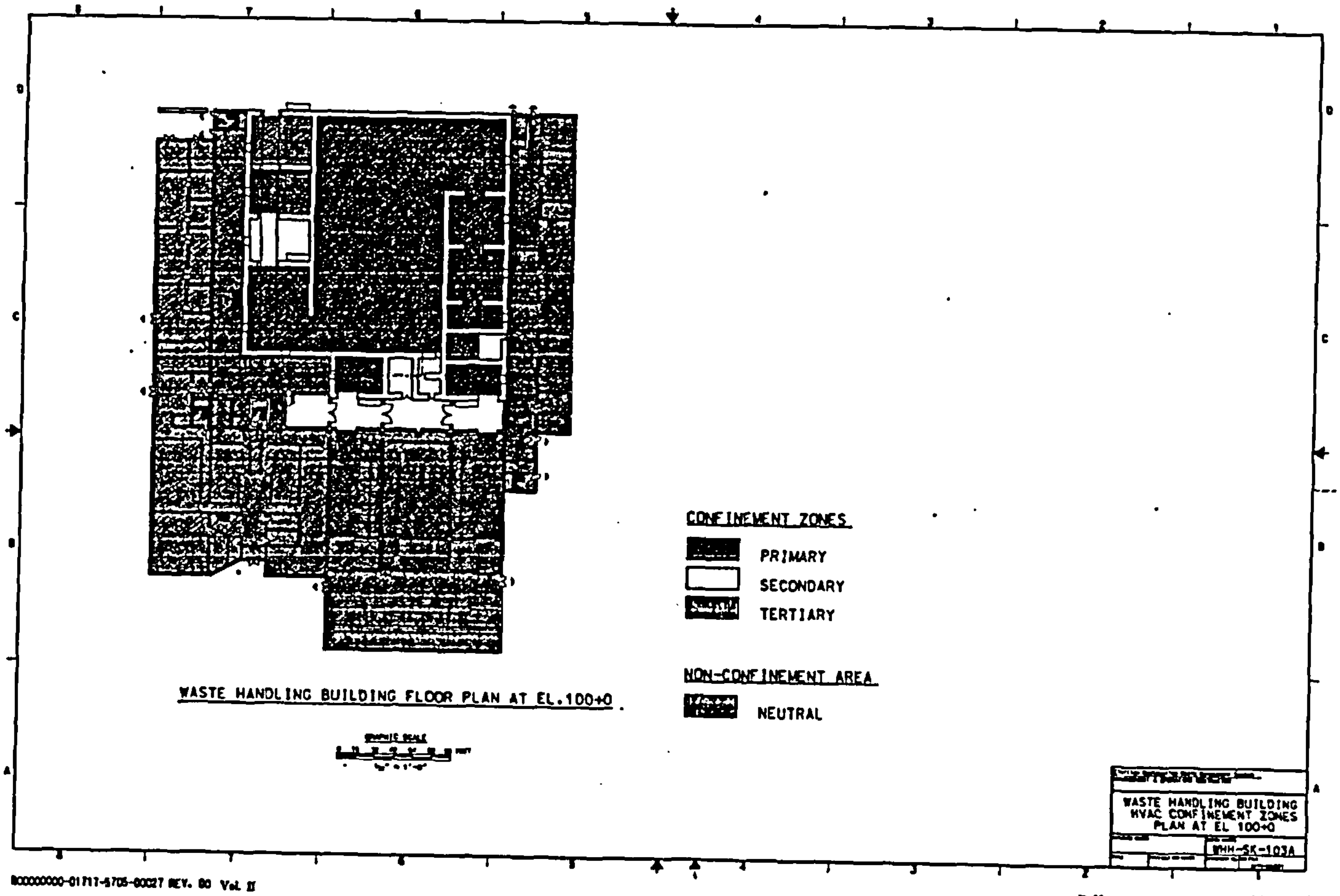
HV - SYSTEM # 102B
WASTE HANDLING BUILDING
HVAC EXHAUST STACK
HVAC FLOW DIAGRAM
WHH-SK-102K


WASTE HANDLING BUILDING
NEUTRAL AREAS
HVAC FLOW DIAGRAM
BHH-SK-102L


WASTE HANDLING BUILDING FLOOR PLAN AT EL.100+0
CONFINEMENT ZONES
PRIMARY
SECONDARY
TERTIARY
NON-CONFINEMENT AREA
NEUTRAL
WASTE HANDLING BUILDING
HVAC CONFINEMENT ZONES
PLAN AT EL 100+0
WHH-SK-103A

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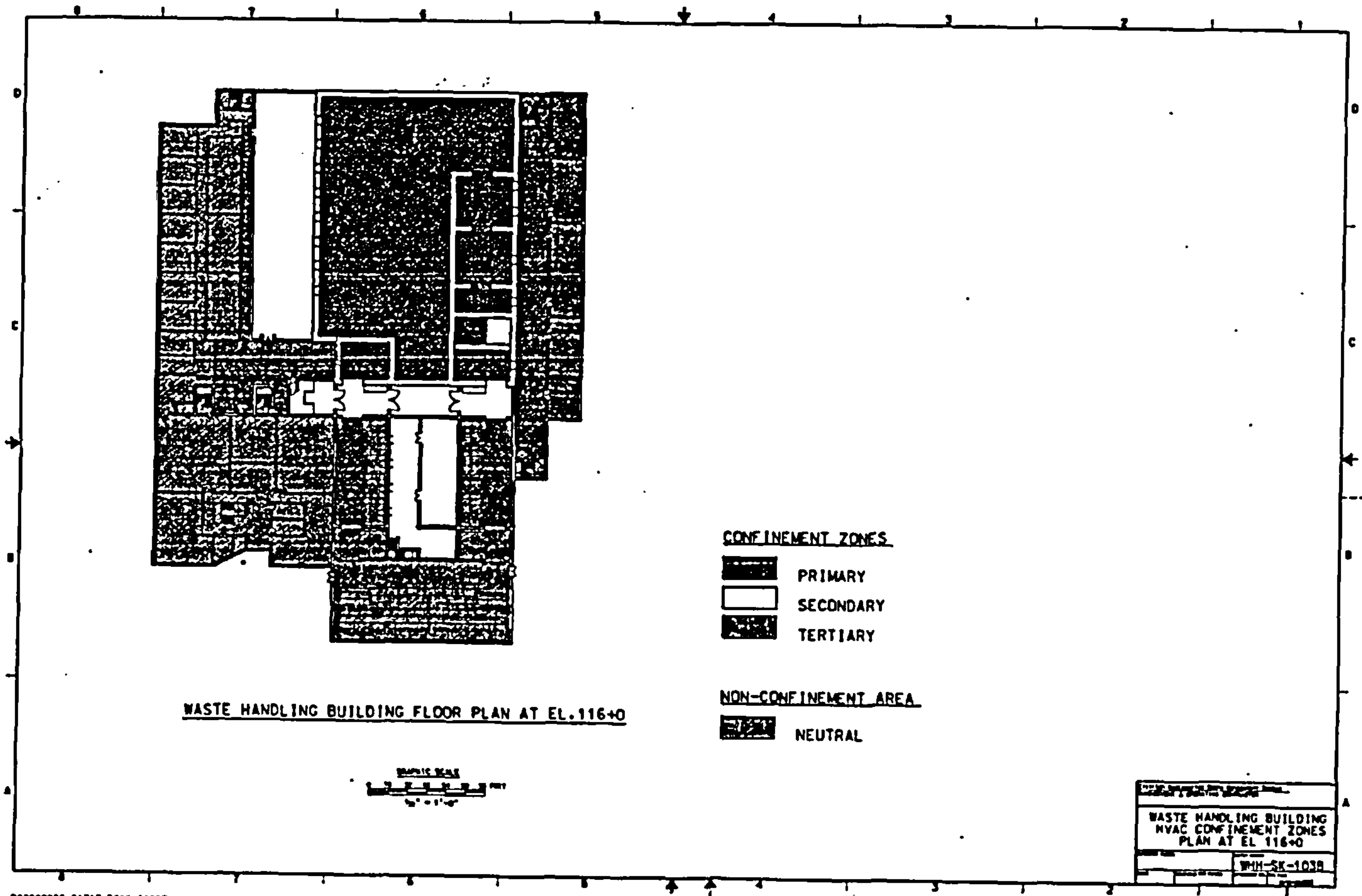
WASTE HANDLING BUILDING FLOOR PLAN AT EL.116+0
CONFINEMENT ZONES
PRIMARY
SECONDARY
TERTIARY
NON-CONFINEMENT AREA
NEUTRAL
WASTE HANDLING BUILDING
HVAC CONFINEMENT ZONES
PLAN AT EL 116+0
WHH-SK-1038

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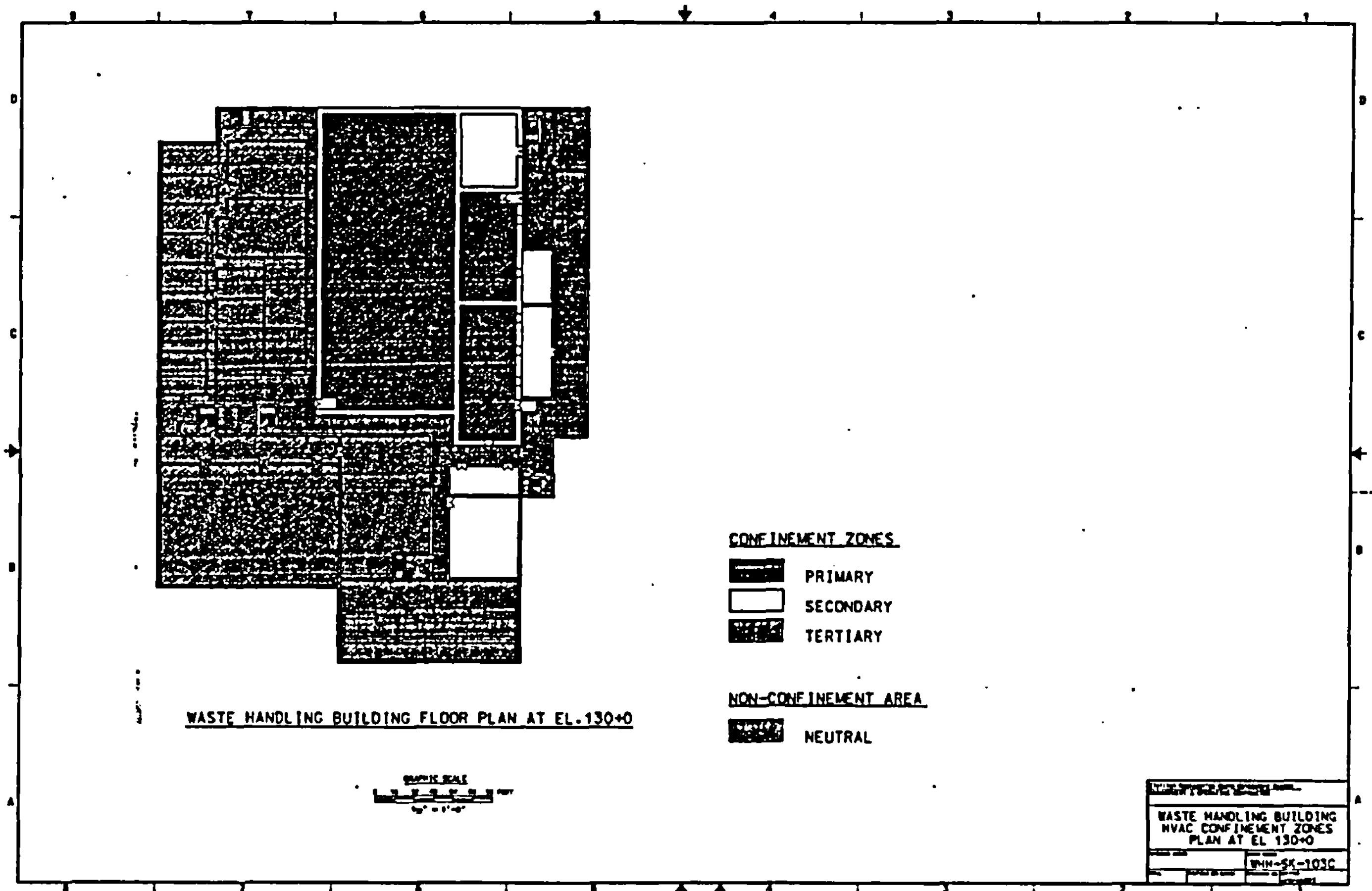
CONFINEMENT ZONES
PRIMARY
SECONDARY
TERTIARY
NON-CONFINEMENT AREA
NEUTRAL
WASTE HANDLING BUILDING FLOOR PLAN AT EL.130+0
WASTE HANDLING BUILDING
HVAC CONFINEMENT ZONES
PLAN AT EL 130+0
WHN-SK-103C

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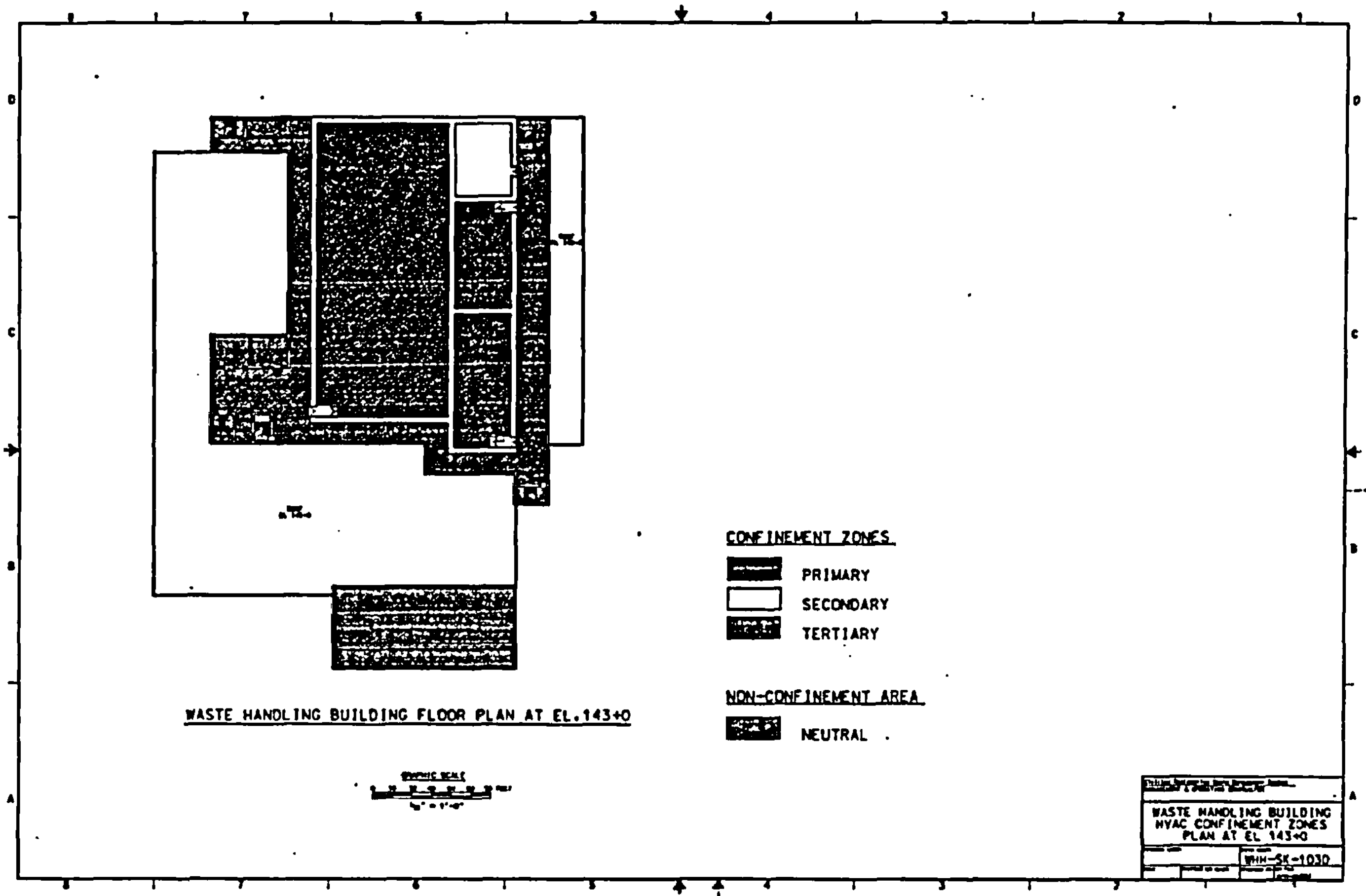
WASTE HANDLING BUILDING FLOOR PLAN AT EL.143+0
CONFINEMENT ZONES
PRIMARY
SECONDARY
TERTIARY
NON-CONFINEMENT AREA
NEUTRAL
WASTE HANDLING BUILDING
HVAC CONFINEMENT ZONES
PLAN AT EL 143+0
WHH-SK-1030

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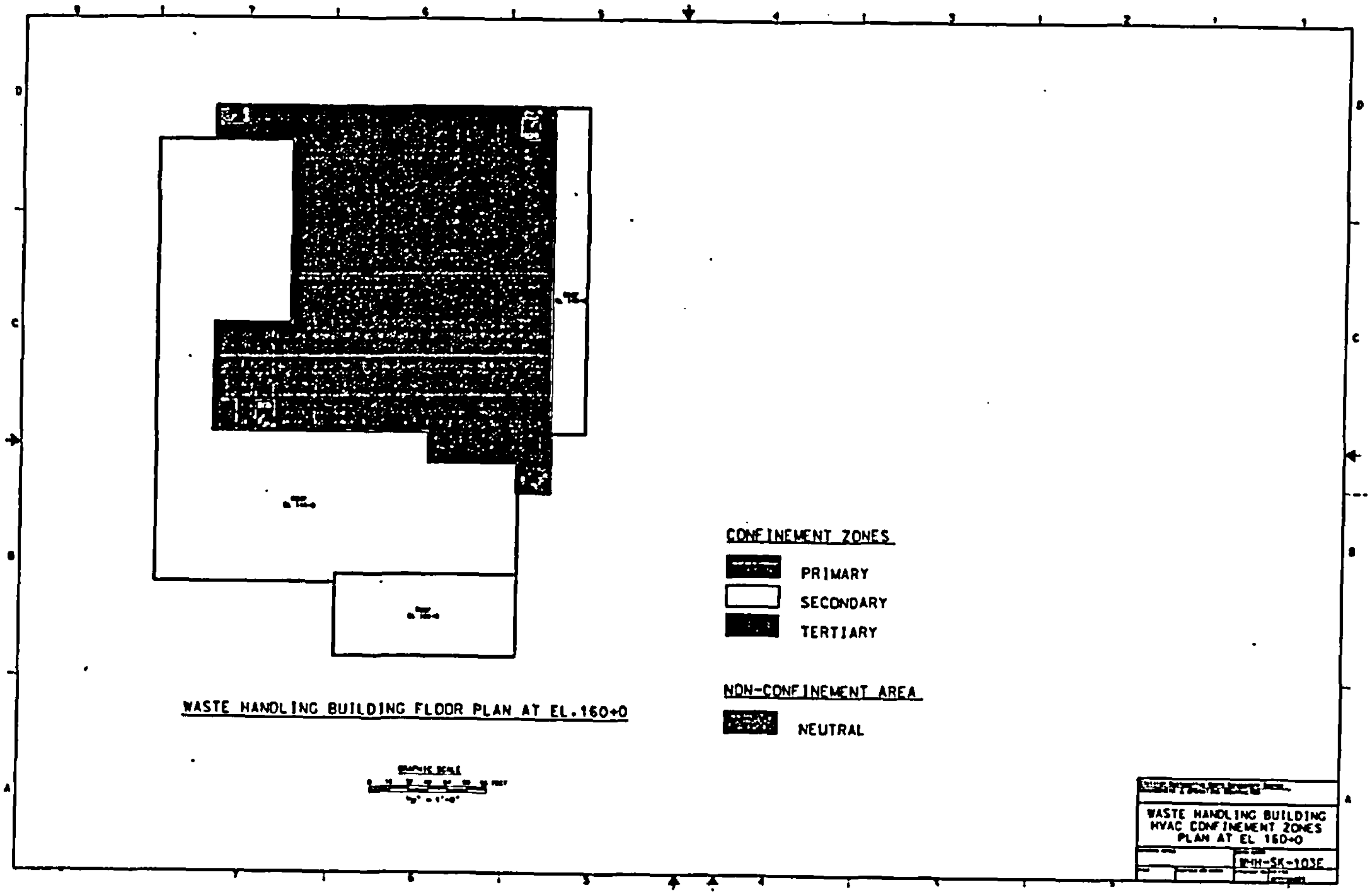
WASTE HANDLING BUILDING FLOOR PLAN AT EL.160+0
CONFINEMENT ZONES
PRIMARY
SECONDARY
TERTIARY
NON-CONFINEMENT AREA
NEUTRAL
WASTE HANDLING BUILDING HVAC CONFINEMENT ZONES PLAN AT EL 160+0
BMH-SK-103E

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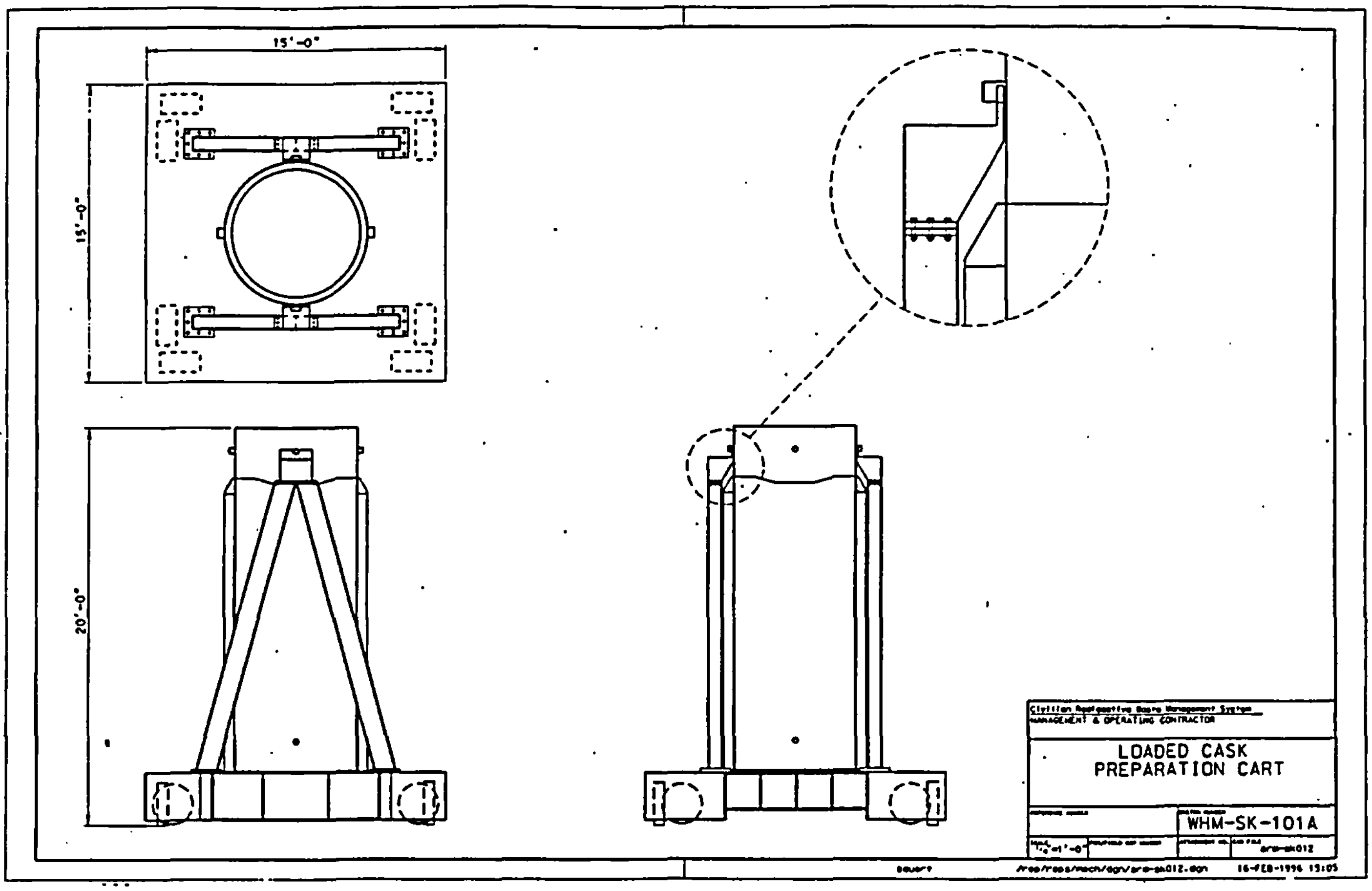
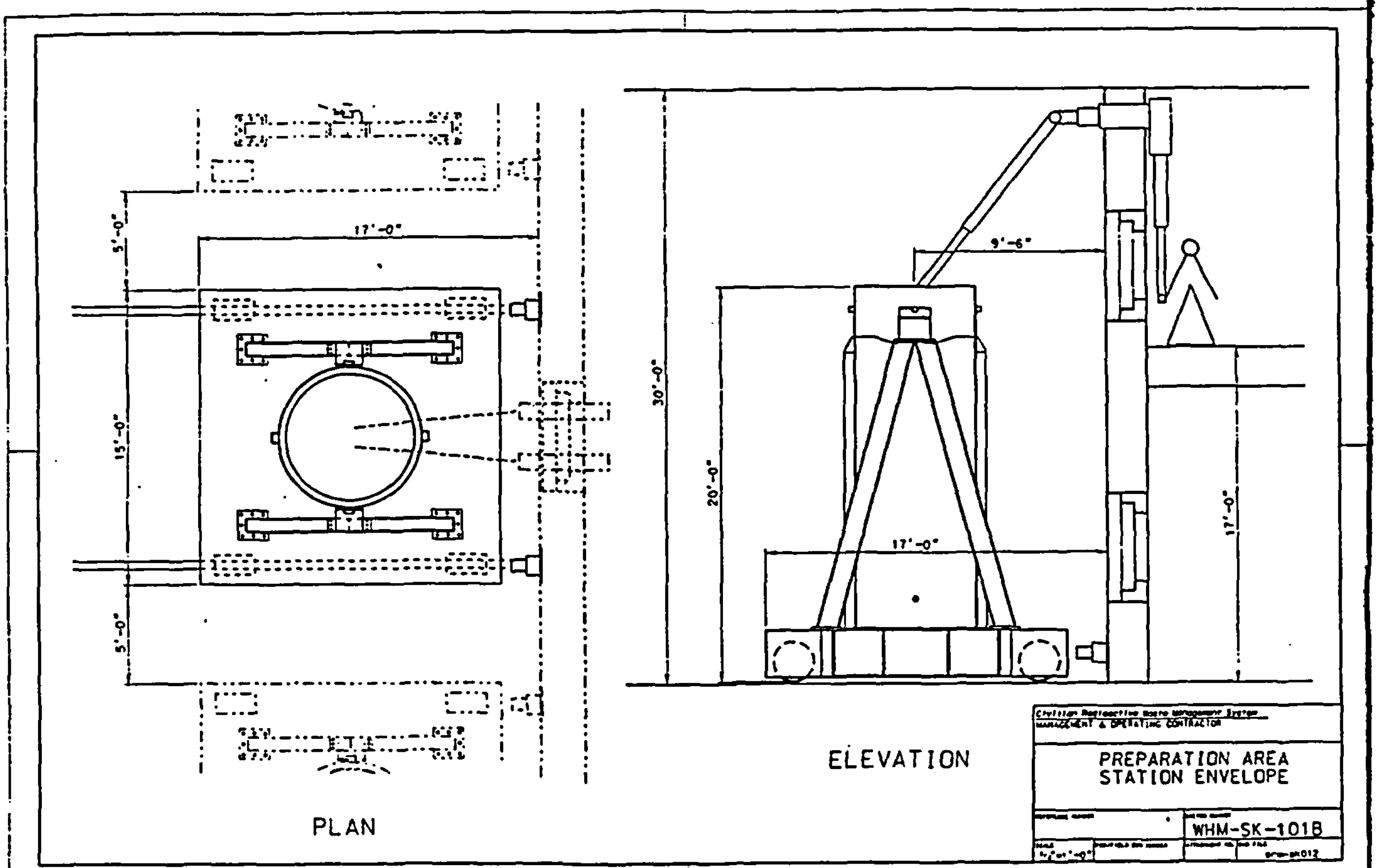
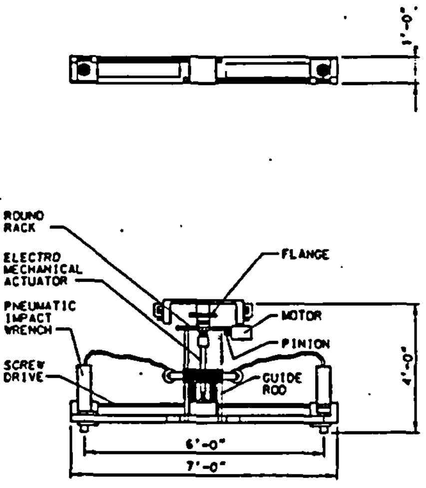

15'-0"
15'-0"
20'-0"
MANAGEMENT & OPERATING CONTRACTOR
LOADED CASK
PREPARATION CART
WHM-SK-101A
16-FEB-1996 15:05



17'-0"
5'-0"
15'-0"
5'-0"
PLAN
9'-6"
30'-0"
20'-0"
17'-0"
17'-0"
ELEVATION
Civilian Radioactive Waste Management System
MANAGEMENT & OPERATING CONTRACTOR
PREPARATION AREA
STATION ENVELOPE
WHM-SK-101B

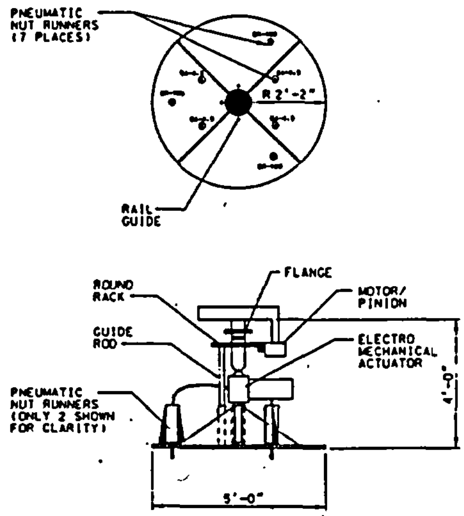


Civilian Radioactive Waste Management System
MANAGEMENT & OPERATING CONTRACTOR

CASK LID BOLTER

WHM-SK-101C

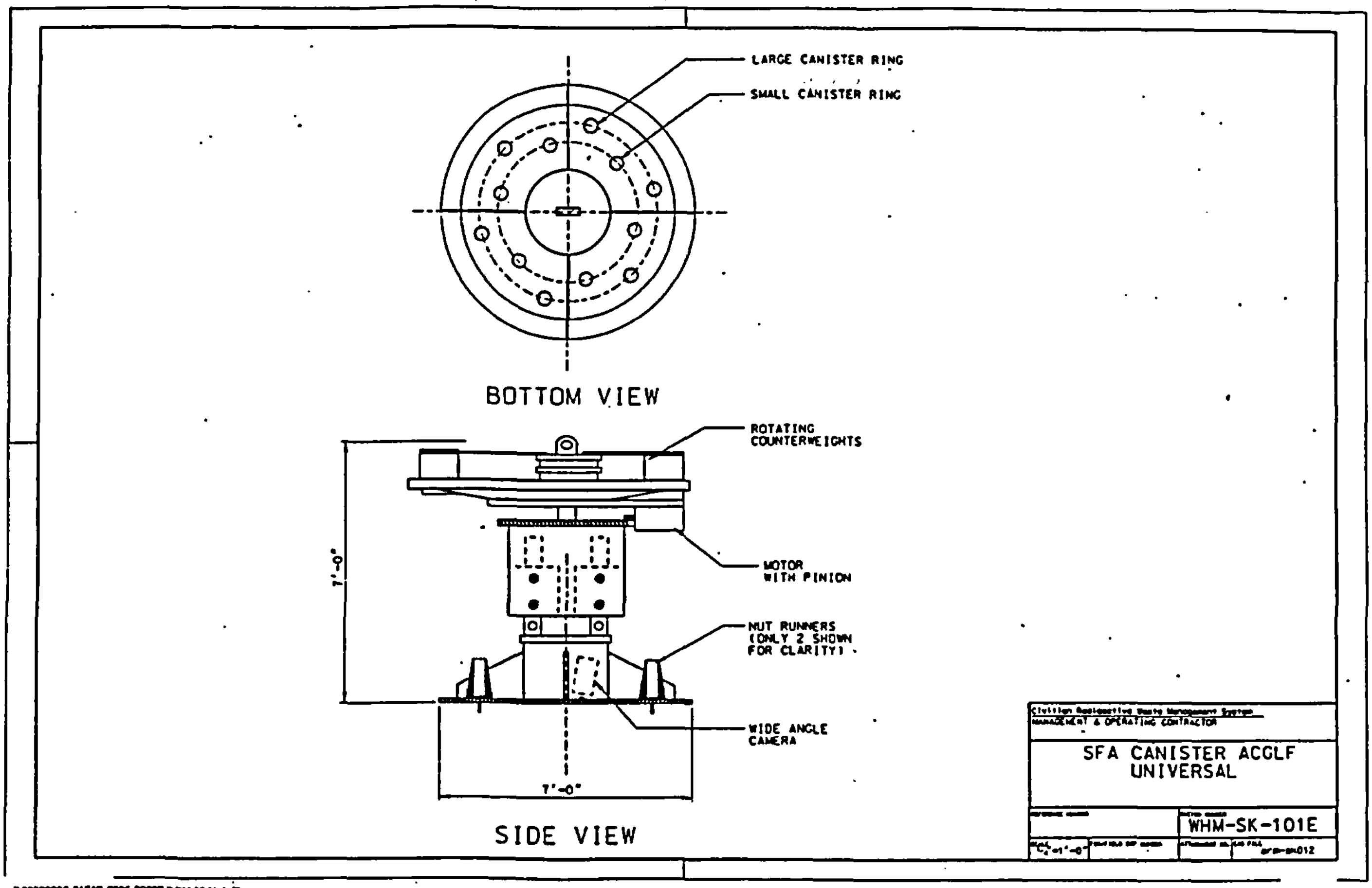
SCALE 1/4"=1'-0"



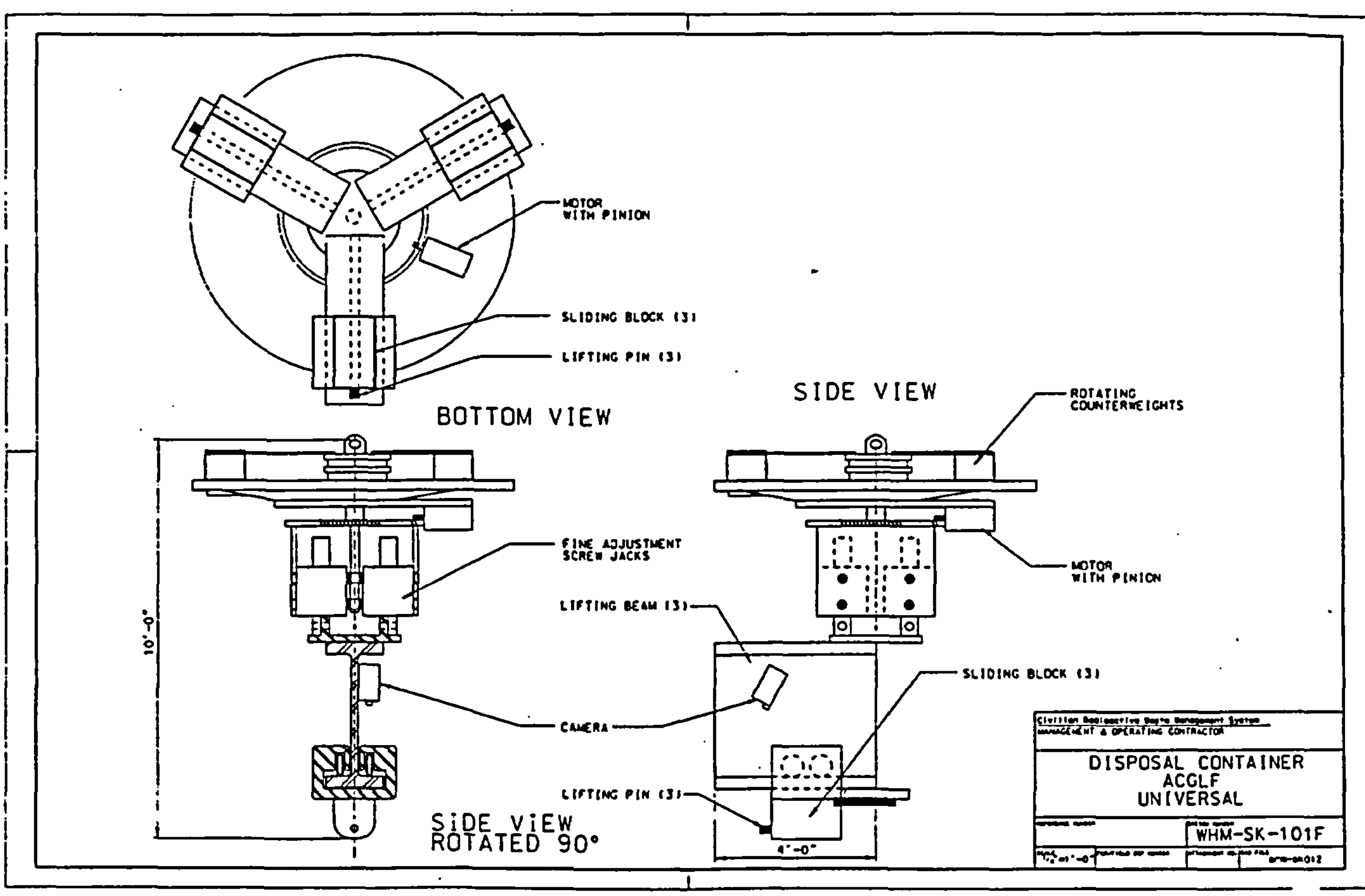
Civilian Radioactive Waste Management System
MANAGEMENT & OPERATING CONTRACTOR

CASK LID REMOVER

WHM-SK-1010



LARGE CANISTER RING
SMALL CANISTER RING
BOTTOM VIEW
ROTATING COUNTERWEIGHTS
MOTOR WITH PINION
NUT RUNNERS (ONLY 2 SHOWN FOR CLARITY)
WIDE ANGLE CAMERA
7'-0"
7'-0"
SIDE VIEW
MANAGEMENT & OPERATING CONTRACTOR
SFA CANISTER ACGLF UNIVERSAL
WHM-SK-101E


MOTOR
WITH PINION
SLIDING BLOCK (3)
LIFTING PIN (3)
BOTTOM VIEW
SIDE VIEW
ROTATING
COUNTERWEIGHTS
FINE ADJUSTMENT
SCREW JACKS
MOTOR
WITH PINION
LIFTING BEAM (3)
SLIDING BLOCK (3)
10'-0"
CAMERA
LIFTING PIN (3)
SIDE VIEW
ROTATED 90°
4'-0"
MANAGEMENT & OPERATING CONTRACTOR
DISPOSAL CONTAINER
ACGLF
UNIVERSAL
WHM-SK-101F

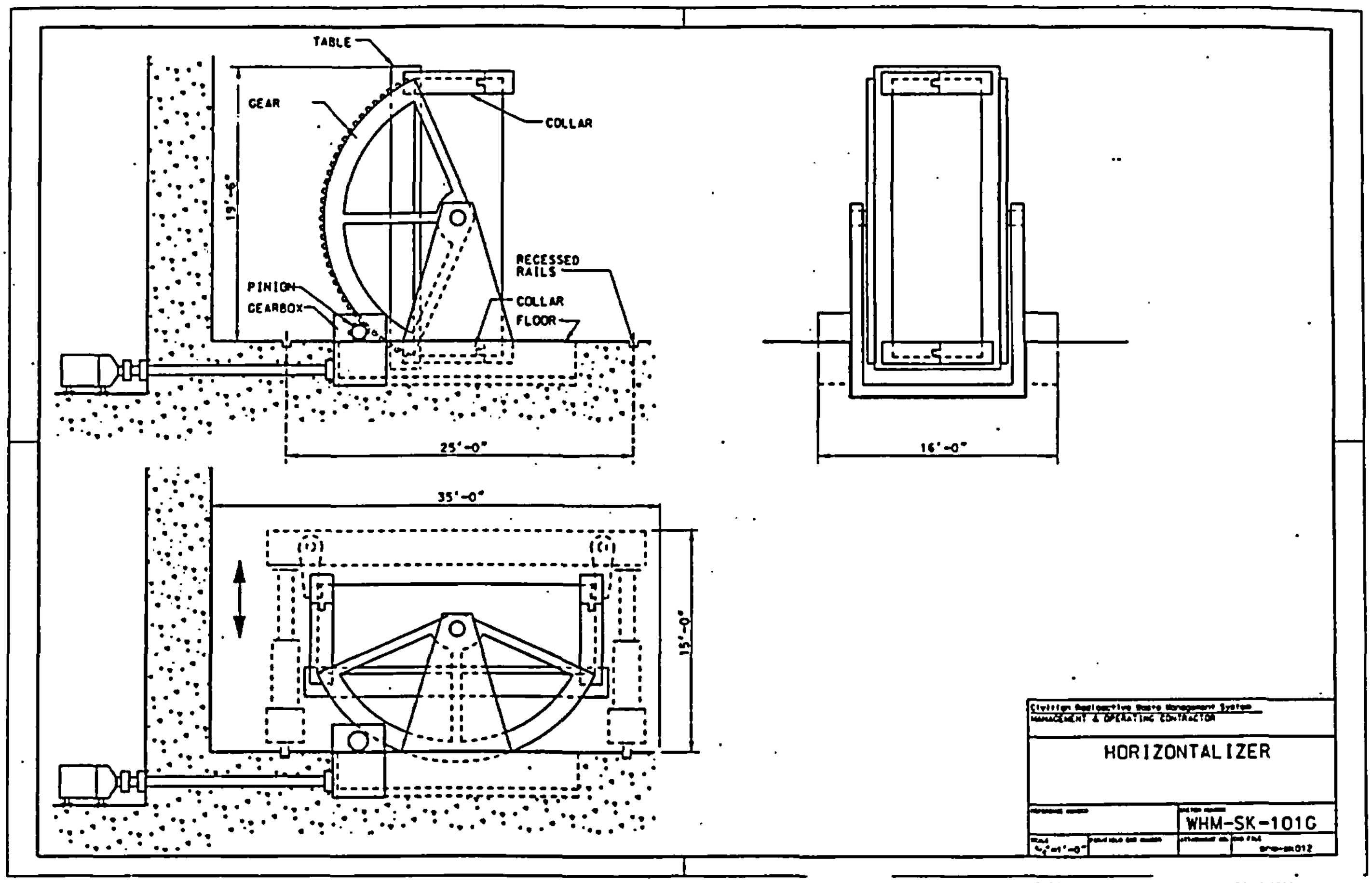
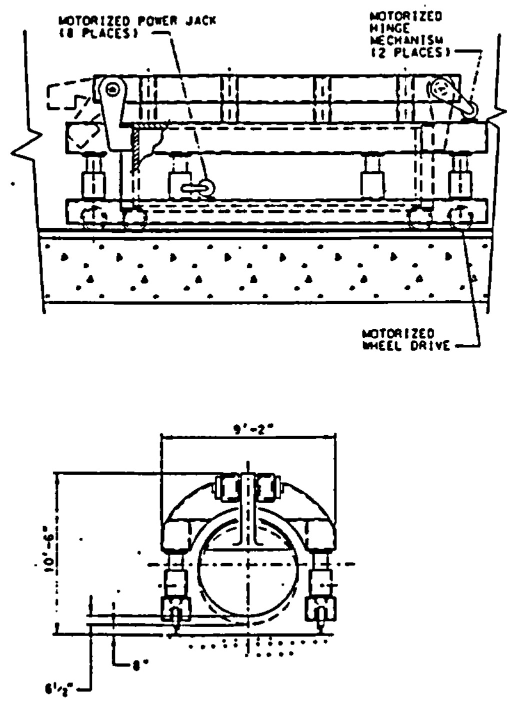


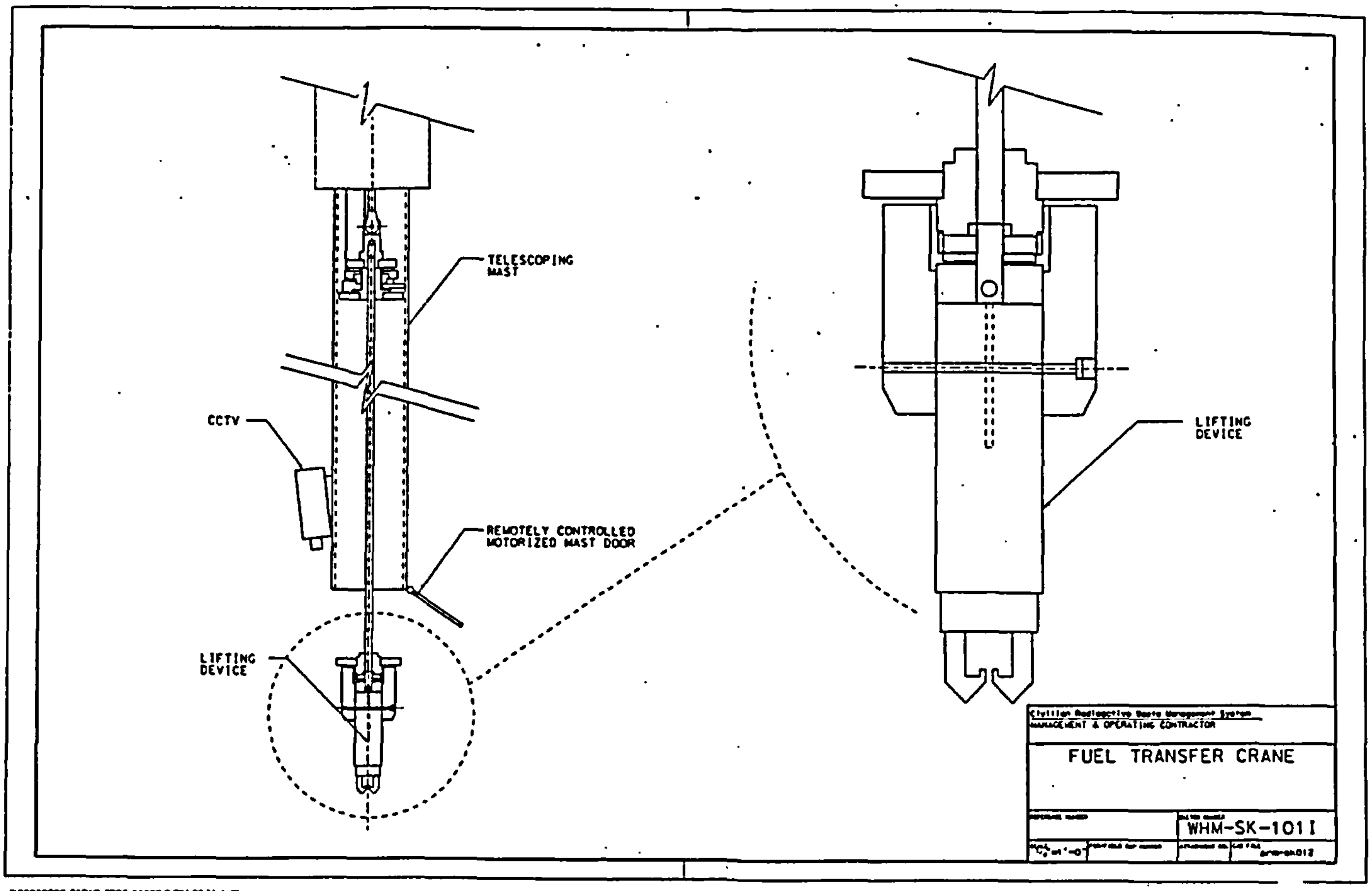
TABLE
GEAR
COLLAR
19'-6"
RECESSED RAILS
PINION
GEARBOX
COLLAR
FLOOR
25'-0"
16'-0"
35'-0"
15'-0"
Civilian Radioactive Waste Management System
MANAGEMENT & OPERATING CONTRACTOR
HORIZONTALIZER
WHM-SK-101G

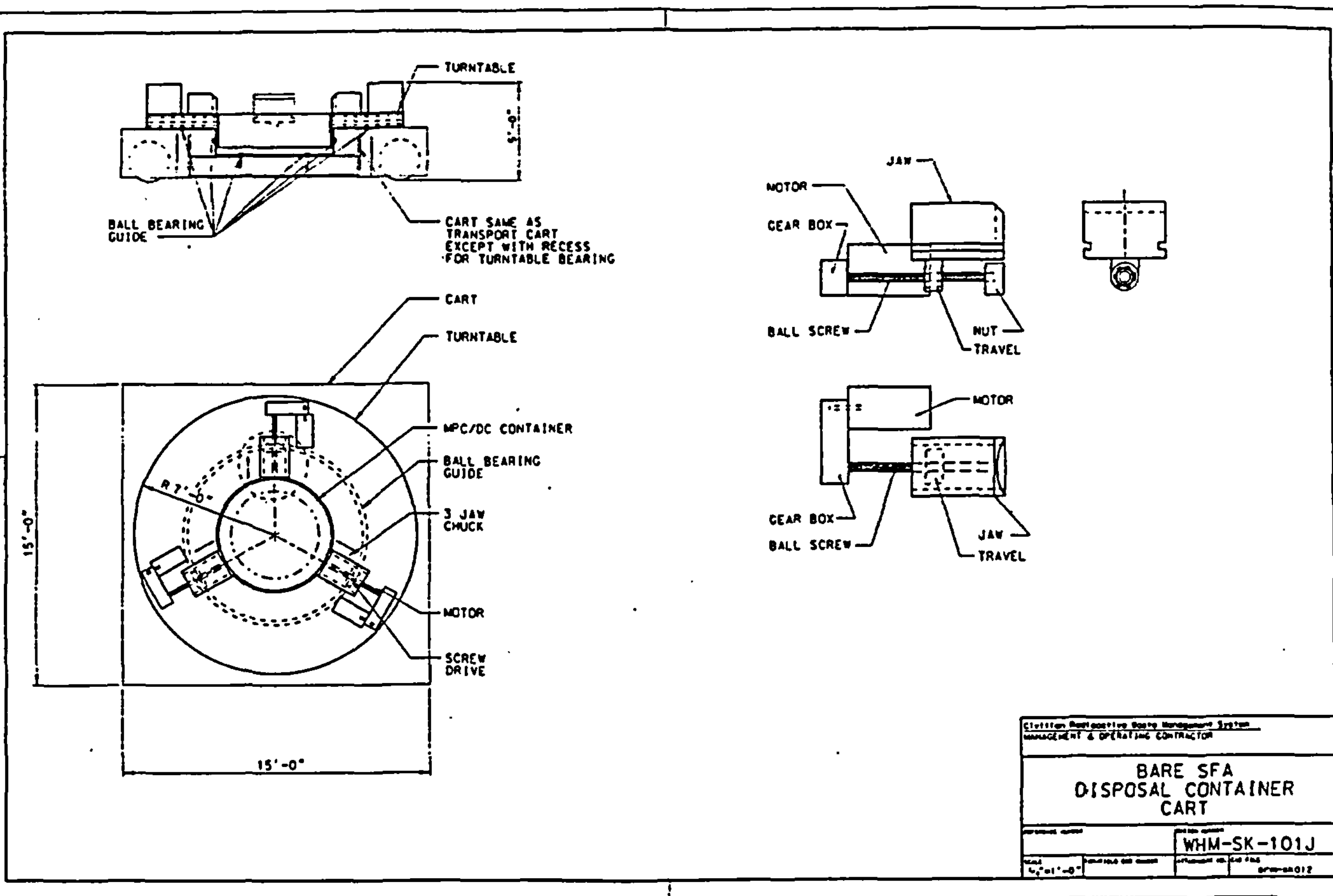


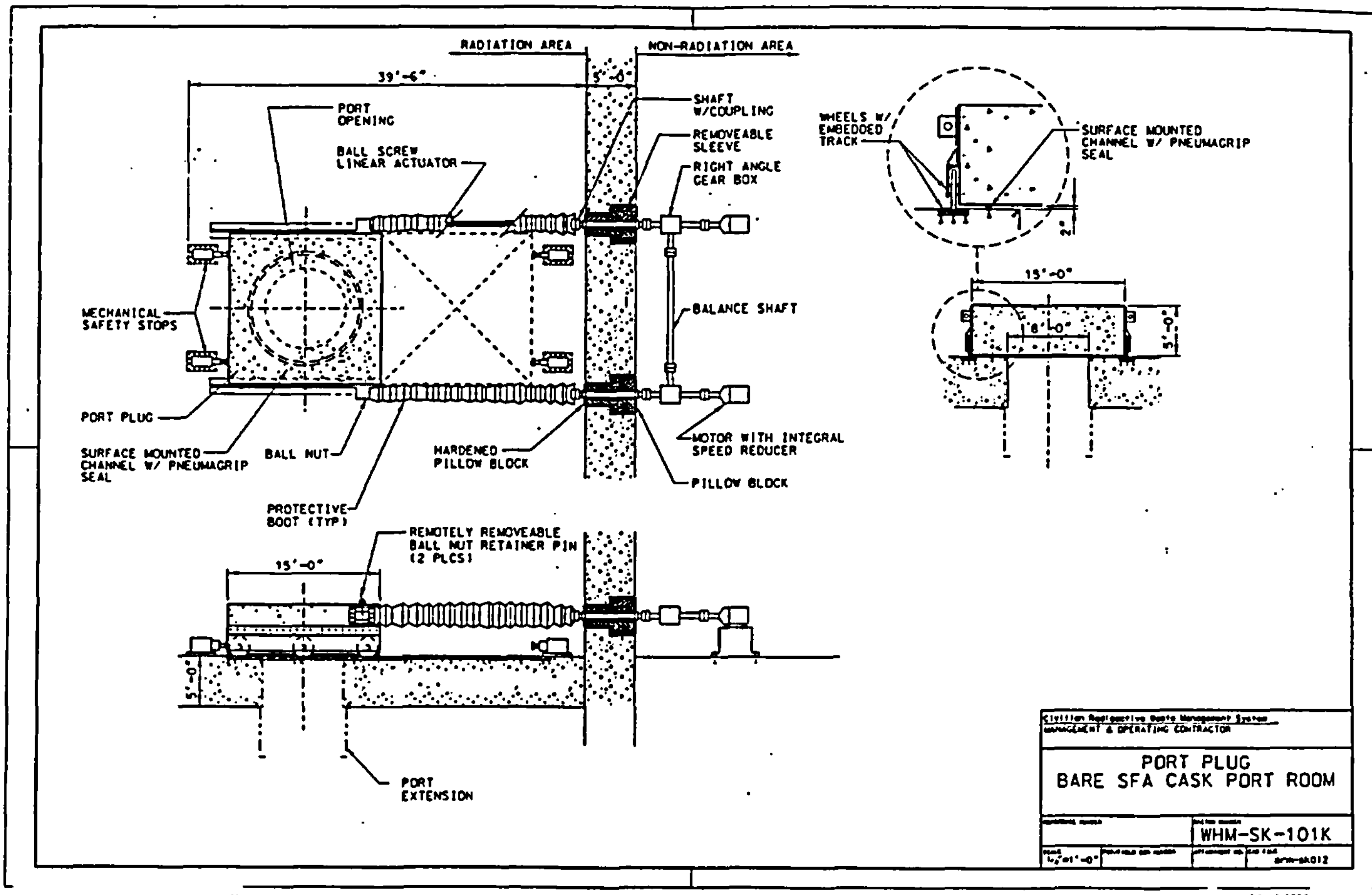
Civilian Radioactive Waste Management System
MANAGEMENT & OPERATING CONTRACTOR

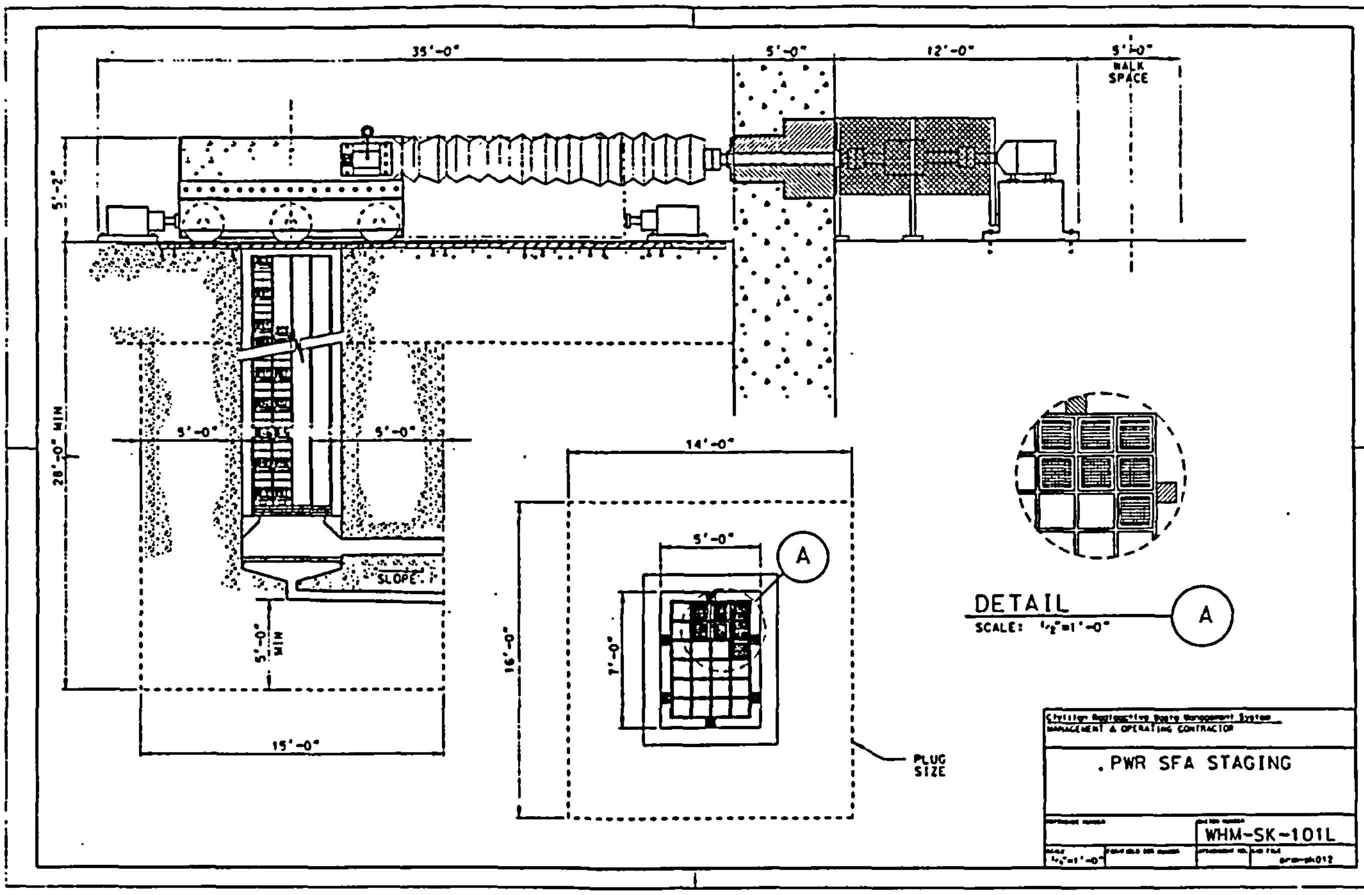
DISPOSAL CONTAINER
TRANSFER GANTRY

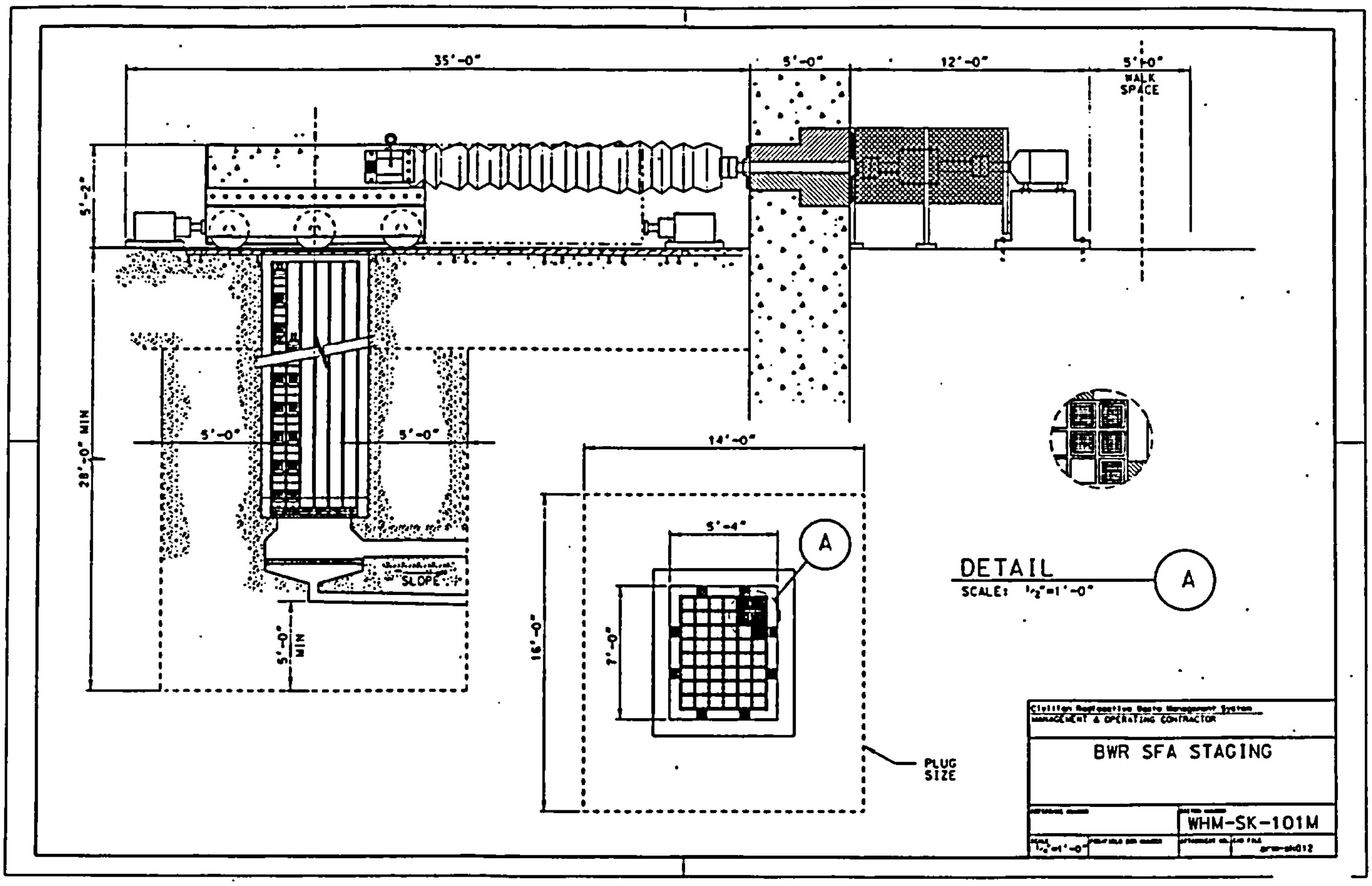
WHM-SK-101H


TELESCOPING MAST
CCTV
REMOTELY CONTROLLED MOTORIZED MAST DOOR
LIFTING DEVICE
LIFTING DEVICE
Civilian Radioactive Waste Management System
MANAGEMENT & OPERATING CONTRACTOR
FUEL TRANSFER CRANE
WHM-SK-1011


TURNTABLE
5'-0"
BALL BEARING GUIDE
CART SAME AS TRANSPORT CART EXCEPT WITH RECESS FOR TURNTABLE BEARING
CART
TURNTABLE
MPC/DC CONTAINER
BALL BEARING GUIDE
R 7'-0"
3 JAW CHUCK
MOTOR
SCREW DRIVE
15'-0"
15'-0"
JAW
MOTOR
GEAR BOX
BALL SCREW
NUT
TRAVEL
MOTOR
GEAR BOX
BALL SCREW
JAW
TRAVEL
Civilian Radioactive Waste Management System
MANAGEMENT & OPERATING CONTRACTOR
BARE SFA
DISPOSAL CONTAINER
CART
WHM-SK-101J


RADIATION AREA
NON-RADIATION AREA
39'-6"
5'-0"
PORT OPENING
BALL SCREW LINEAR ACTUATOR
SHAFT W/COUPLING
REMOVEABLE SLEEVE
RIGHT ANGLE GEAR BOX
BALANCE SHAFT
MECHANICAL SAFETY STOPS
PORT PLUG
SURFACE MOUNTED CHANNEL W/ PNEUMAGRIP SEAL
BALL NUT
HARDENED PILLOW BLOCK
MOTOR WITH INTEGRAL SPEED REDUCER
PILLOW BLOCK
PROTECTIVE BOOT (TYP)
REMOTELY REMOVEABLE BALL NUT RETAINER PIN (2 PLCS)
15'-0"
5'-0"
PORT EXTENSION
WHEELS W/ EMBEDDED TRACK
SURFACE MOUNTED CHANNEL W/ PNEUMAGRIP SEAL
15'-0"
8'-0"
5'-0"
Civilian Radioactive Waste Management System
MANAGEMENT & OPERATING CONTRACTOR
PORT PLUG
BARE SFA CASK PORT ROOM
WHM-SK-101K


35'-0"
5'-0"
12'-0"
5'-0"
WALK SPACE
5'-2"
28'-0" MIN
5'-0"
5'-0"
SLOPE
5'-0" MIN
15'-0"
14'-0"
16'-0"
5'-0"
7'-0"
A
PLUG SIZE
DETAIL
SCALE: 1/2"=1'-0"
A
Civilian Radioactive Waste Management System
MANAGEMENT & OPERATING CONTRACTOR
PWR SFA STAGING
WHM-SK-101L


35'-0"
5'-0"
12'-0"
5'-0"
WALK SPACE
5'-2"
28'-0" MIN
5'-0"
5'-0"
SLOPE
5'-0" MIN
14'-0"
16'-0"
5'-4"
7'-0"
A
PLUG SIZE
DETAIL
A
SCALE: 1/2"=1'-0"
Civilian Radioactive Waste Management System
MANAGEMENT & OPERATING CONTRACTOR
BWR SFA STAGING
WHM-SK-101M

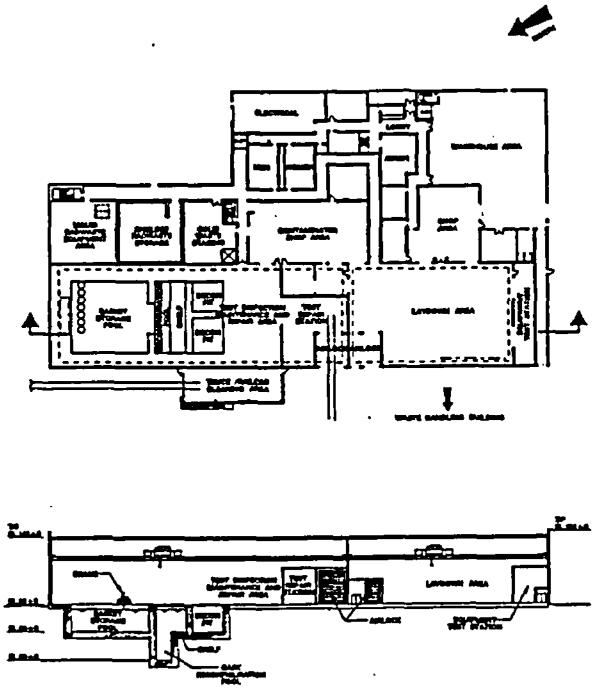


Figure 7.2.3-1. Cask Maintenance Facility (Floor Plan and Building Section)

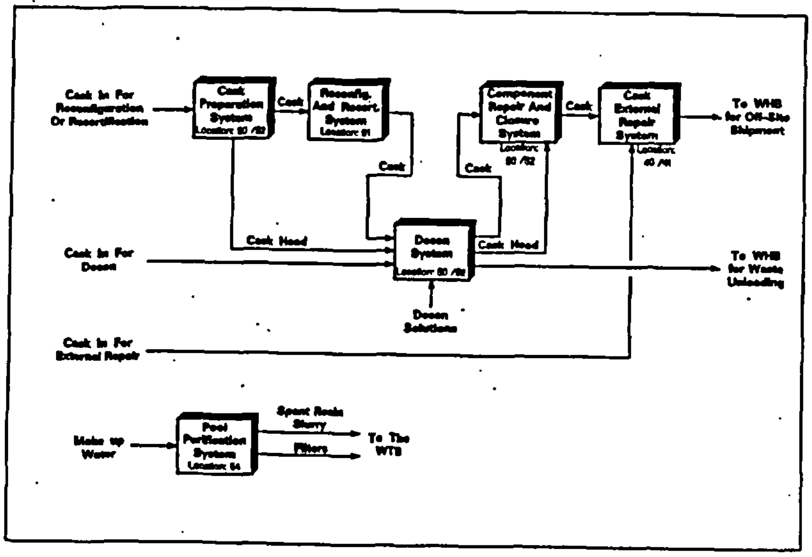


Figure 7.2.3-2 Cask Maintenance System Overview

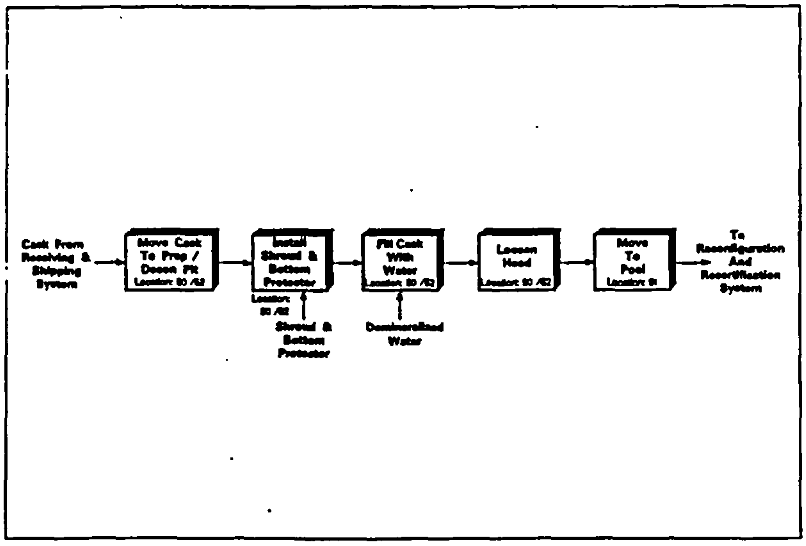


Figure 7.2.3-3. Cask Preparation System

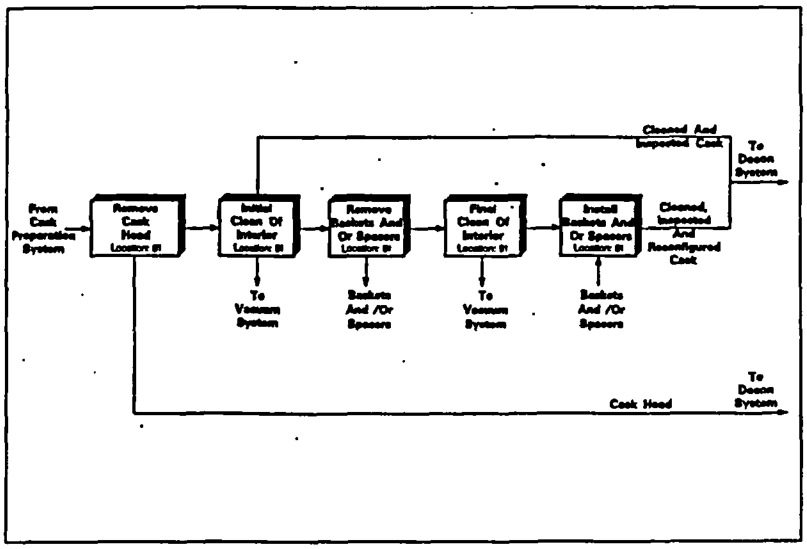


Figure 7.2.3-4. Cask Reconfiguration & Recertification System

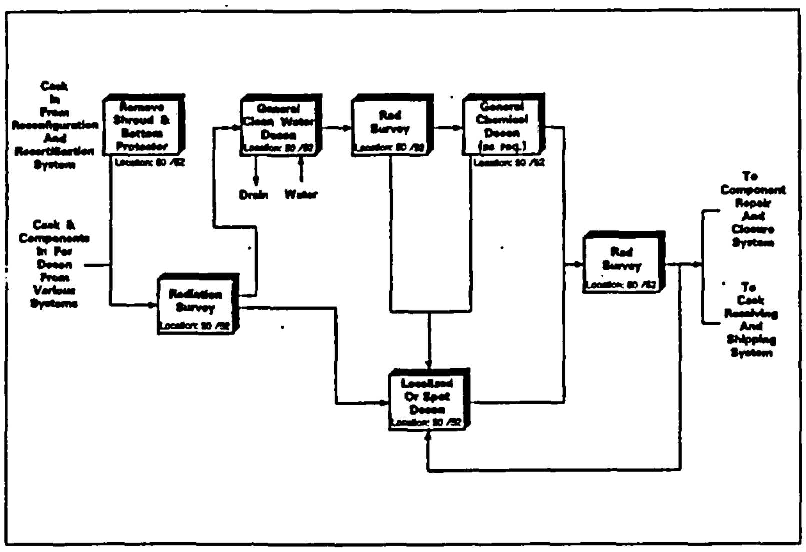


Figure 7.2.3-5. Decontamination System

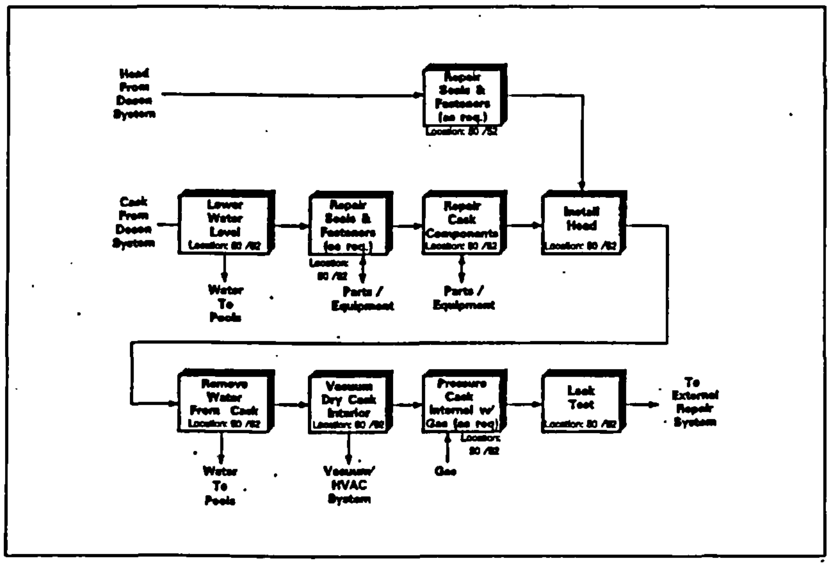


Figure 7.2.3-6. Cask Component Repair And Closure System

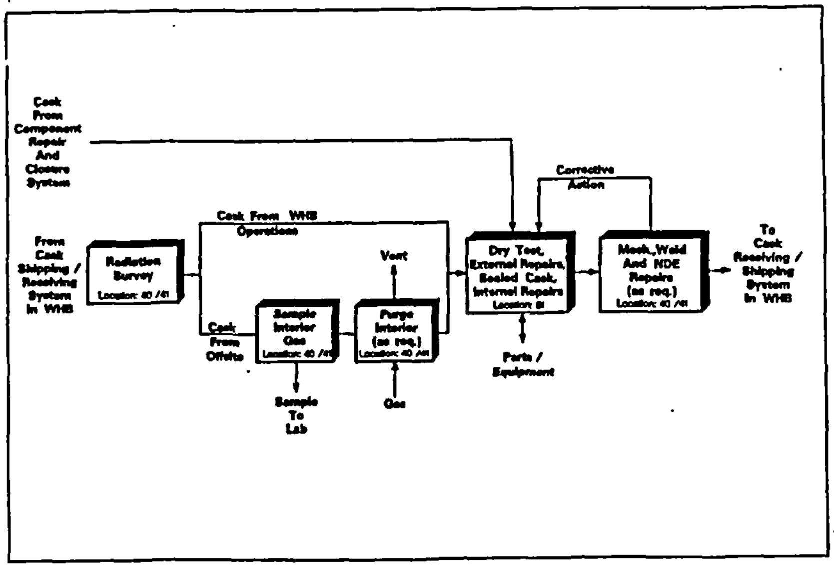


Figure 7.2.3-7. Cask External Repair System

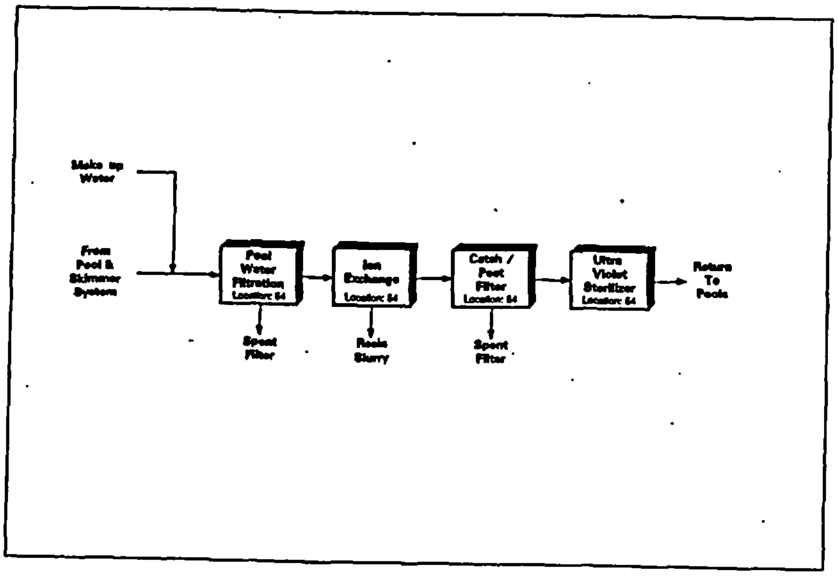
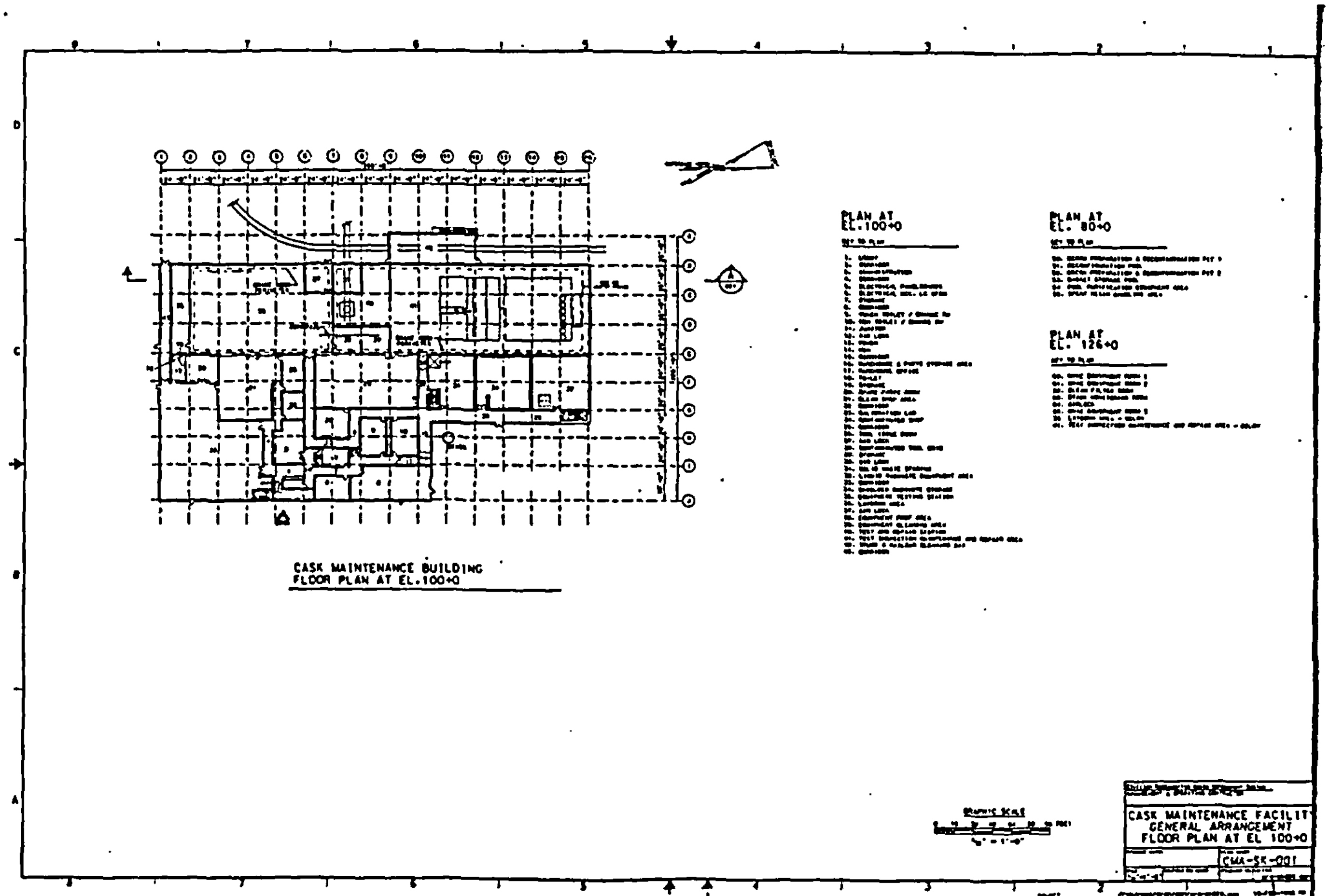
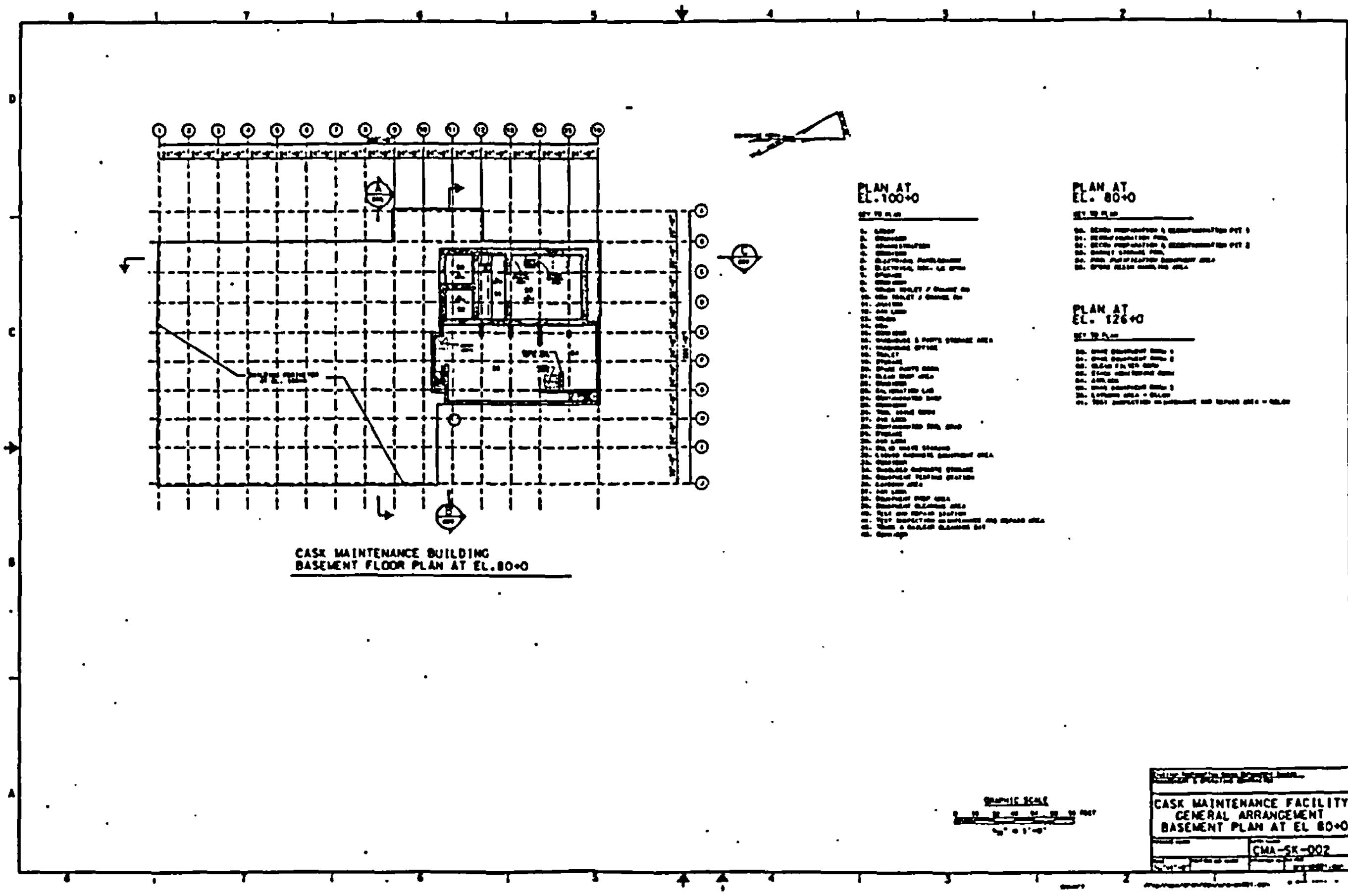
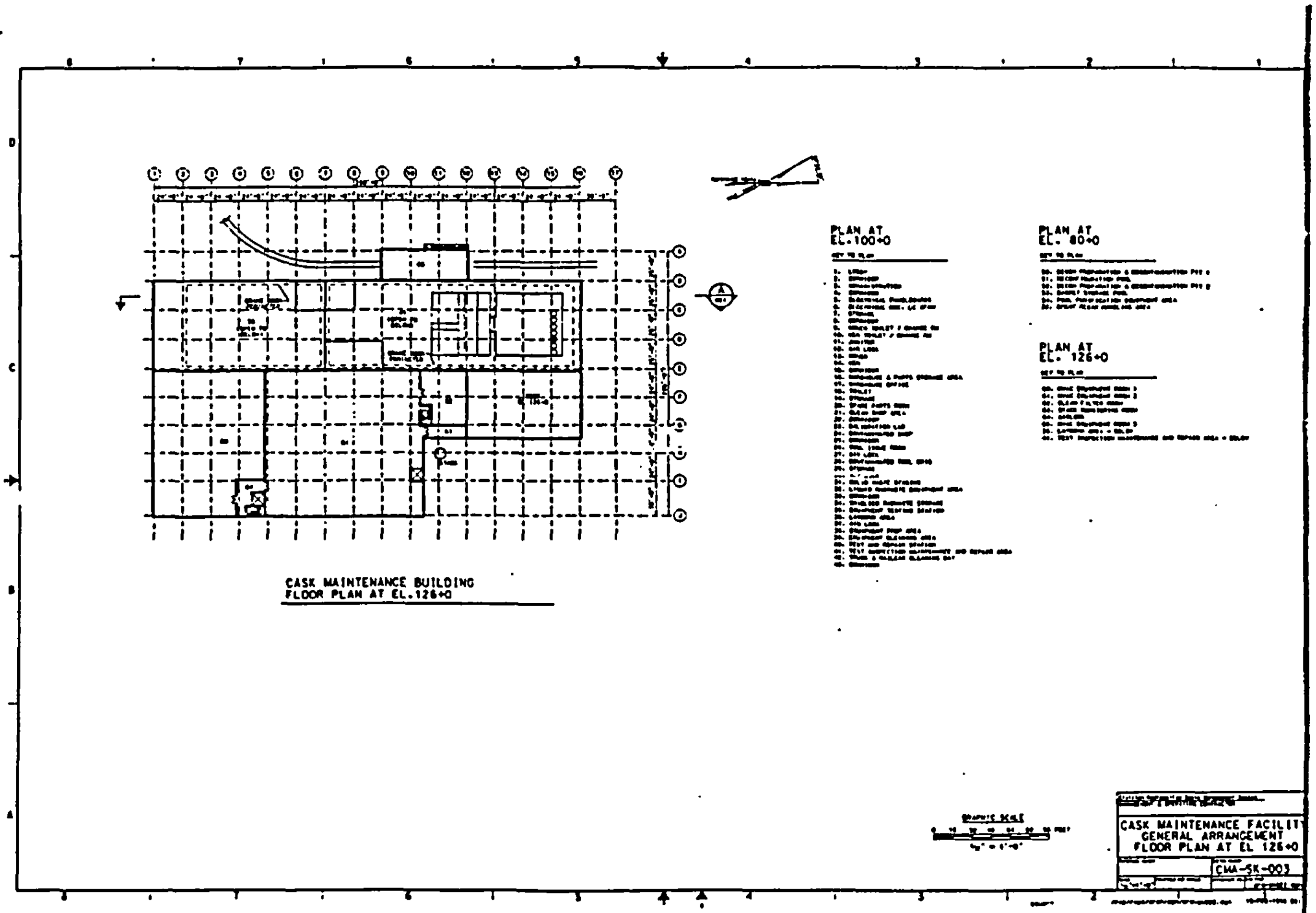


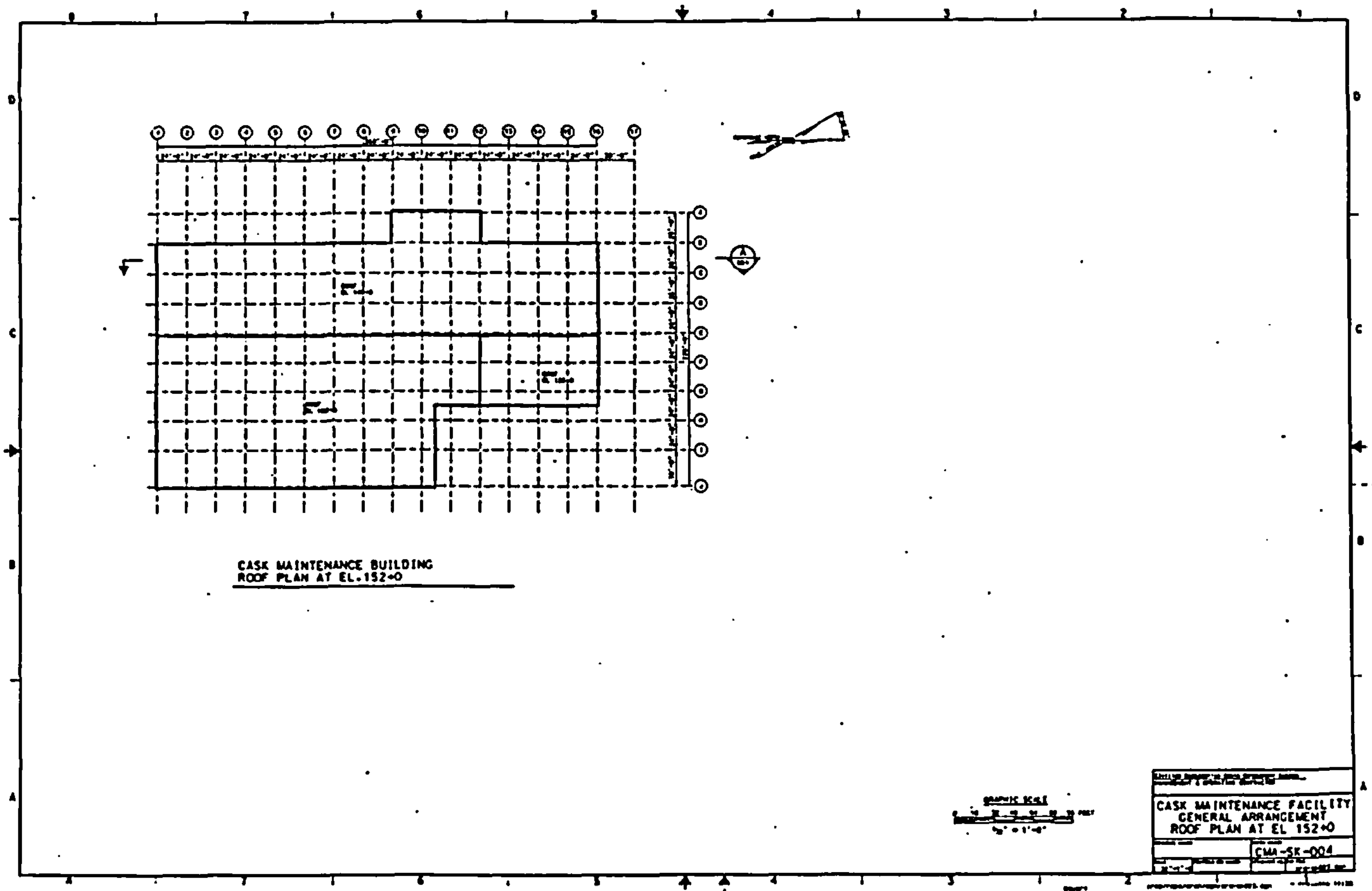
Figure 7.2.3-8. Pool Purification System

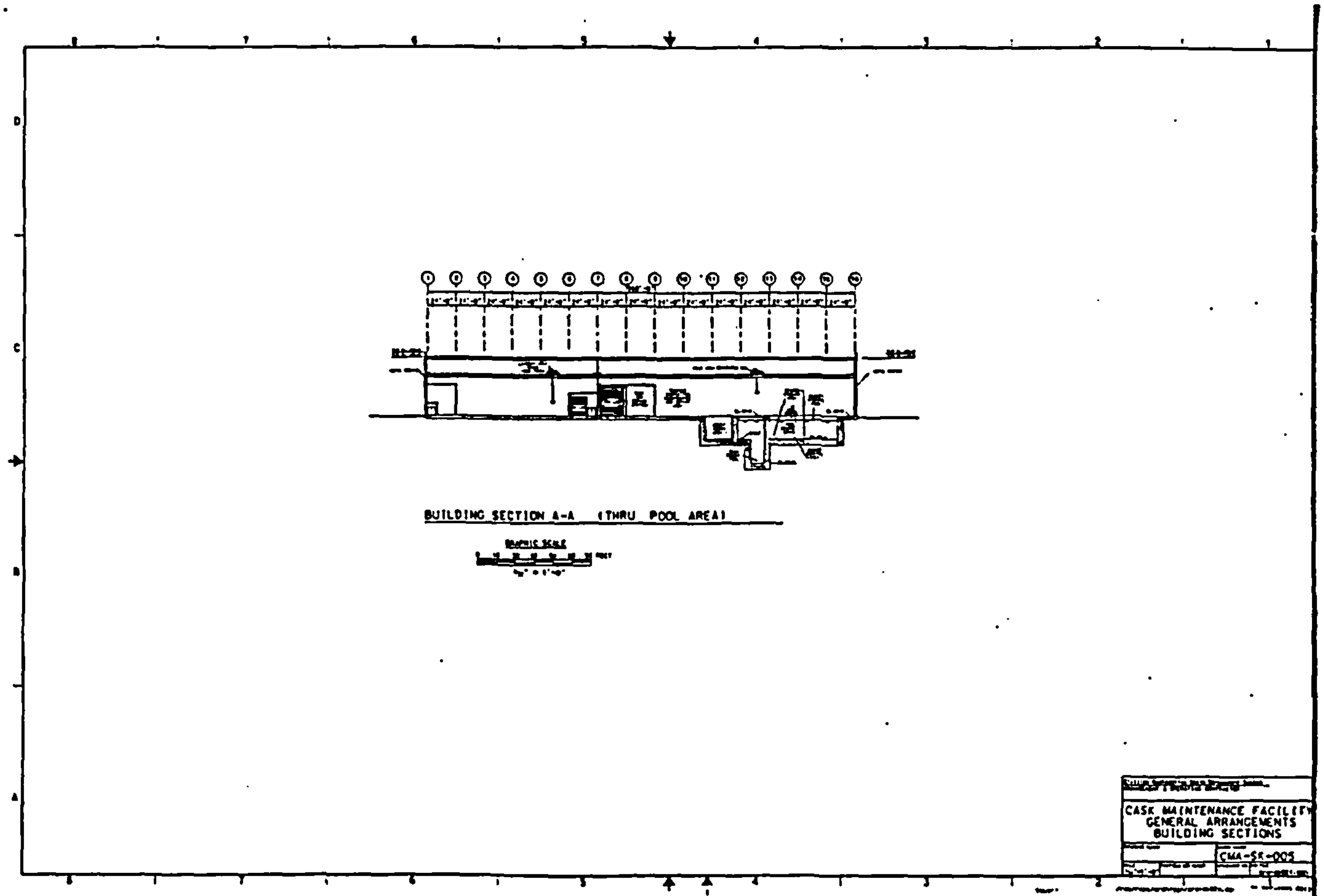


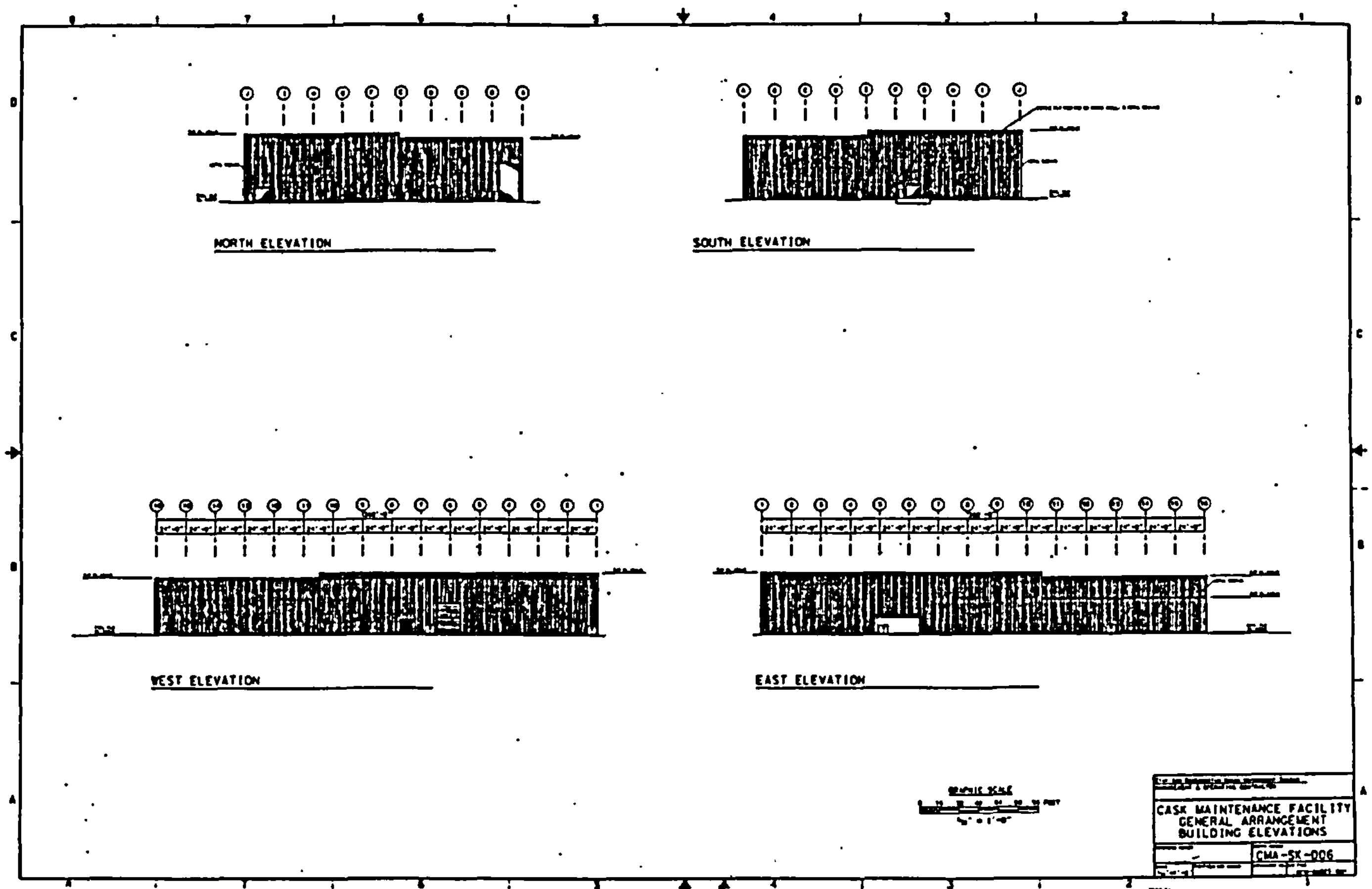
CASK MAINTENANCE BUILDING
FLOOR PLAN AT EL.100+0
PLAN AT EL.100+0
PLAN AT EL. 80+0
PLAN AT EL. 126+0
GRAPHIC SCALE
CASK MAINTENANCE FACILITY
GENERAL ARRANGEMENT
FLOOR PLAN AT EL 100+0
CMA-SK-001


CASK MAINTENANCE BUILDING
BASEMENT FLOOR PLAN AT EL.80+0
PLAN AT EL.100+0
PLAN AT EL. 80+0
PLAN AT EL. 126+0
GRAPHIC SCALE
CASK MAINTENANCE FACILITY
GENERAL ARRANGEMENT
BASEMENT PLAN AT EL 80+0
CMA-SK-002

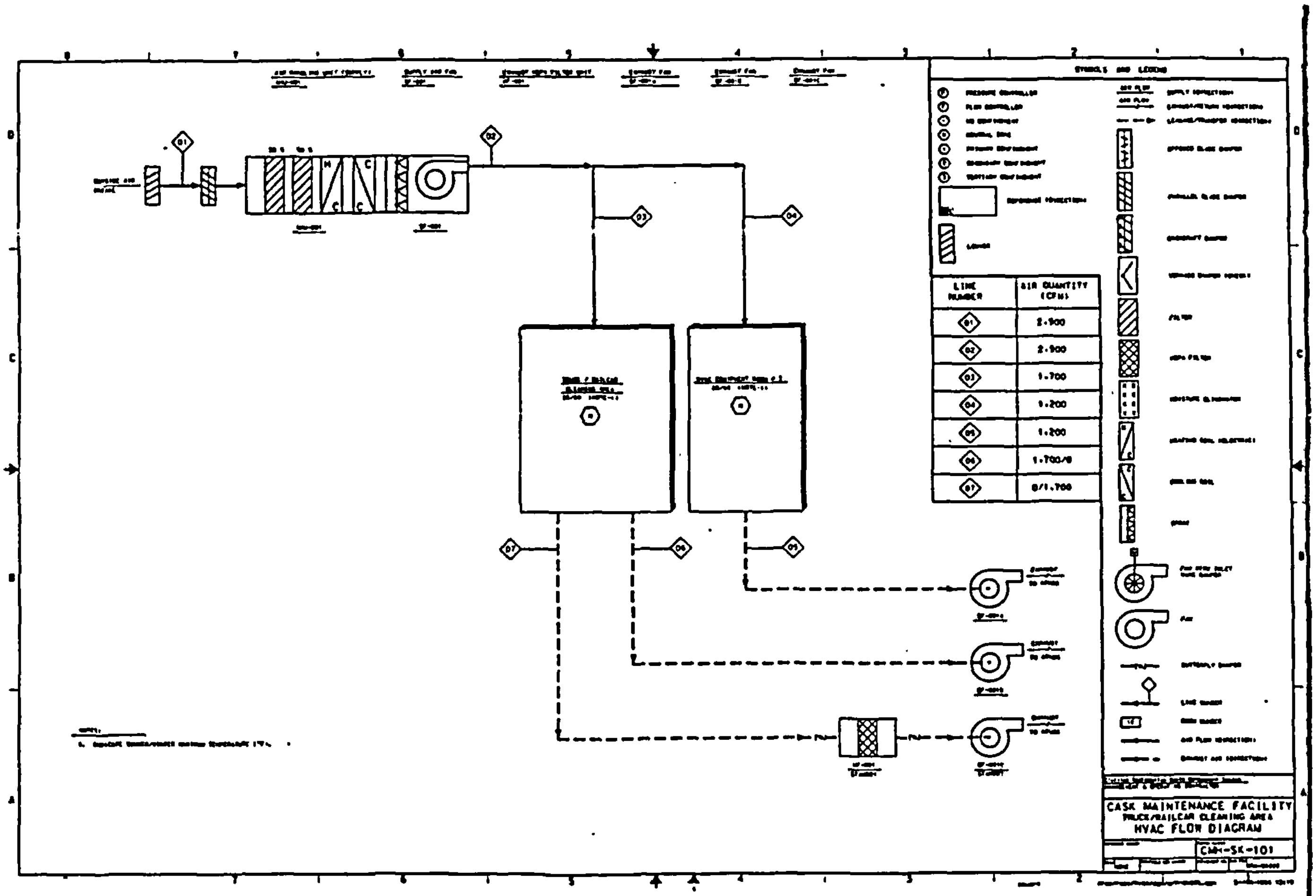

CASK MAINTENANCE BUILDING
FLOOR PLAN AT EL. 126+0
PLAN AT
EL. 100+0
PLAN AT
EL. 80+0
PLAN AT
EL. 126+0
CASK MAINTENANCE FACILITY
GENERAL ARRANGEMENT
FLOOR PLAN AT EL 126+0
CMA-SK-003


CASK MAINTENANCE BUILDING
ROOF PLAN AT EL.152-0
CASK MAINTENANCE FACILITY
GENERAL ARRANGEMENT
ROOF PLAN AT EL 152+0
CMA-SK-004

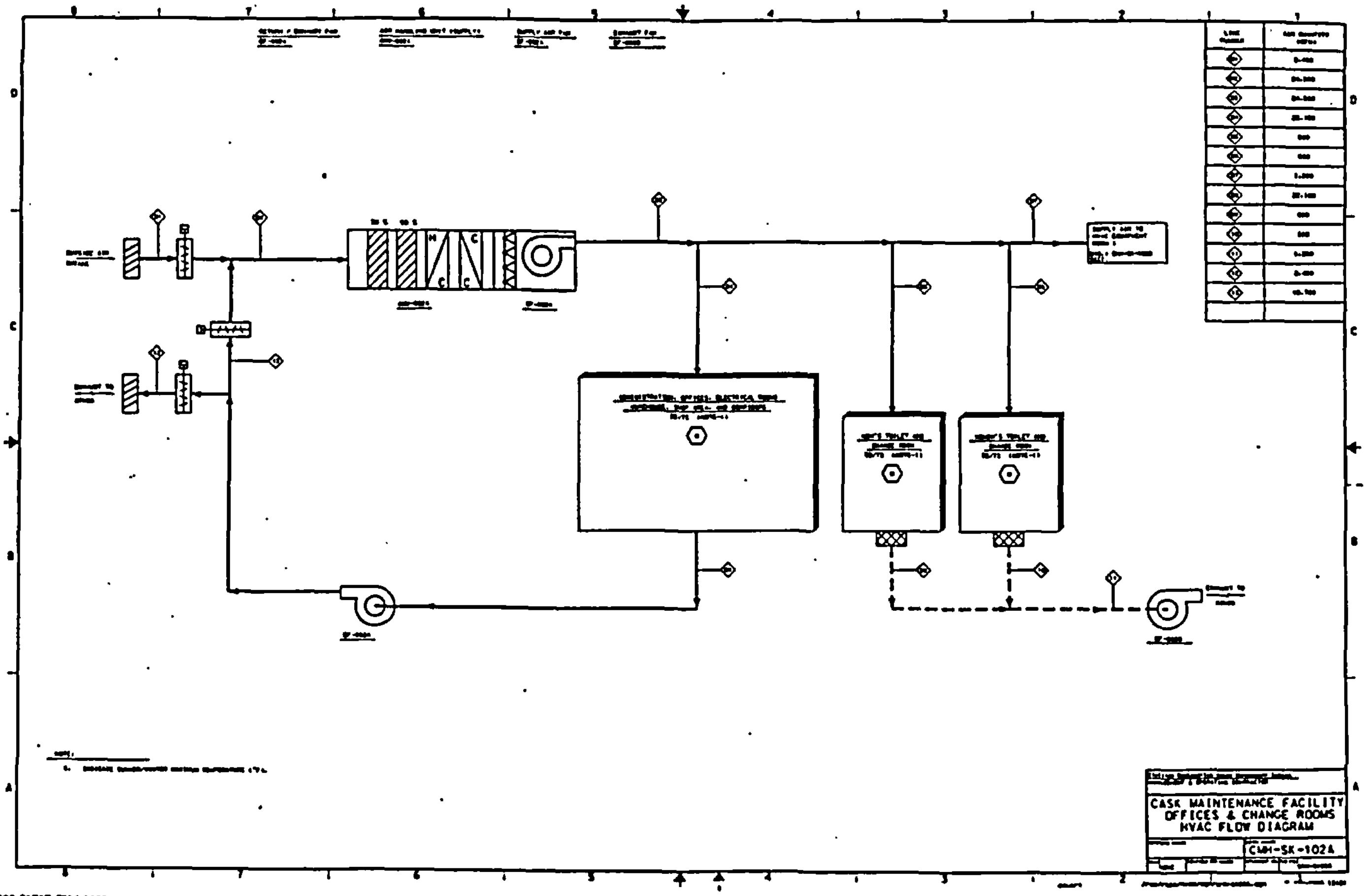

BUILDING SECTION A-A (THRU POOL AREA)
GRAPHIC SCALE
CASK MAINTENANCE FACILITY
GENERAL ARRANGEMENTS
BUILDING SECTIONS
CMA-SK-005

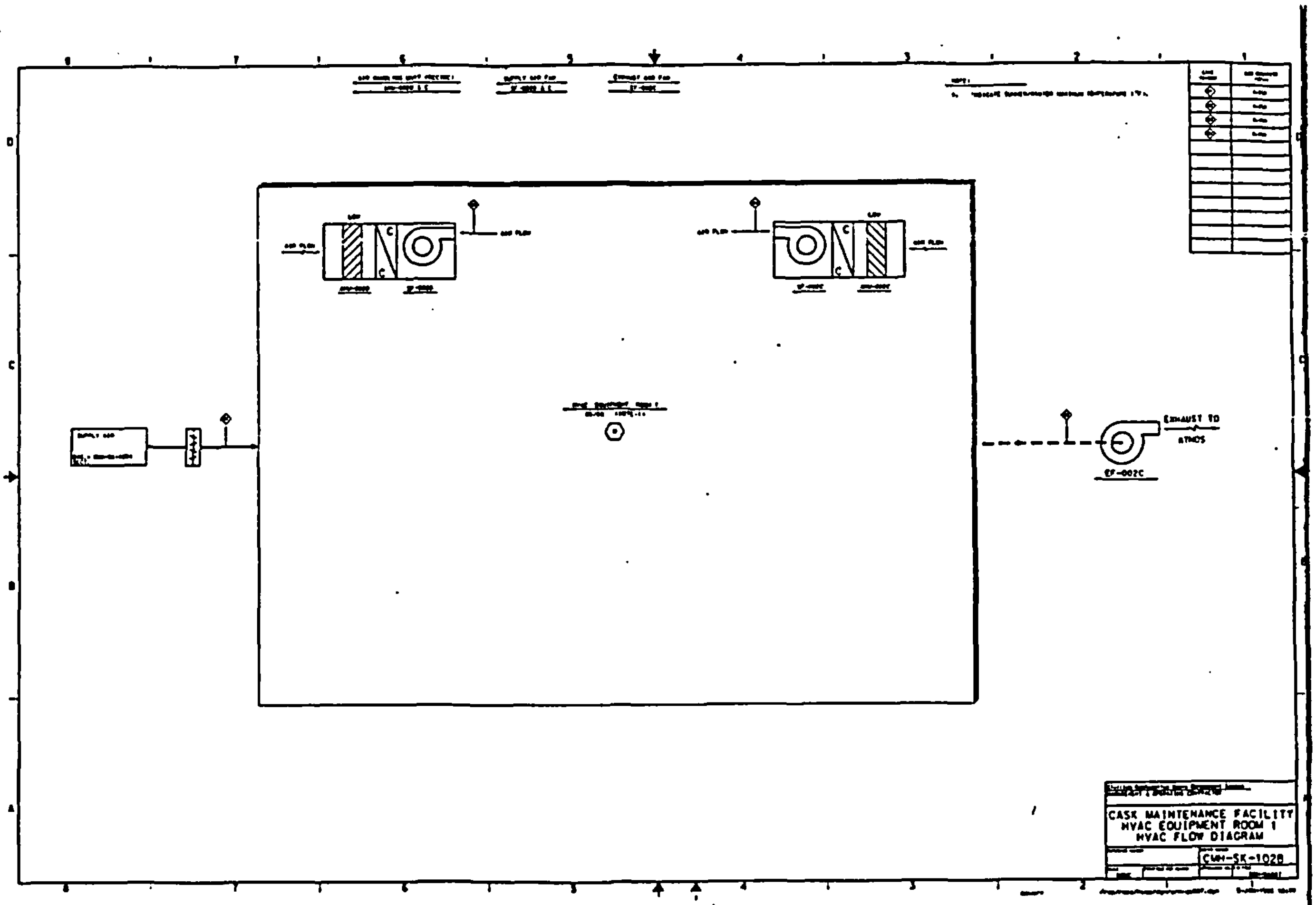


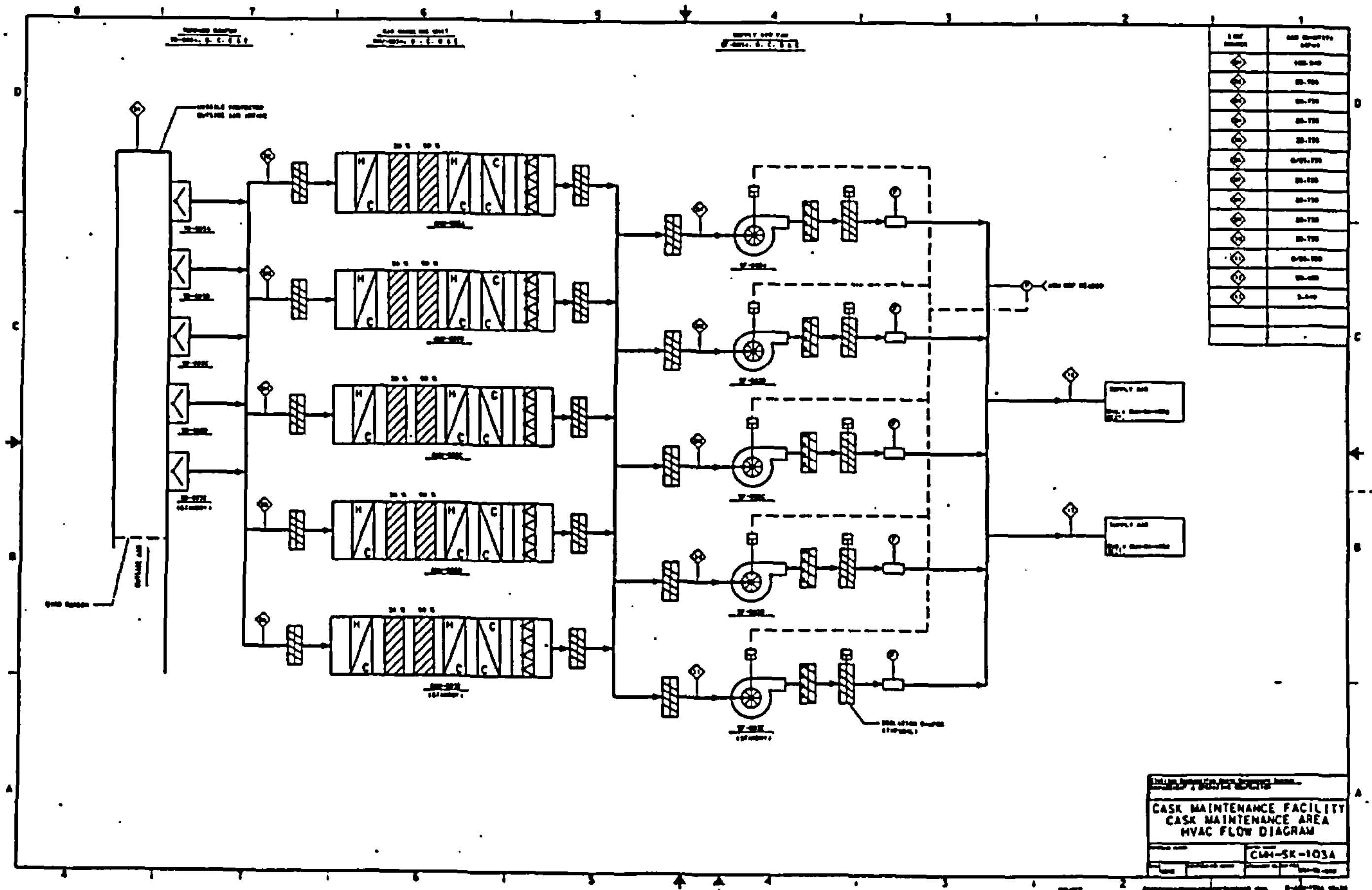
NORTH ELEVATION
SOUTH ELEVATION
WEST ELEVATION
EAST ELEVATION
GRAPHIC SCALE
CASK MAINTENANCE FACILITY
GENERAL ARRANGEMENT
BUILDING ELEVATIONS
CMA-SK-006

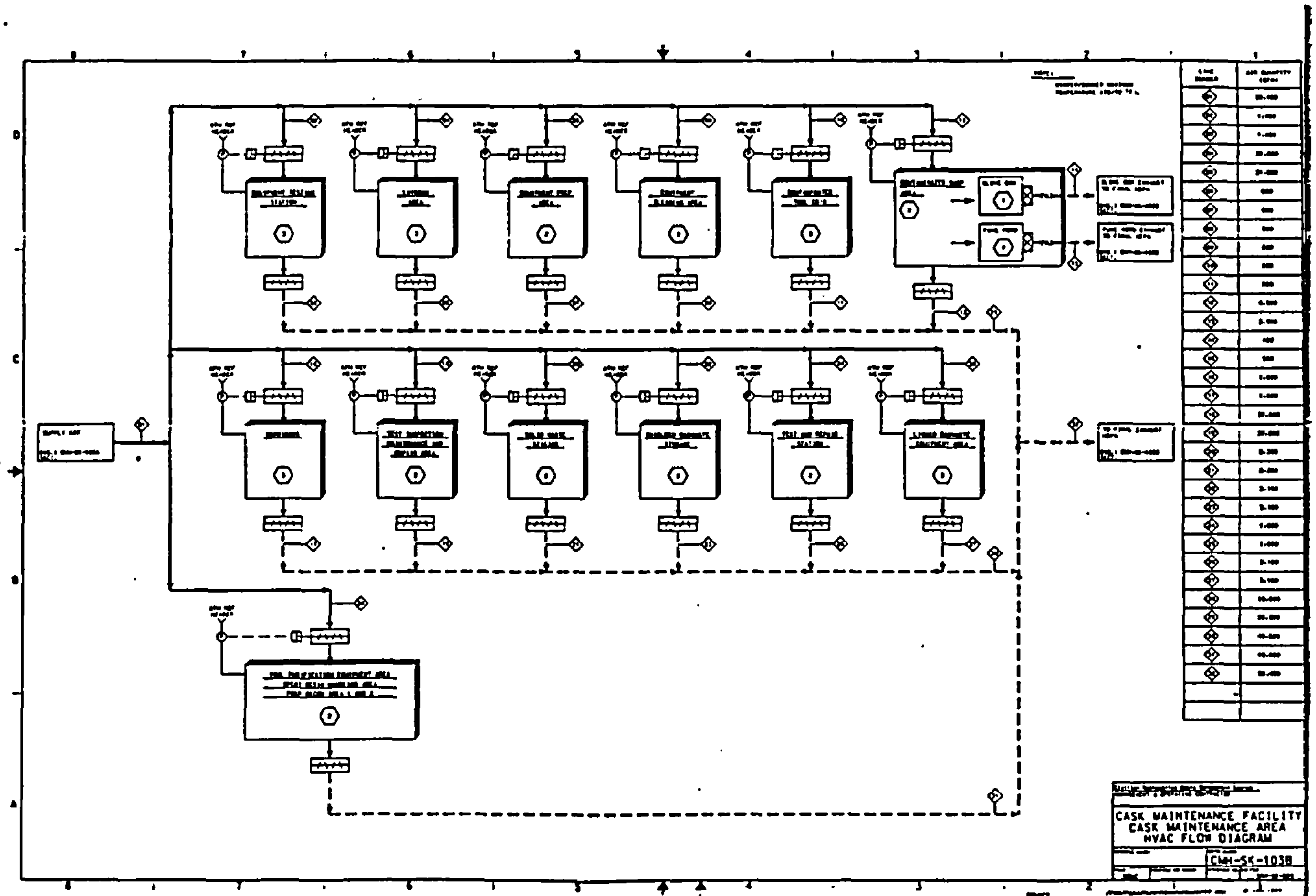


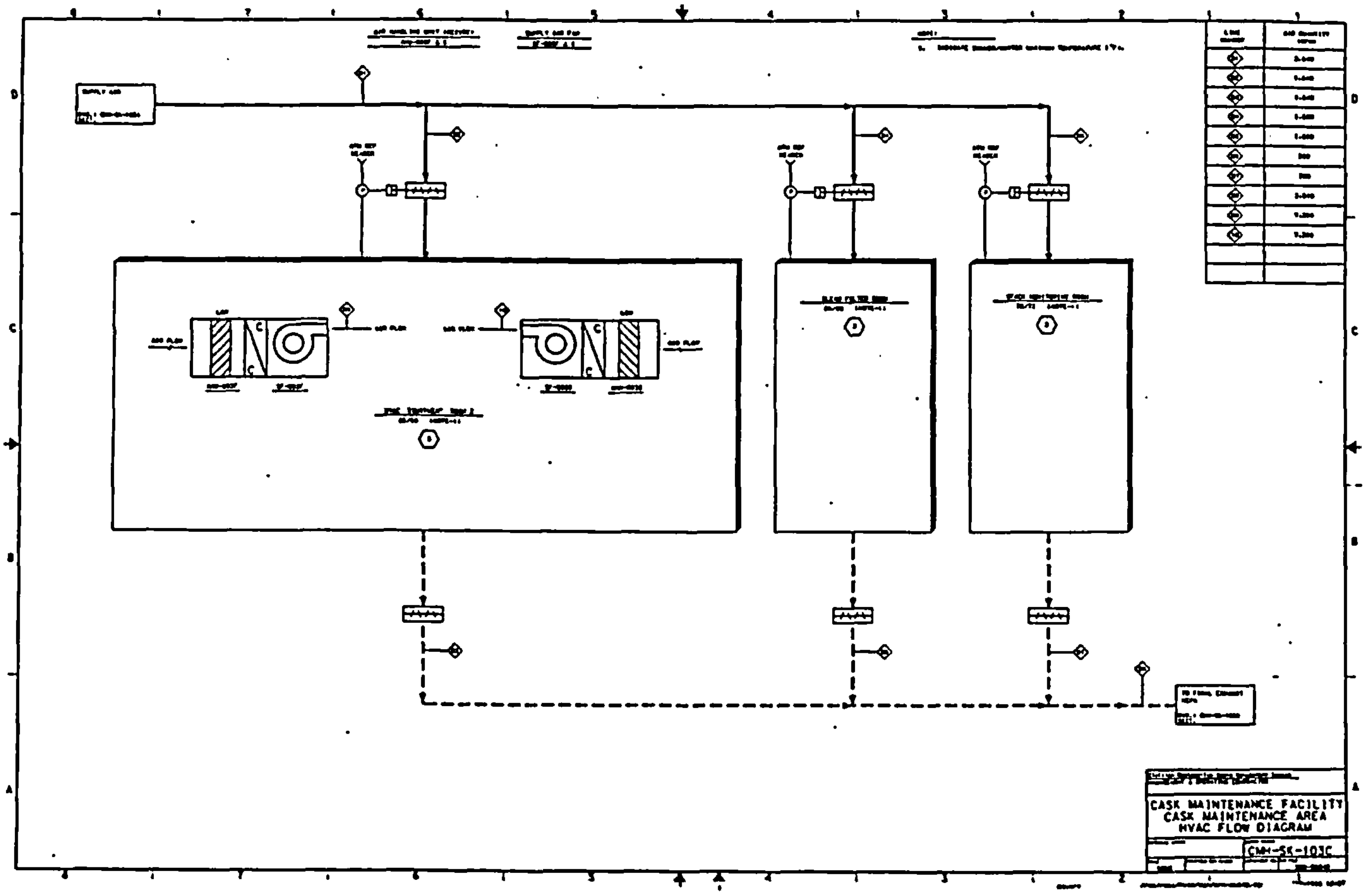
LINE NUMBER
AIR QUANTITY (CFM)
01 2,900
02 2,900
03 1,700
04 1,200
05 1,200
06 1,700/0
07 0/1,700
CASK MAINTENANCE FACILITY
TRUCK/RAILCAR CLEANING AREA
HVAC FLOW DIAGRAM
CMM-SK-101

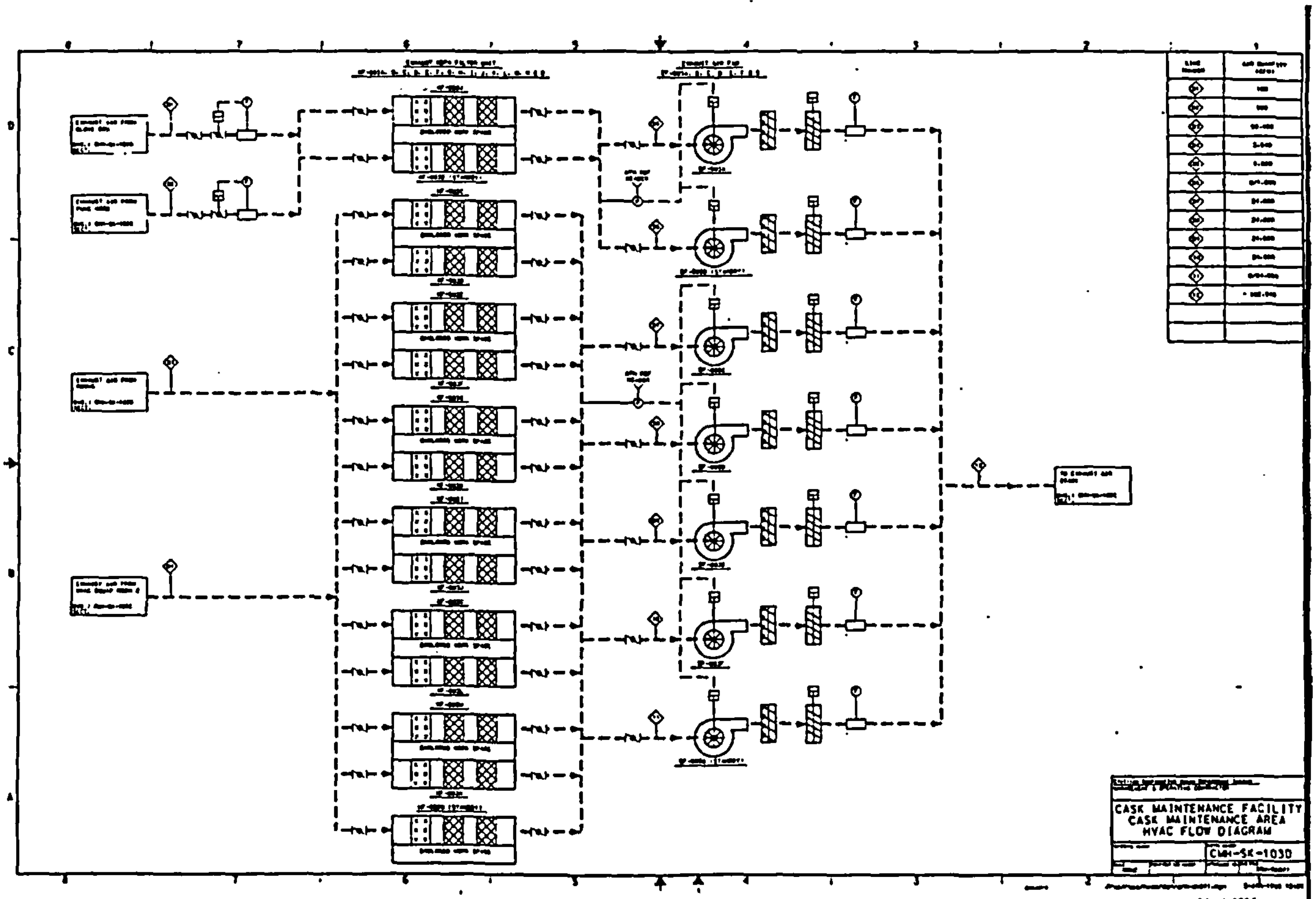

CASK MAINTENANCE FACILITY
OFFICES & CHANGE ROOMS
HVAC FLOW DIAGRAM
CMH-SK-102A


EXHAUST TO
ATMOS
EF-002C
CASK MAINTENANCE FACILITY
HVAC EQUIPMENT ROOM 1
HVAC FLOW DIAGRAM
CMH-SK-1028

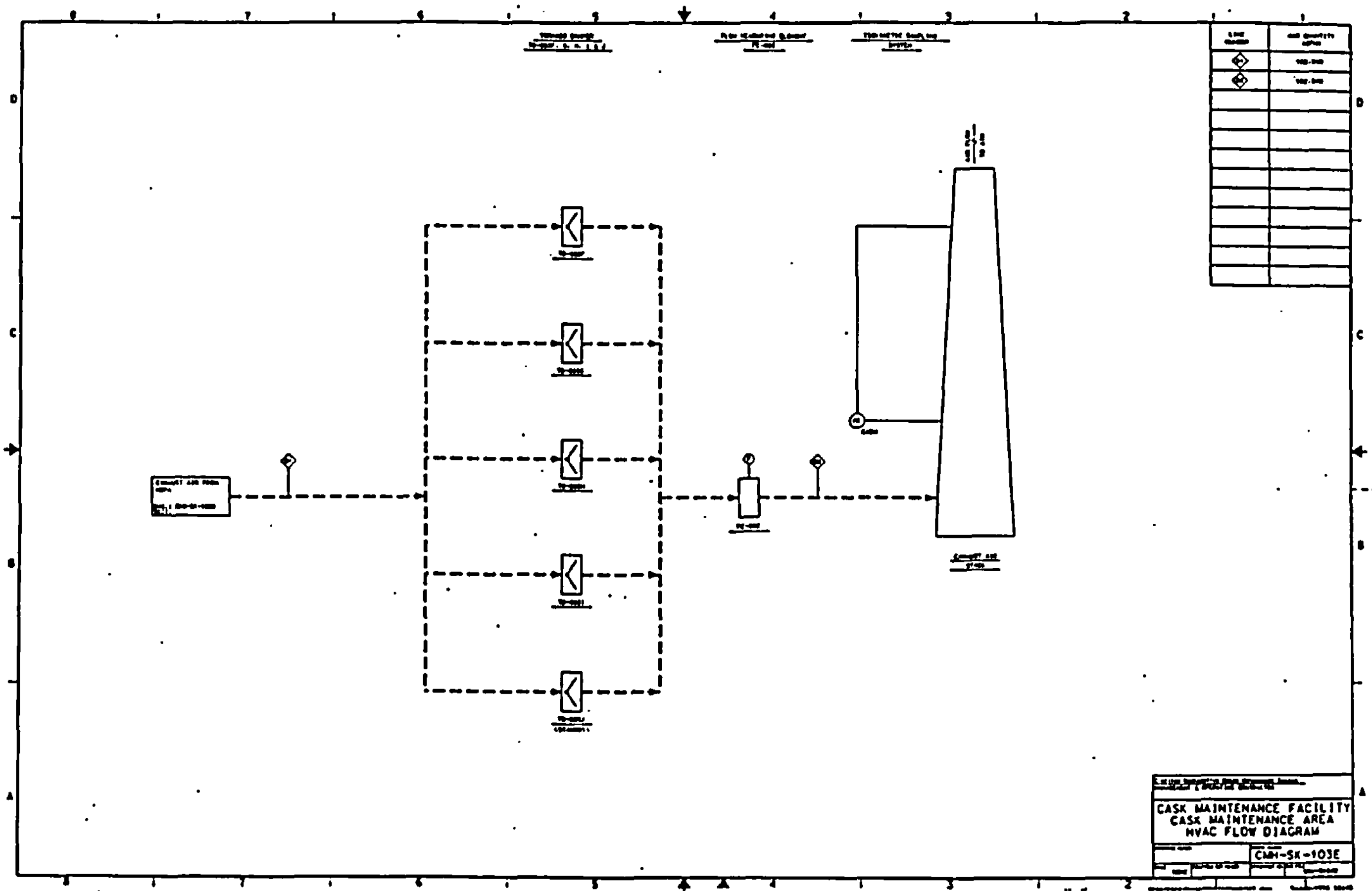

CASK MAINTENANCE FACILITY
CASK MAINTENANCE AREA
HVAC FLOW DIAGRAM
CMH-SK-103A


CASK MAINTENANCE FACILITY
CASK MAINTENANCE AREA
HVAC FLOW DIAGRAM
CMH-SK-1038


CASK MAINTENANCE FACILITY
CASK MAINTENANCE AREA
HVAC FLOW DIAGRAM
CMH-SK-103C



CASK MAINTENANCE FACILITY
CASK MAINTENANCE AREA
HVAC FLOW DIAGRAM
CMH-SK-103D


CASK MAINTENANCE FACILITY
CASK MAINTENANCE AREA
HVAC FLOW DIAGRAM
CMH-SK-103E

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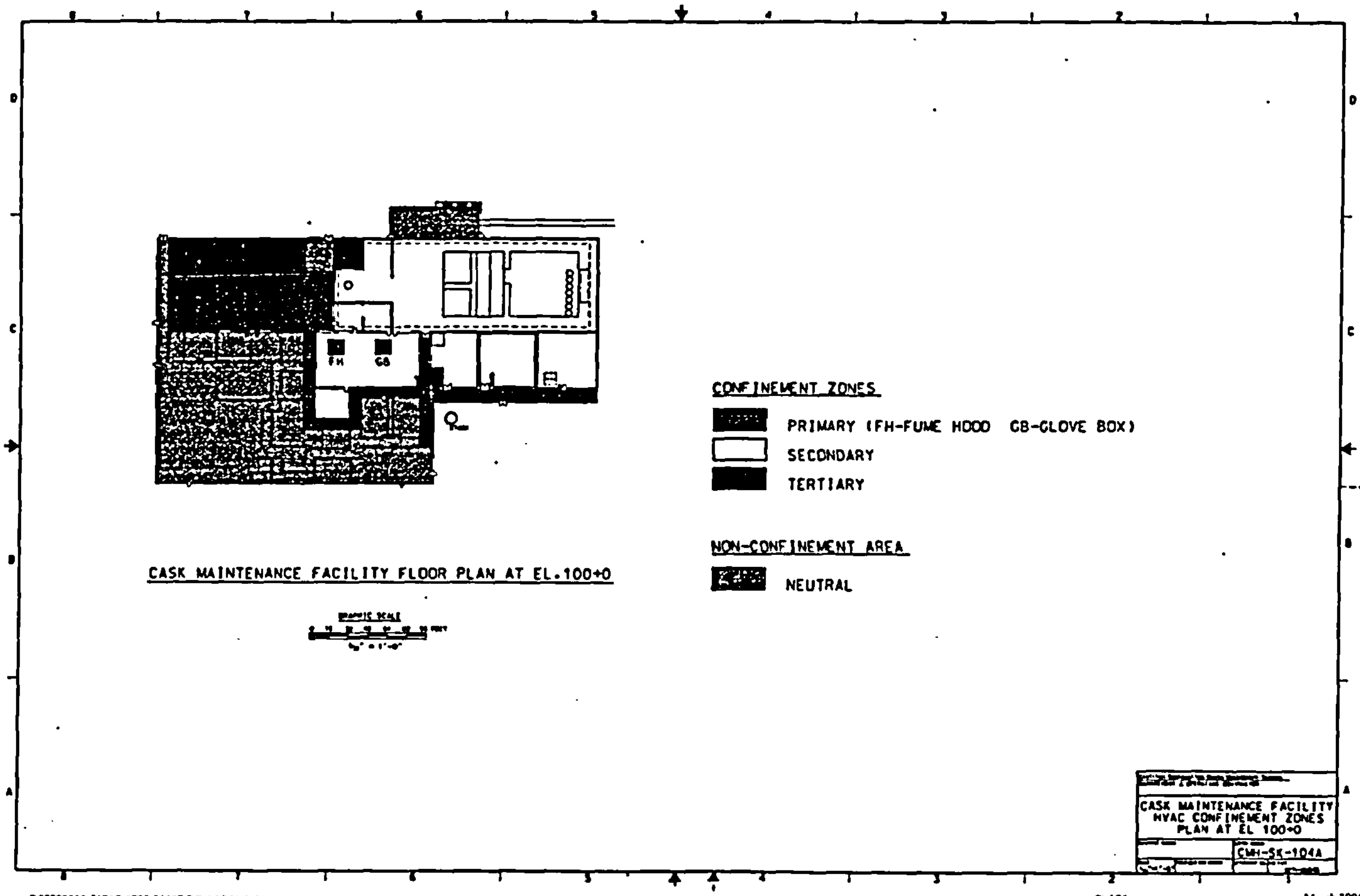
FH
GB
CASK MAINTENANCE FACILITY FLOOR PLAN AT EL.100+0
CONFINEMENT ZONES
PRIMARY (FH-FUME HOOD GB-GLOVE BOX)
SECONDARY
TERTIARY
NON-CONFINEMENT AREA
NEUTRAL
CASK MAINTENANCE FACILITY
HVAC CONFINEMENT ZONES
PLAN AT EL 100+0
CMH-SK-104A

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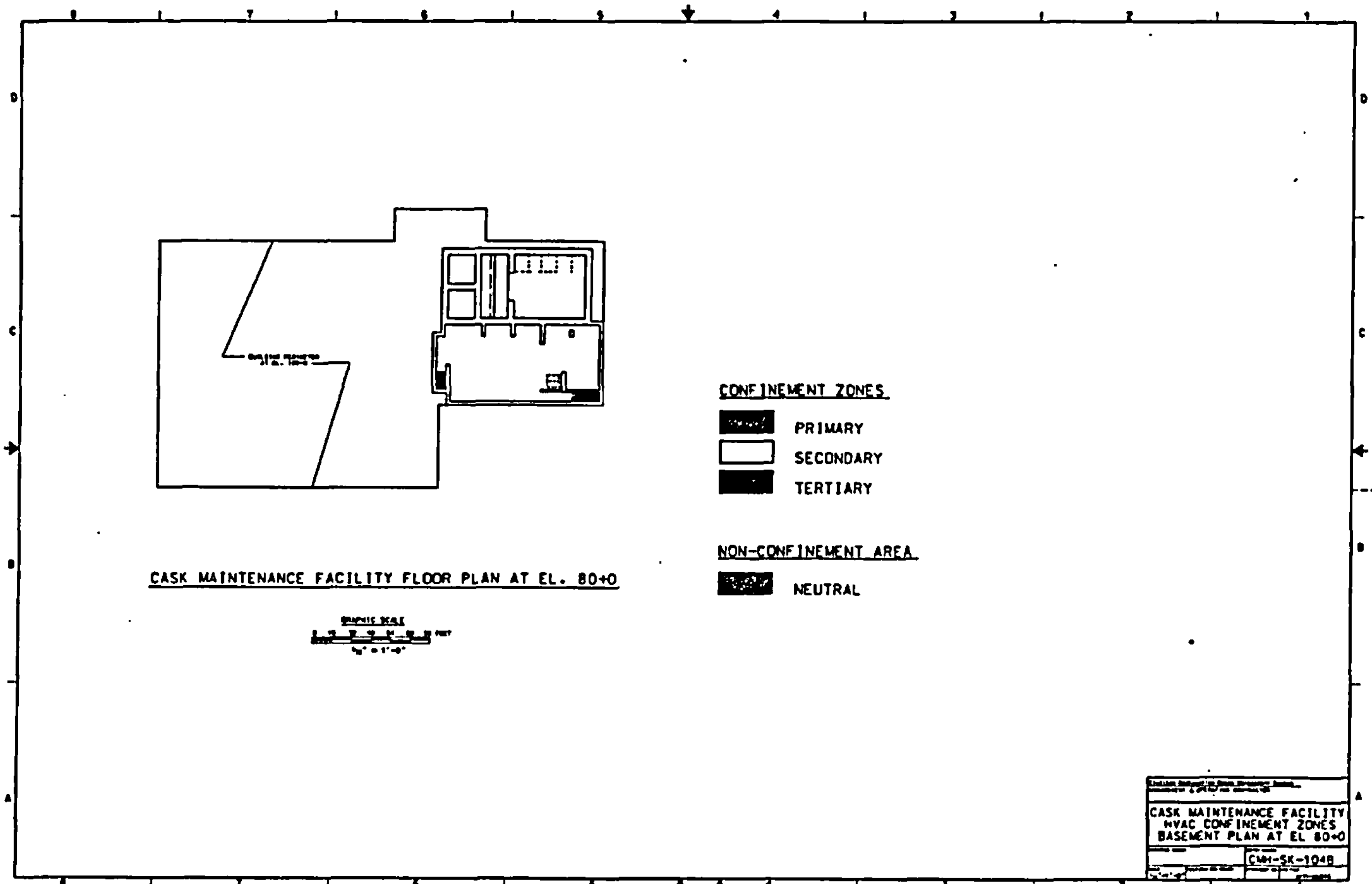
CASK MAINTENANCE FACILITY FLOOR PLAN AT EL. 80+0
CONFINEMENT ZONES
PRIMARY
SECONDARY
TERTIARY
NON-CONFINEMENT AREA
NEUTRAL
CASK MAINTENANCE FACILITY
HVAC CONFINEMENT ZONES
BASEMENT PLAN AT EL 80+0
CMH-SK-104B

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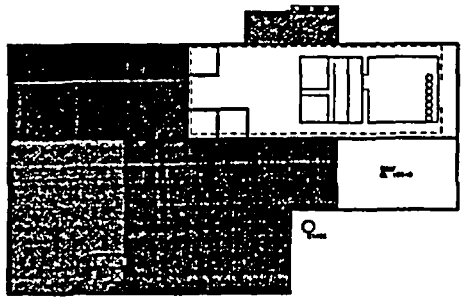

CASK MAINTENANCE FACILITY FLOOR PLAN AT EL.126+0

CONFINEMENT ZONES

- PRIMARY
- SECONDARY
- TERTIARY

NON-CONFINEMENT AREA

- NEUTRAL

CASK MAINTENANCE FACILITY
HVAC CONFINEMENT ZONES
PLAN AT EL 126+0

CMH-SK-104C

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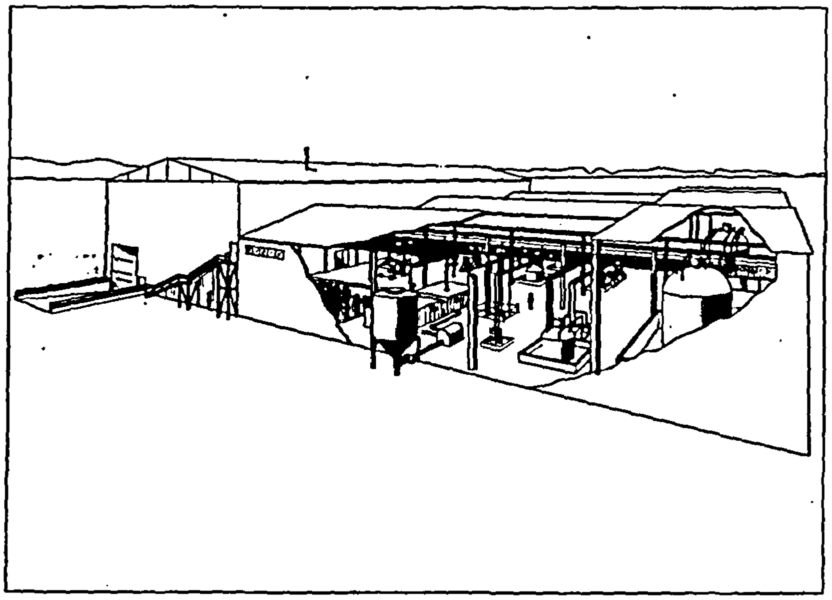

Figure 7.2.4-1. Waste Treatment Operations.

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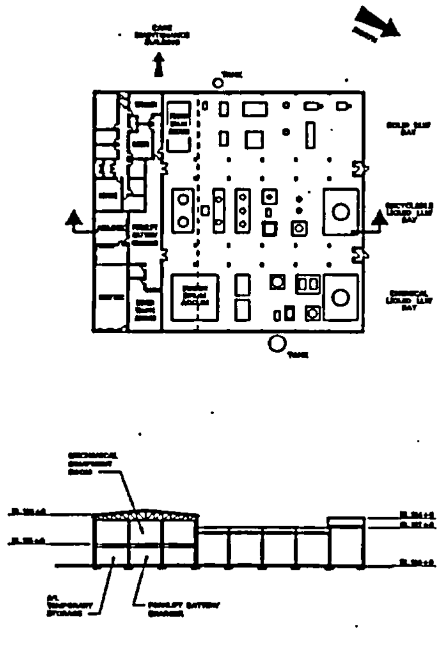


Figure 7.2.4-2. Waste Treatment Building (Floor Plan and Building Section)

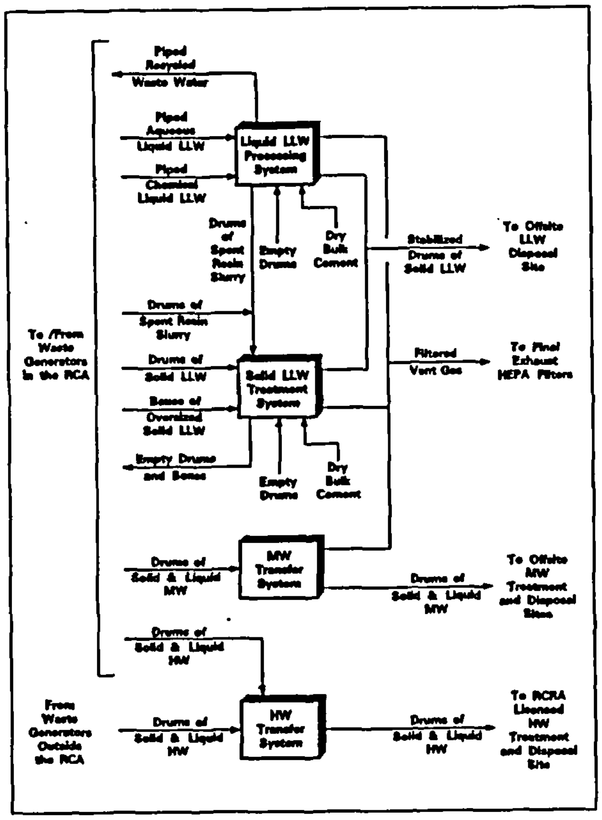


Figure 7.2.4-3. Waste Treatment System Overview

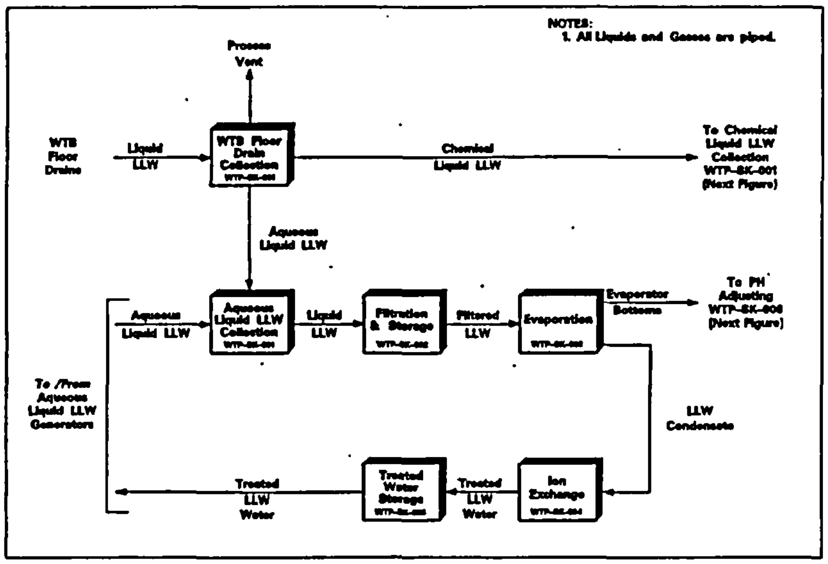


Figure 7.2.4-4. Liquid Low-Level Waste Processing (Aqueous)

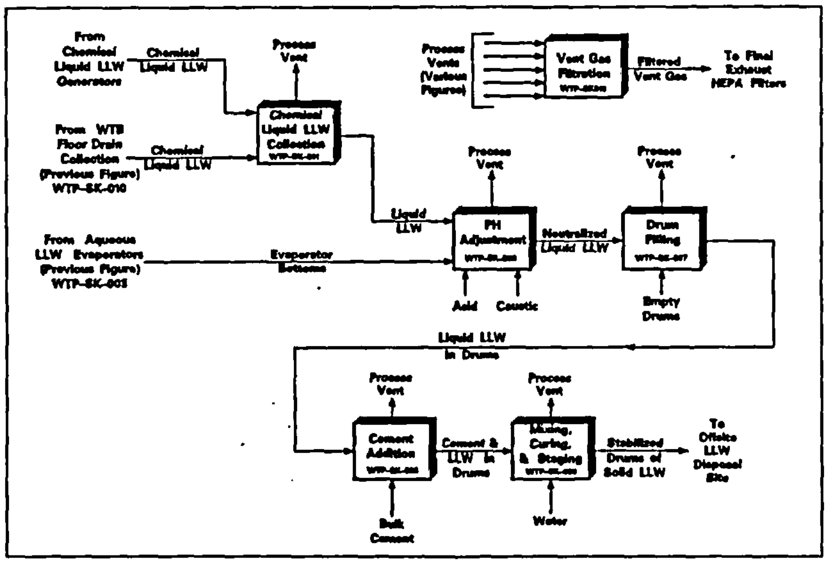


Figure 7.2.4-6. Liquid Low-Level Waste Processing (Chemical)

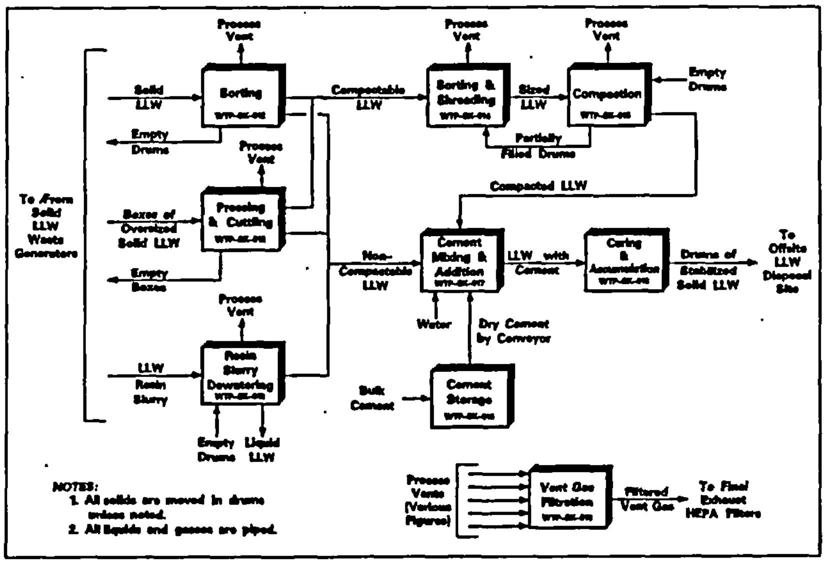


Figure 7.2.4-6. Solid Low-Level Waste Treatment System

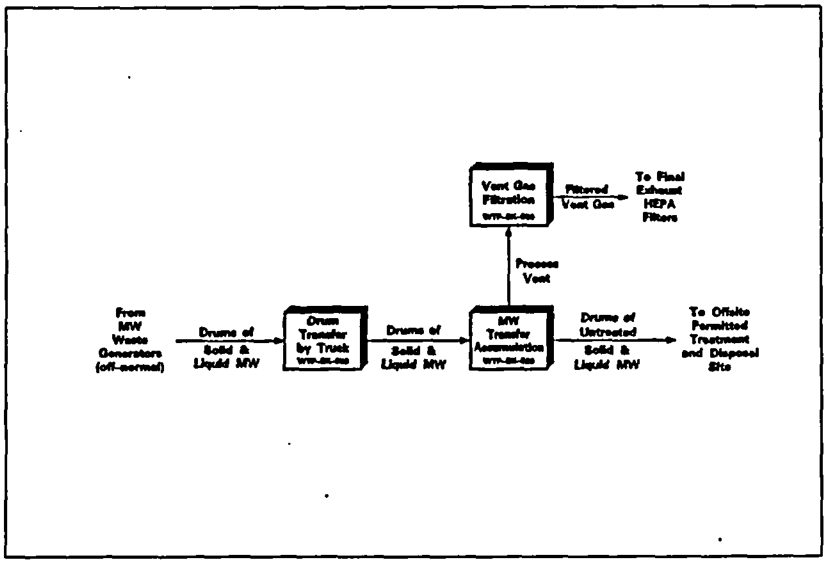


Figure 7.2.4-7. Mixed Waste Transfer System

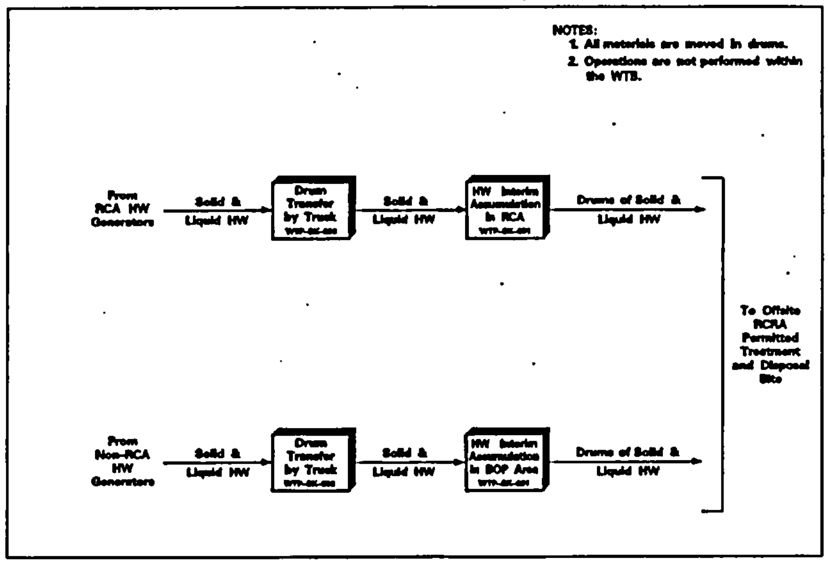
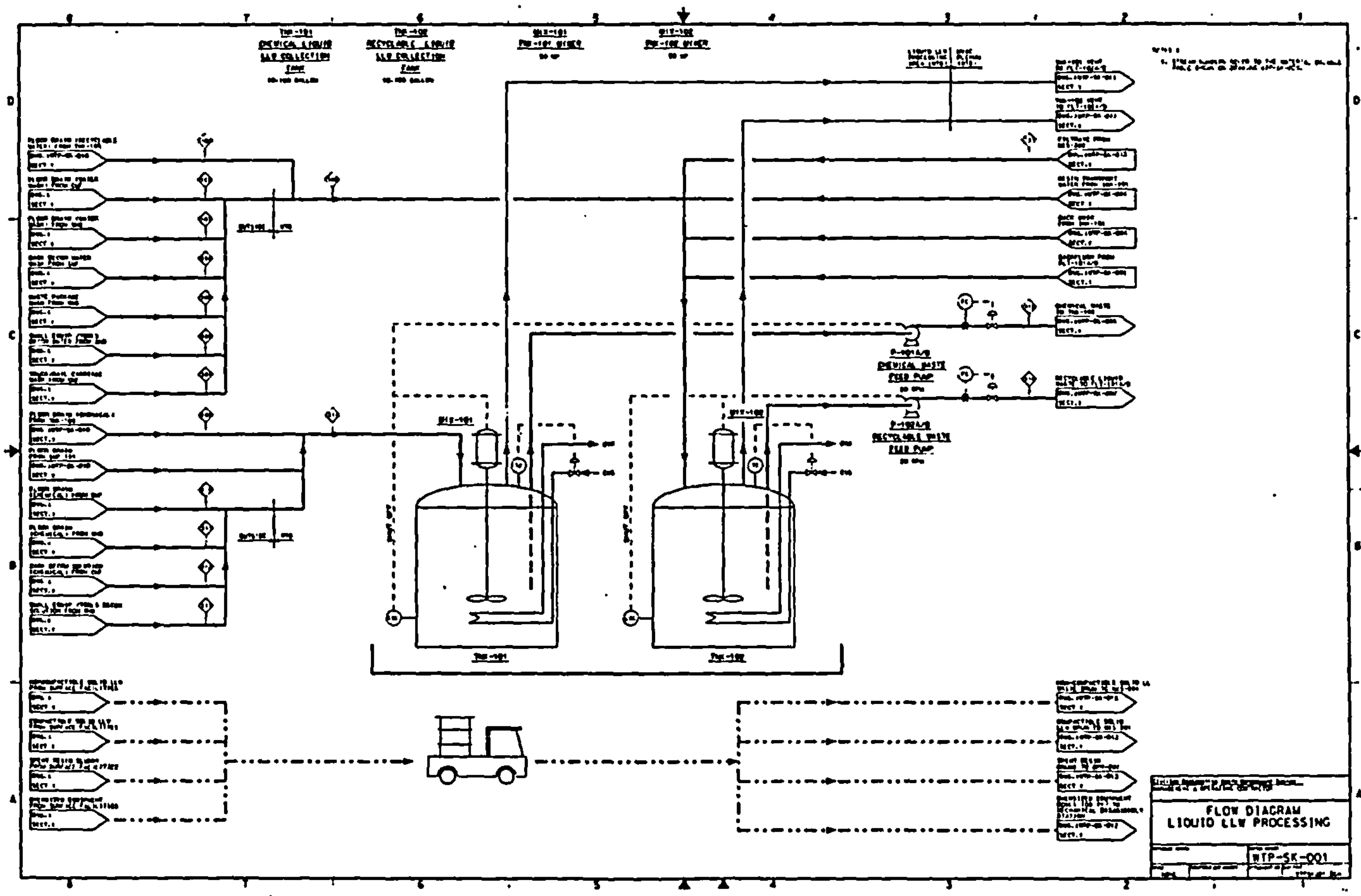
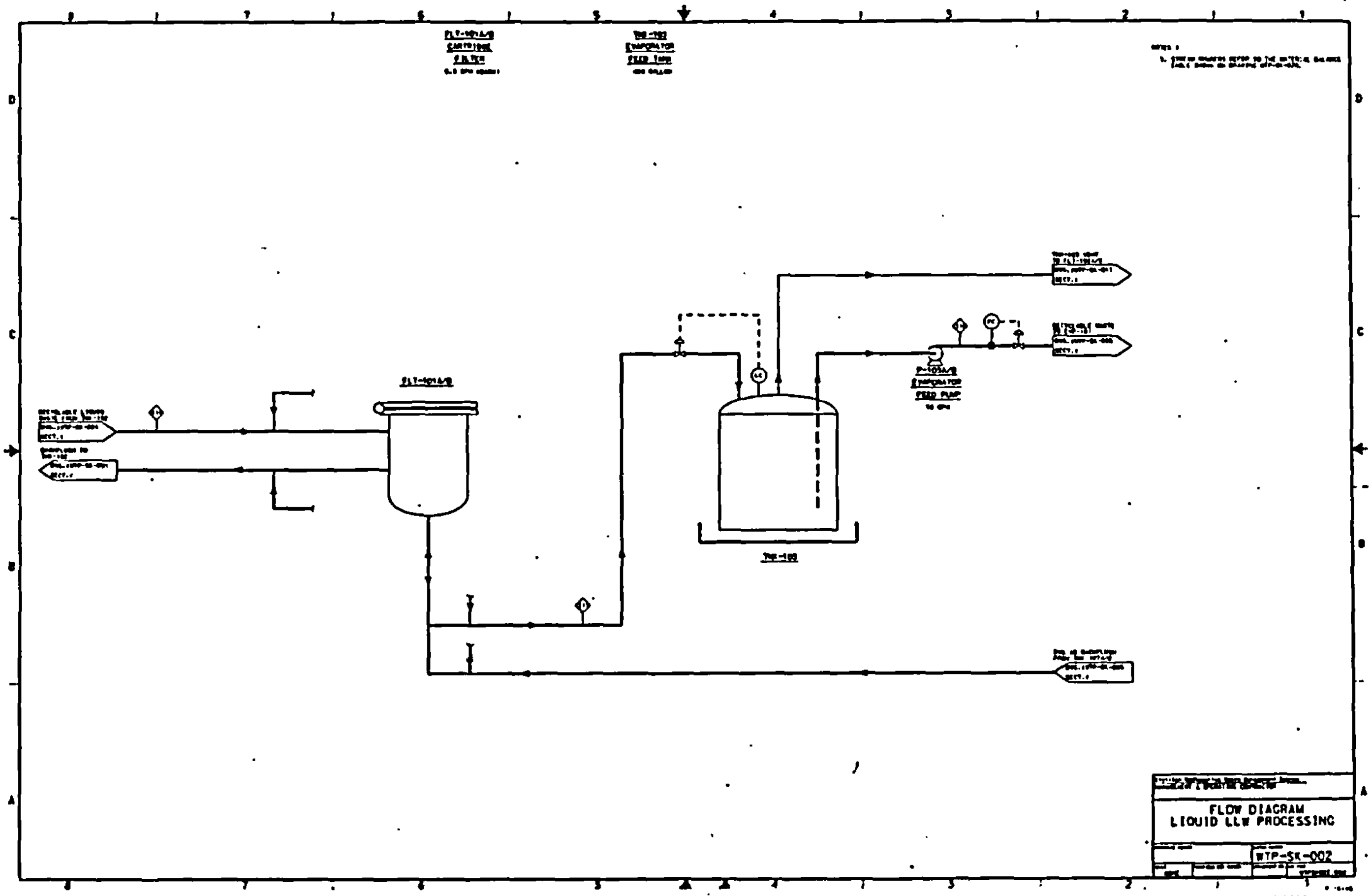
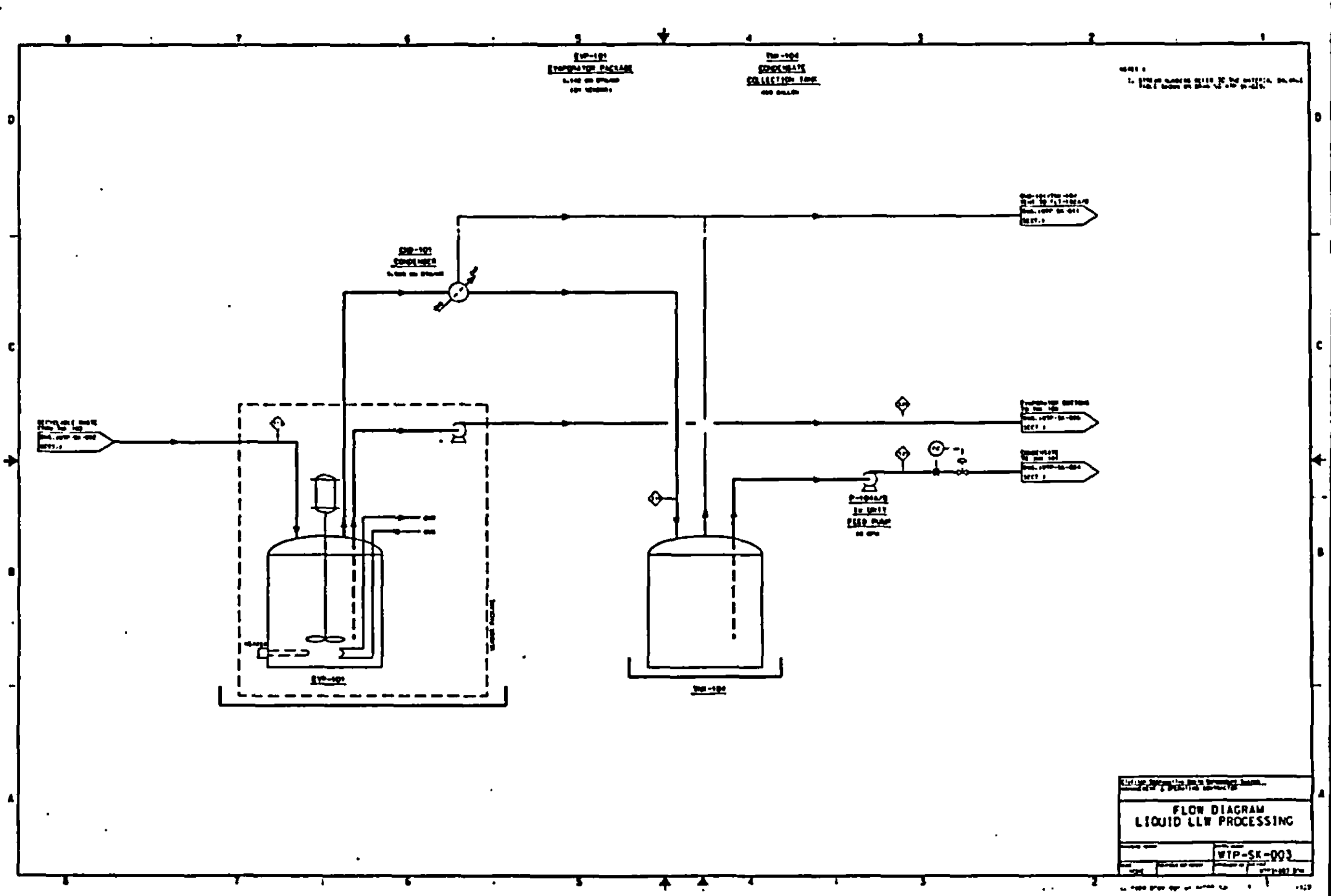


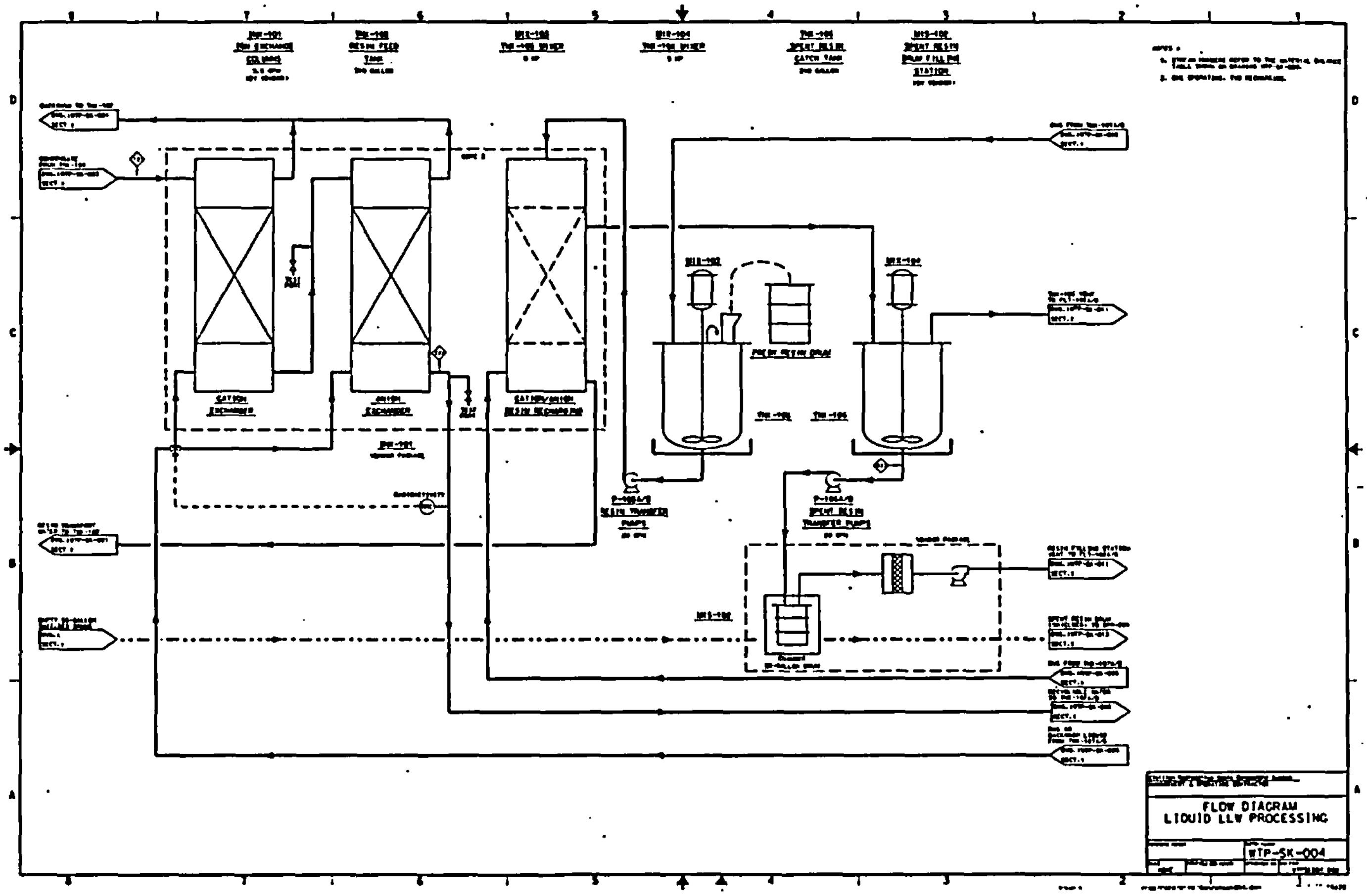
Figure 7.2.4-8. Hazardous Waste Transfer System

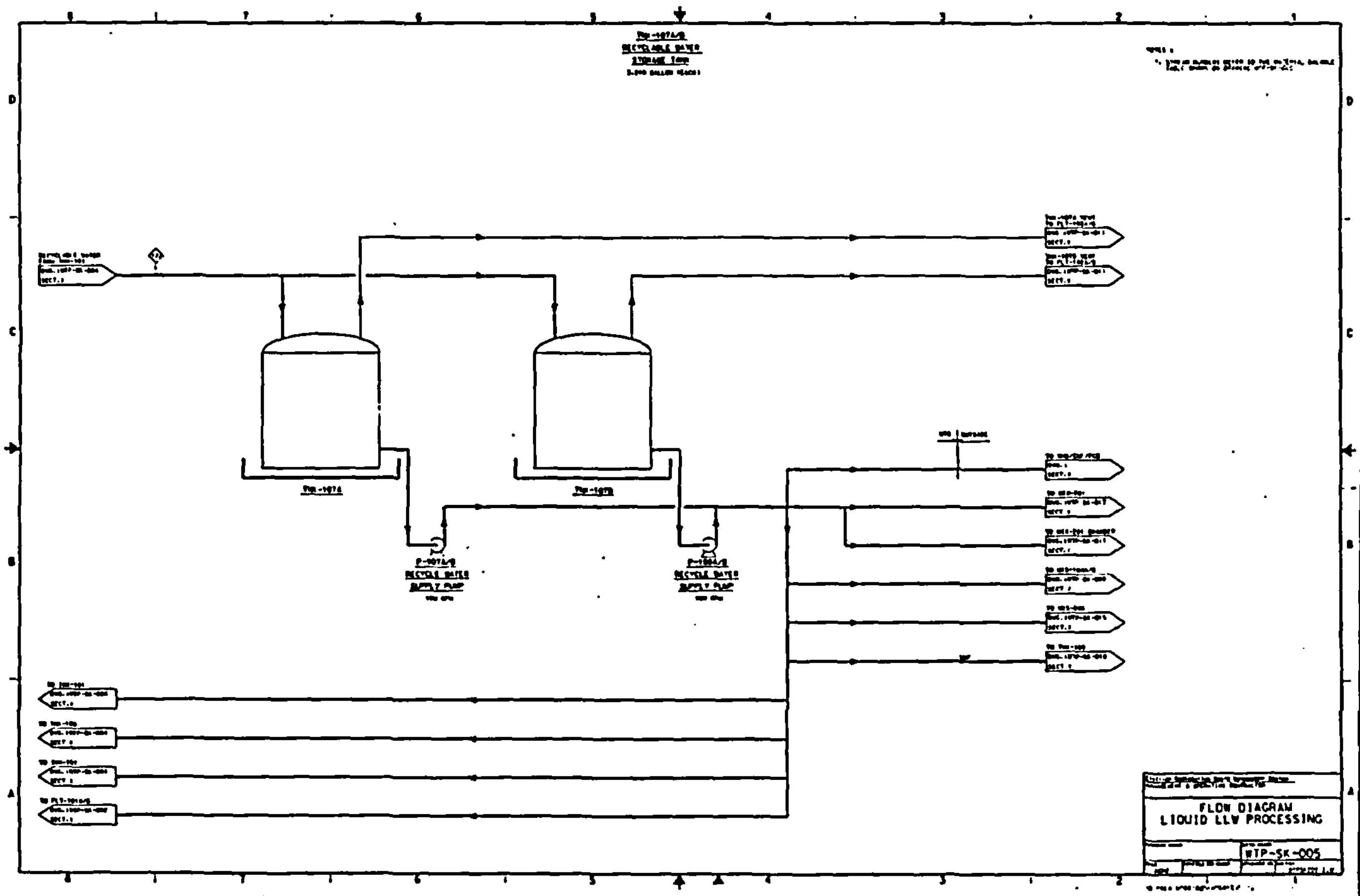

FLOW DIAGRAM
LIQUID LLW PROCESSING
WTP-SK-001


FLOW DIAGRAM
LIQUID LLW PROCESSING
WTP-SK-002

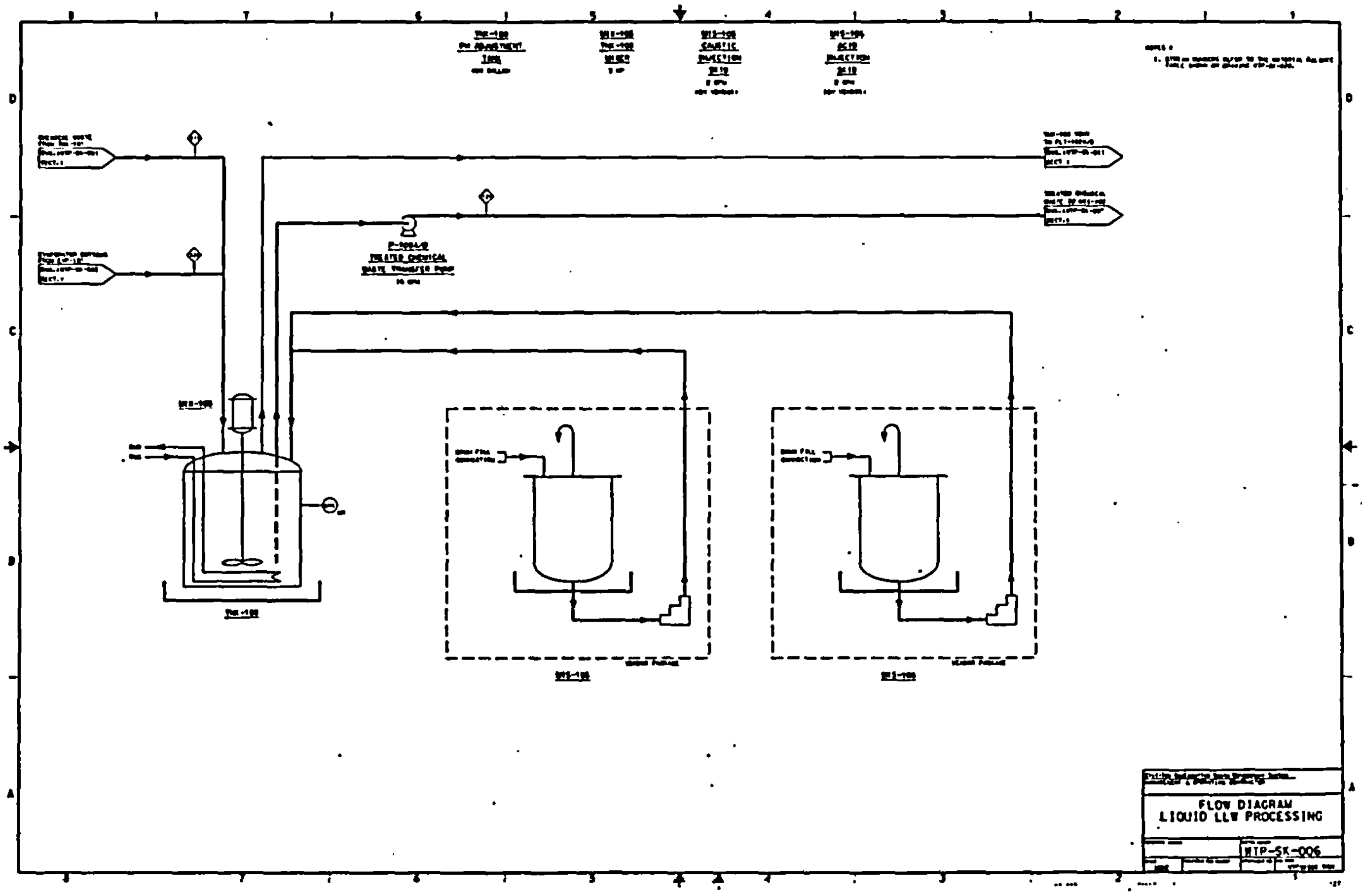


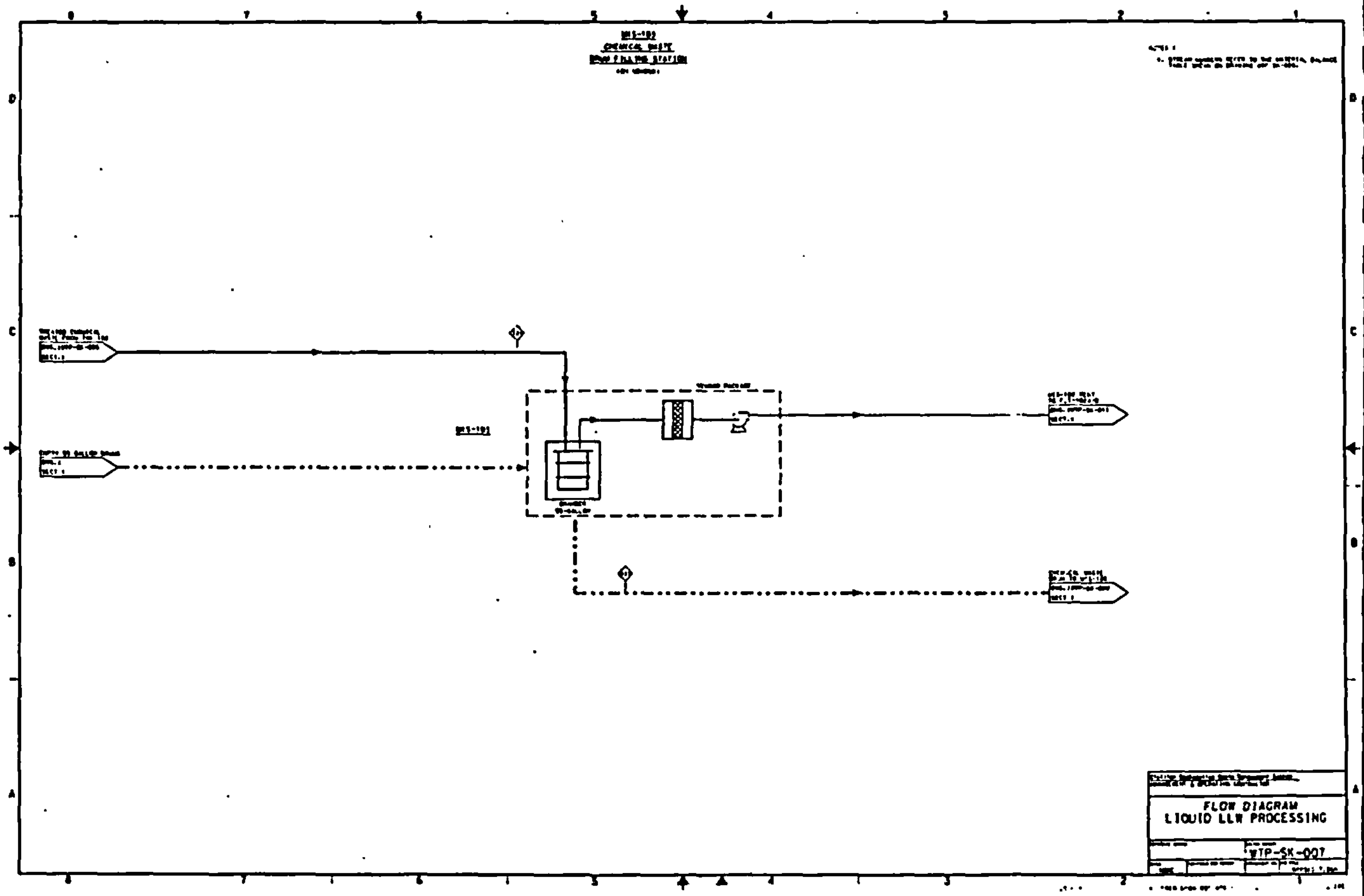
FLOW DIAGRAM
LIQUID LLW PROCESSING
WTP-SK-003

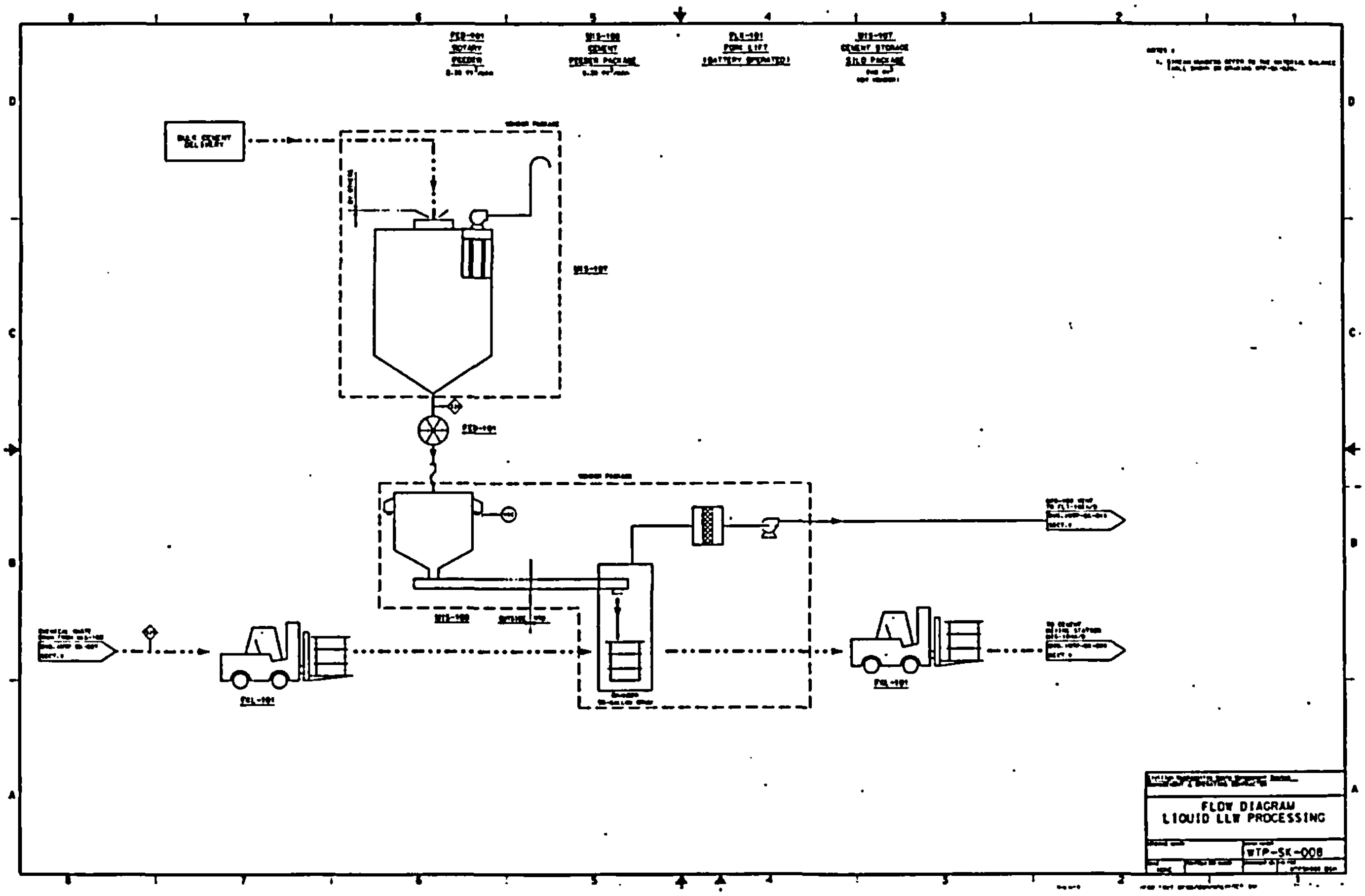

FLOW DIAGRAM
LIQUID LLW PROCESSING
WTP-SK-004

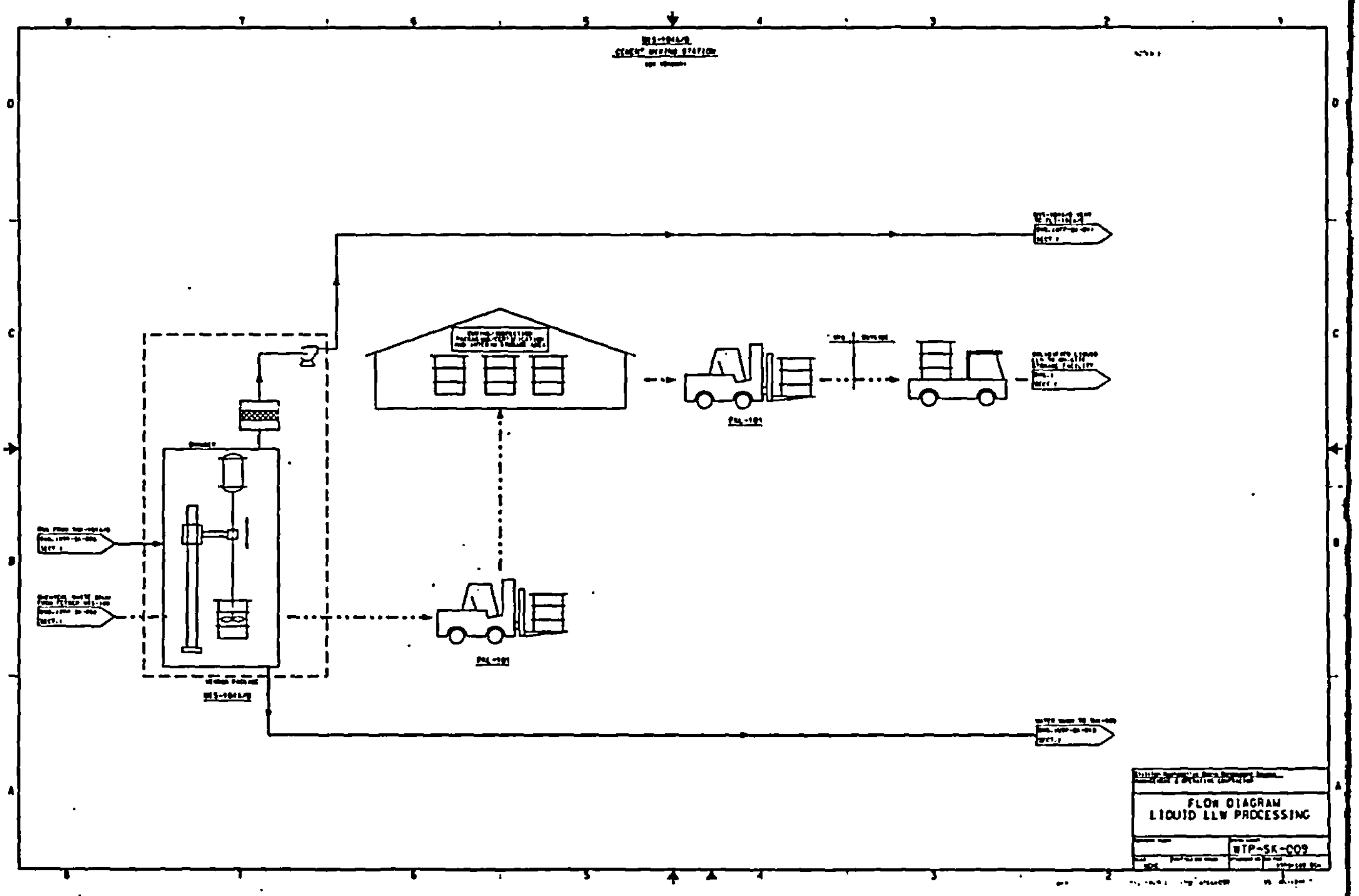


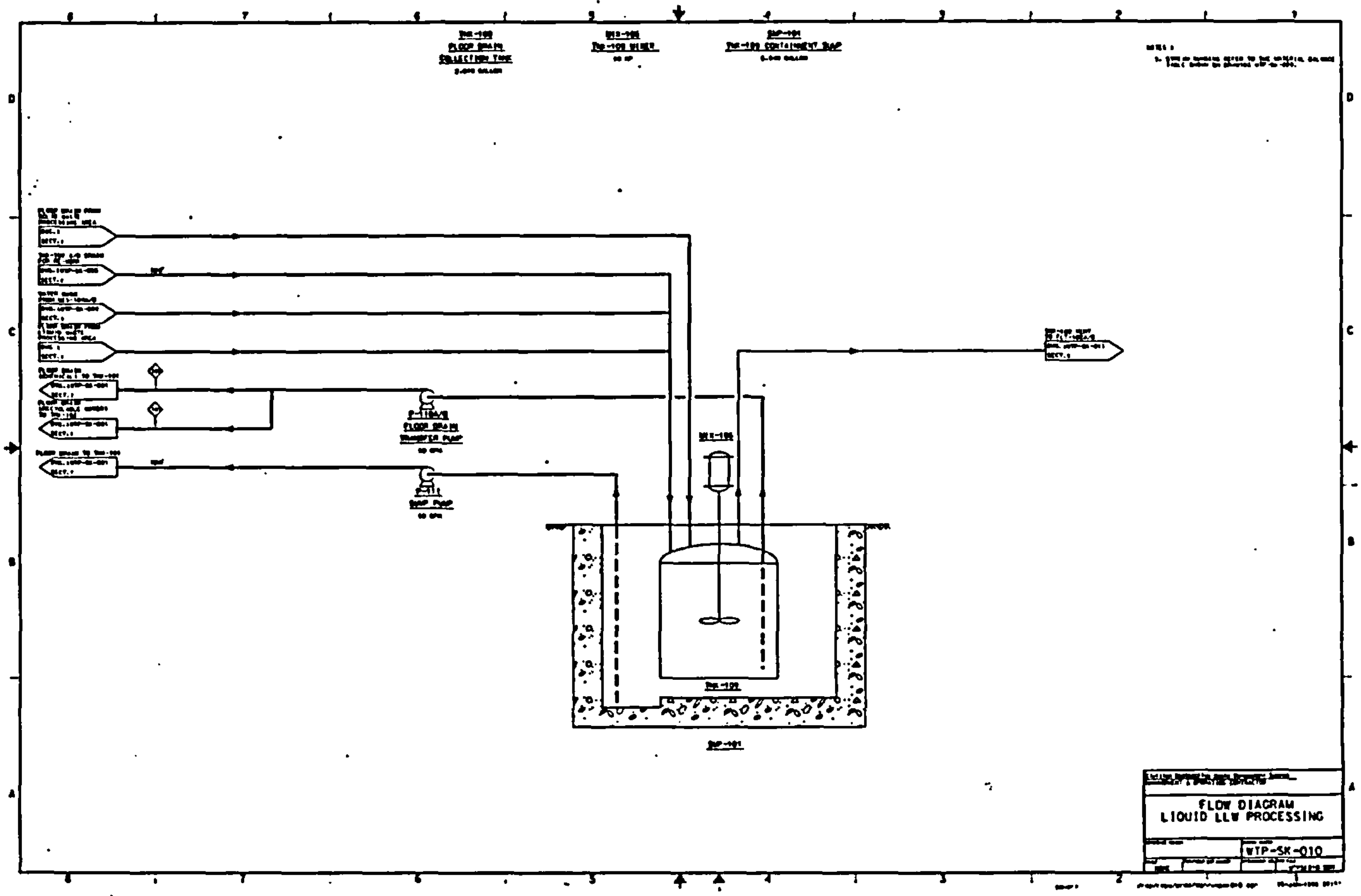
FLOW DIAGRAM
LIOUID LLW PROCESSING
WTP-SK-005

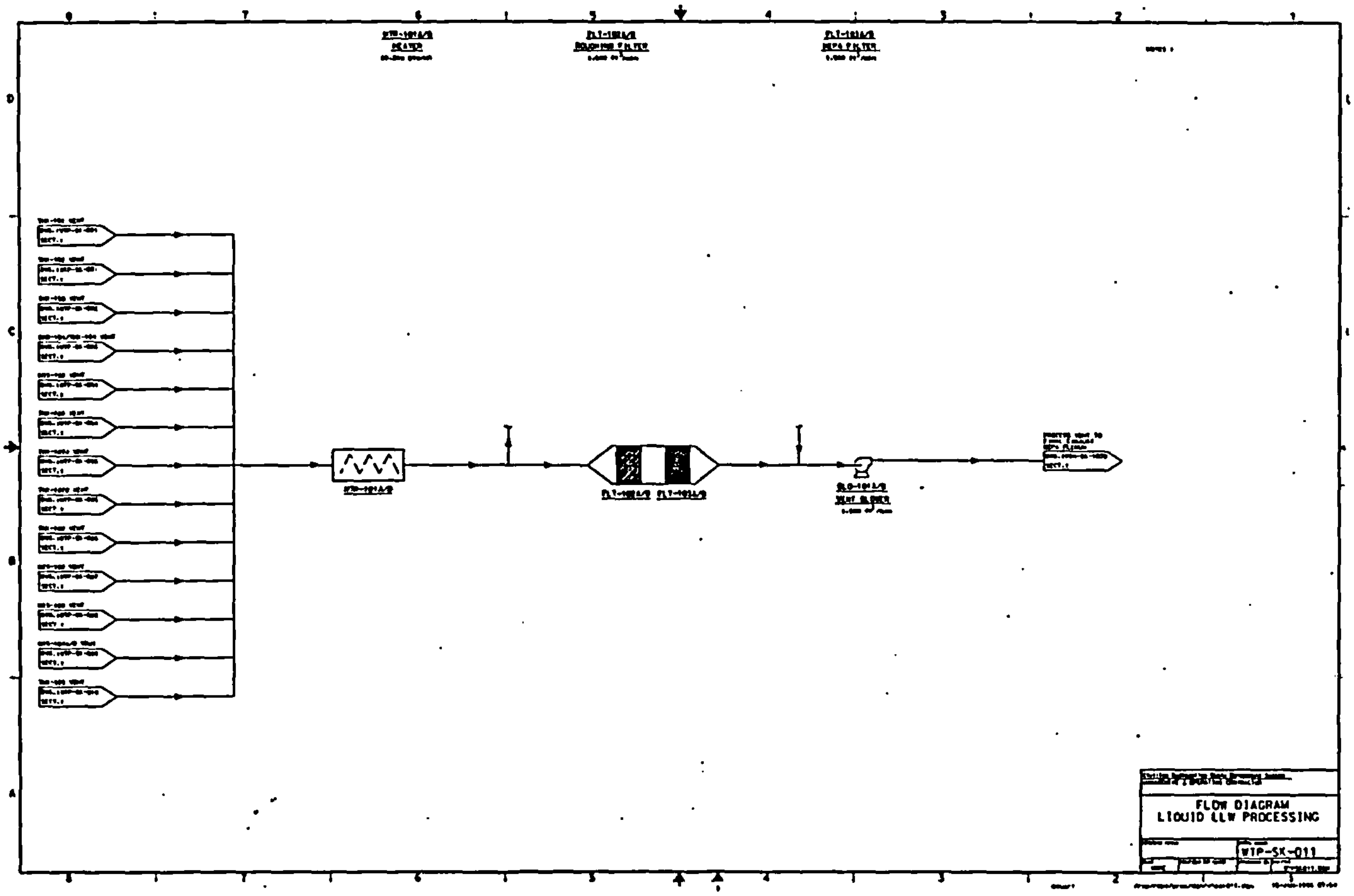

FLOW DIAGRAM
LIQUID LLW PROCESSING
WTP-SK-006

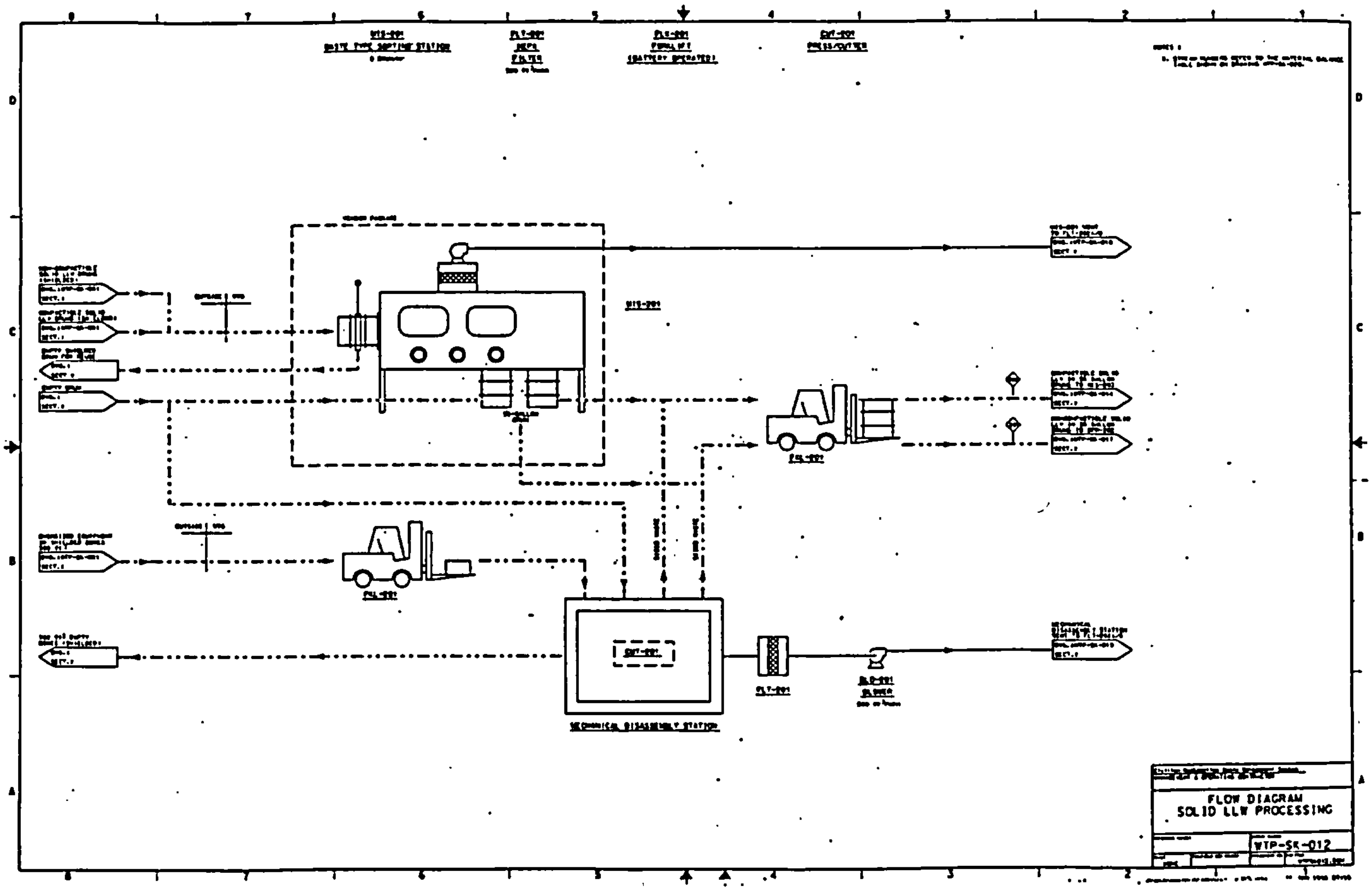

FLOW DIAGRAM
LIQUID LLW PROCESSING
WTP-SK-007


FLOW DIAGRAM
LIQUID LLW PROCESSING
WTP-SK-008

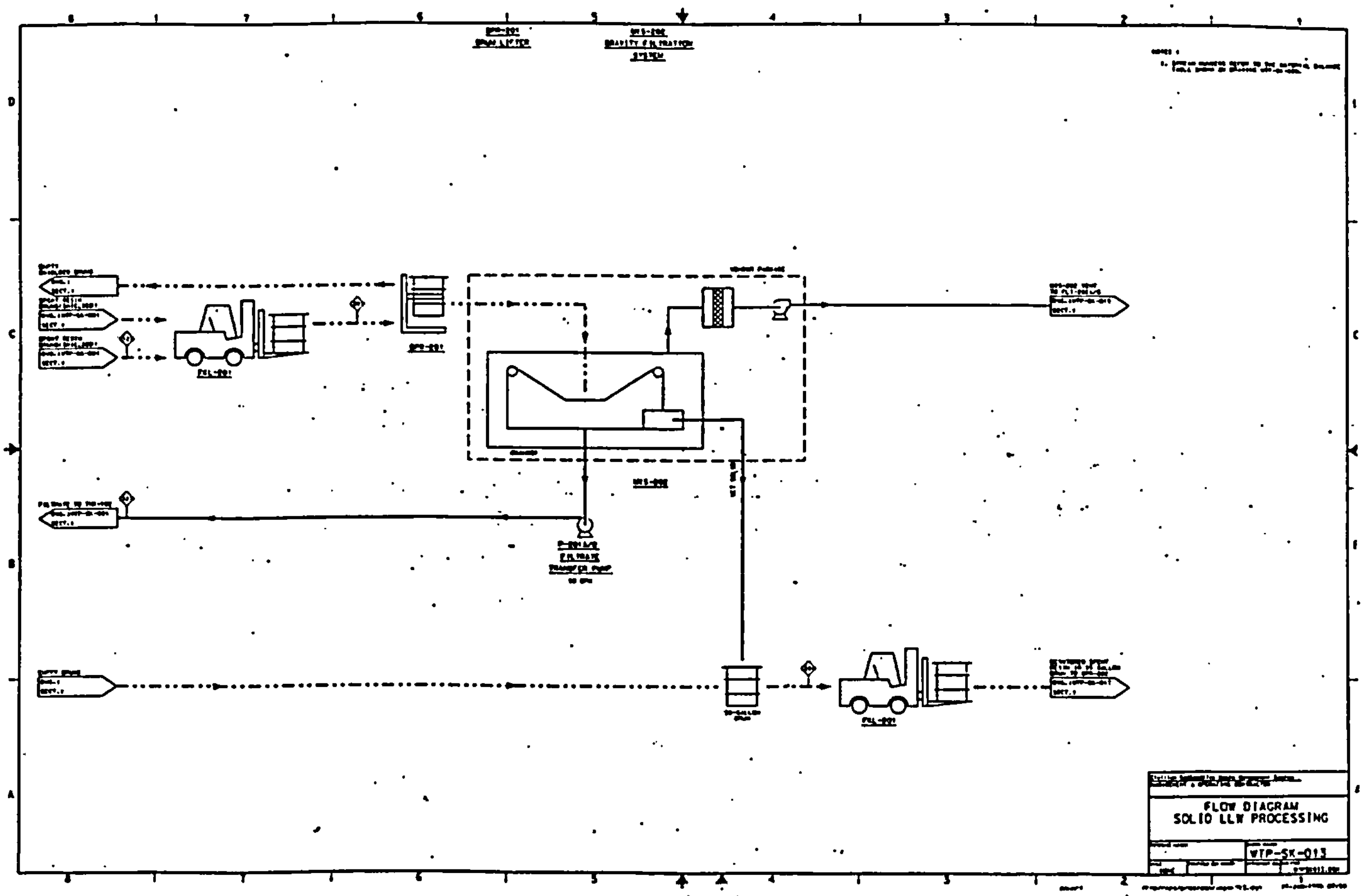

FLOW DIAGRAM
LIQUID LLW PROCESSING
WTP-SK-C09

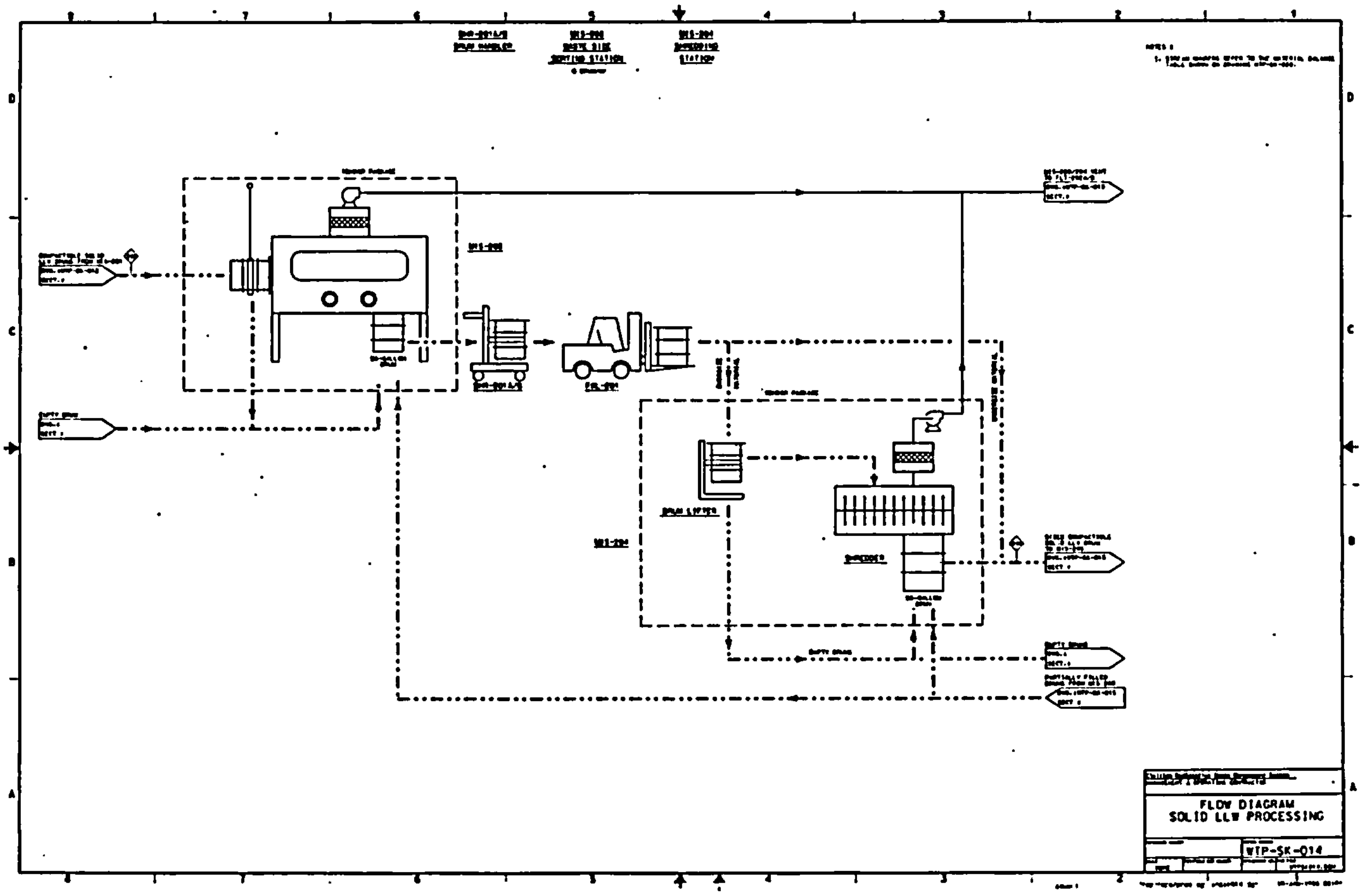

FLOW DIAGRAM
LIQUID LLW PROCESSING
WTP-SK-010


FLOW DIAGRAM
LIQUID LLW PROCESSING
WTP-SK-011

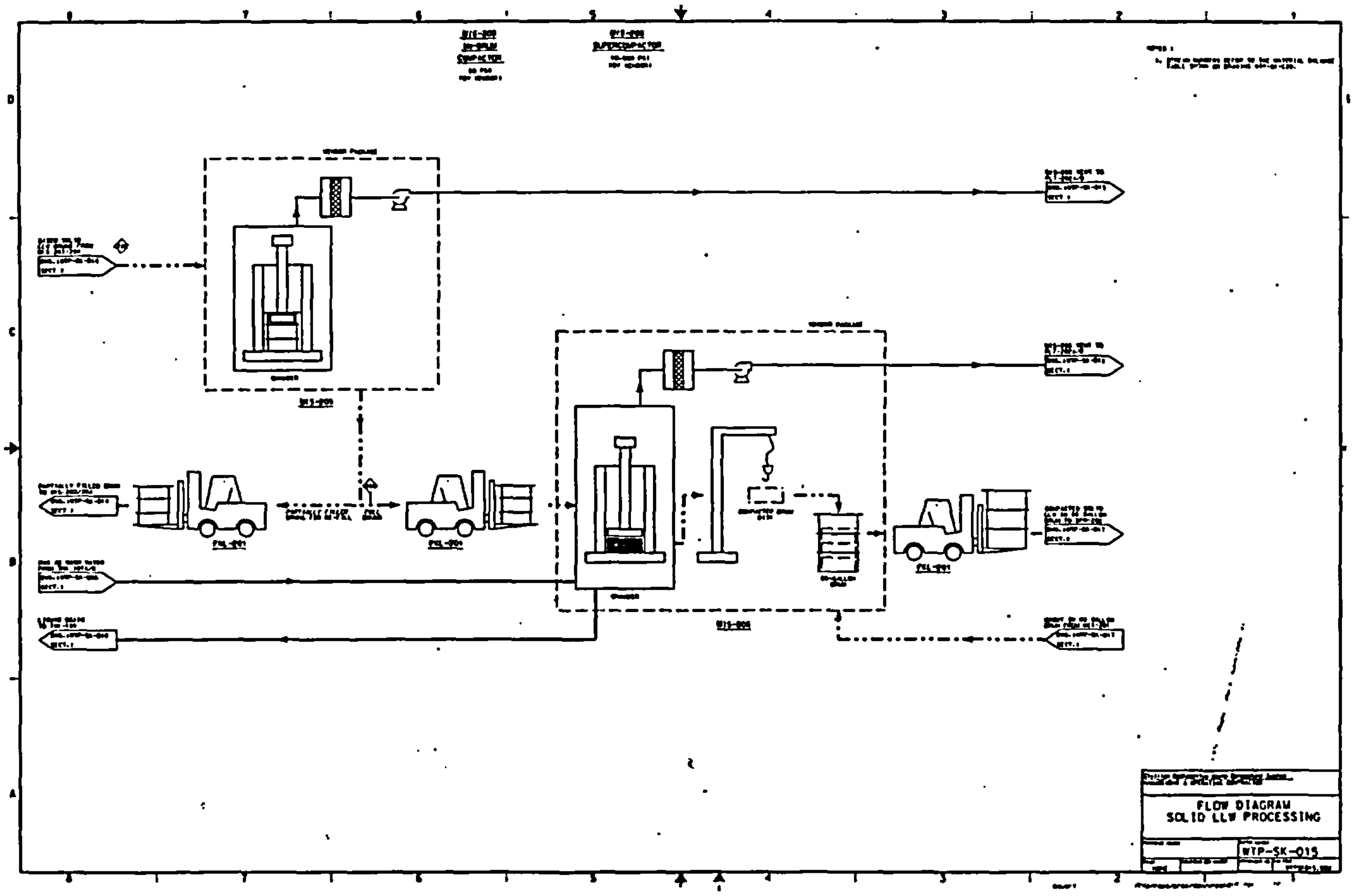


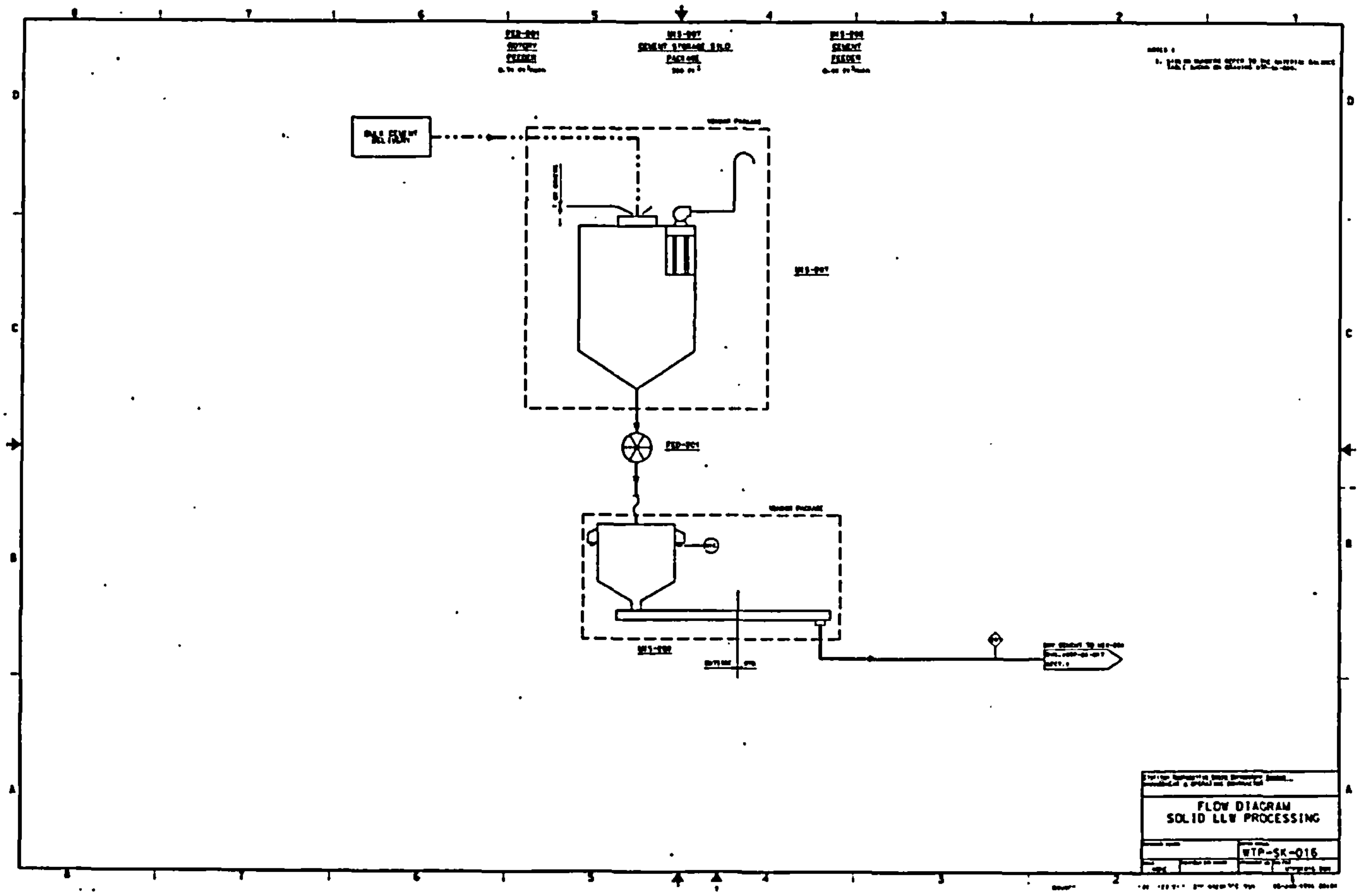
FLOW DIAGRAM
SOLID LLW PROCESSING
WTP-SK-012

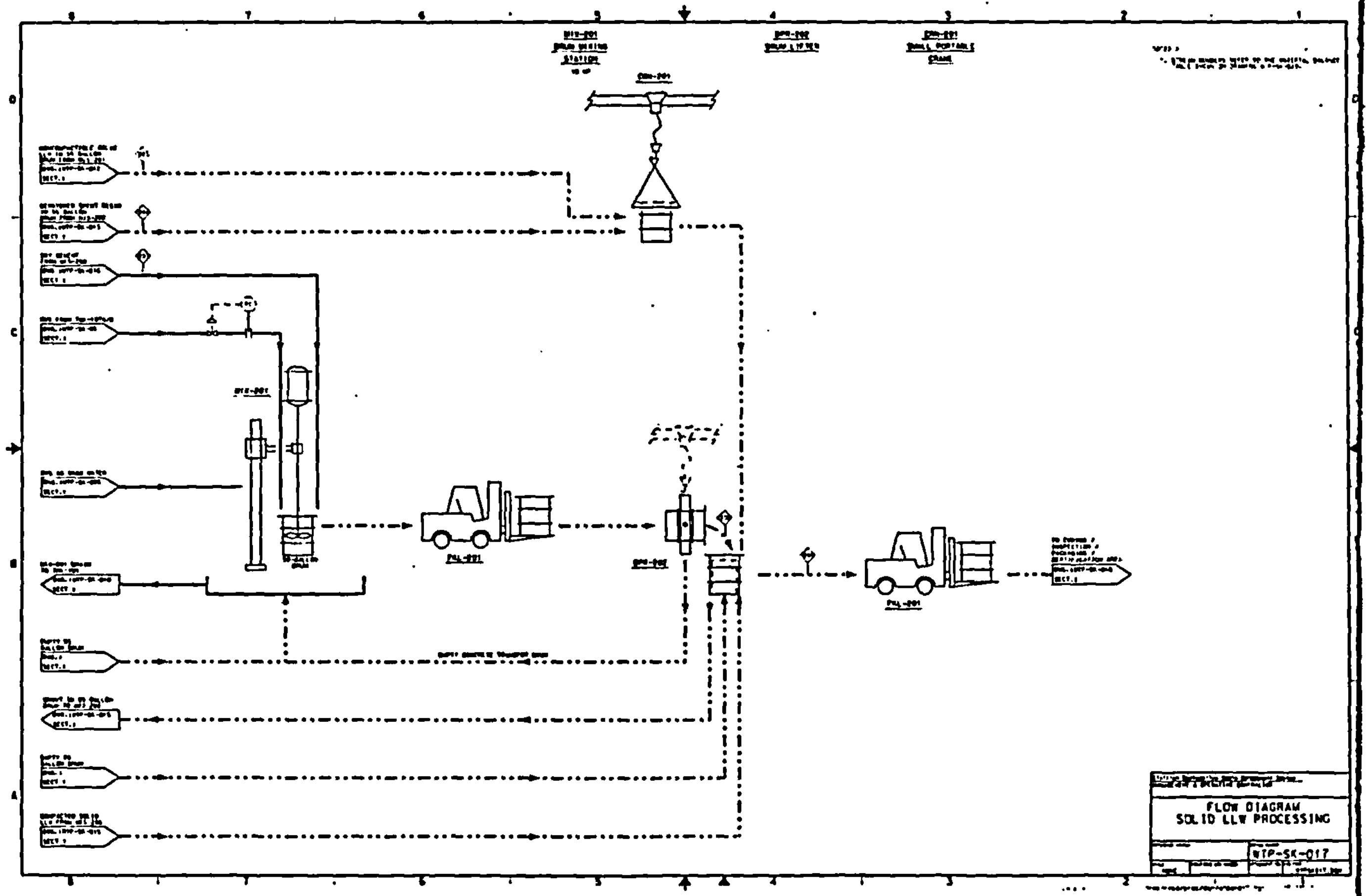

FLOW DIAGRAM
SOLID LLW PROCESSING
WTP-SK-013



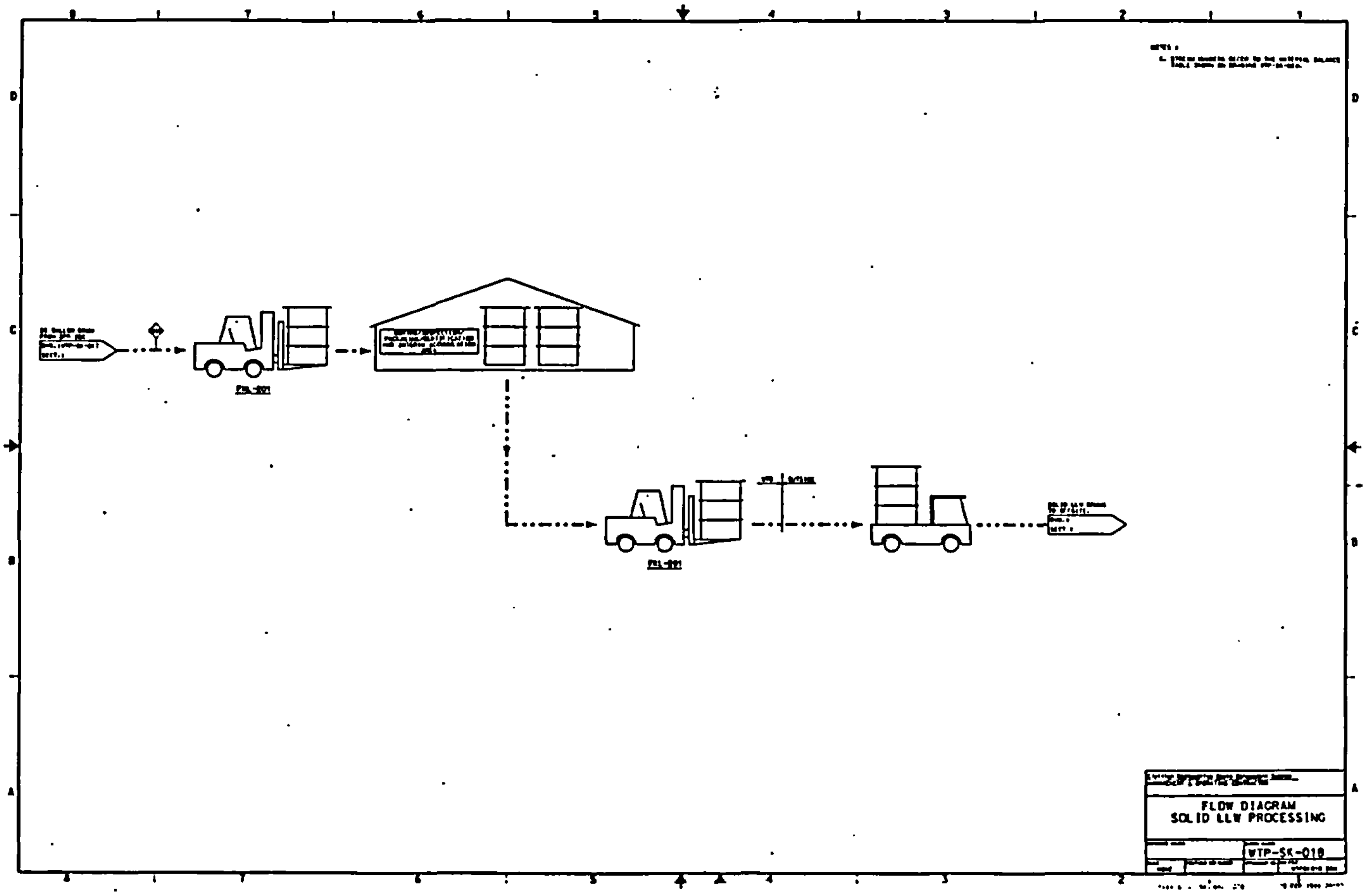
FLOW DIAGRAM
SOLID LLW PROCESSING
WTP-SK-014

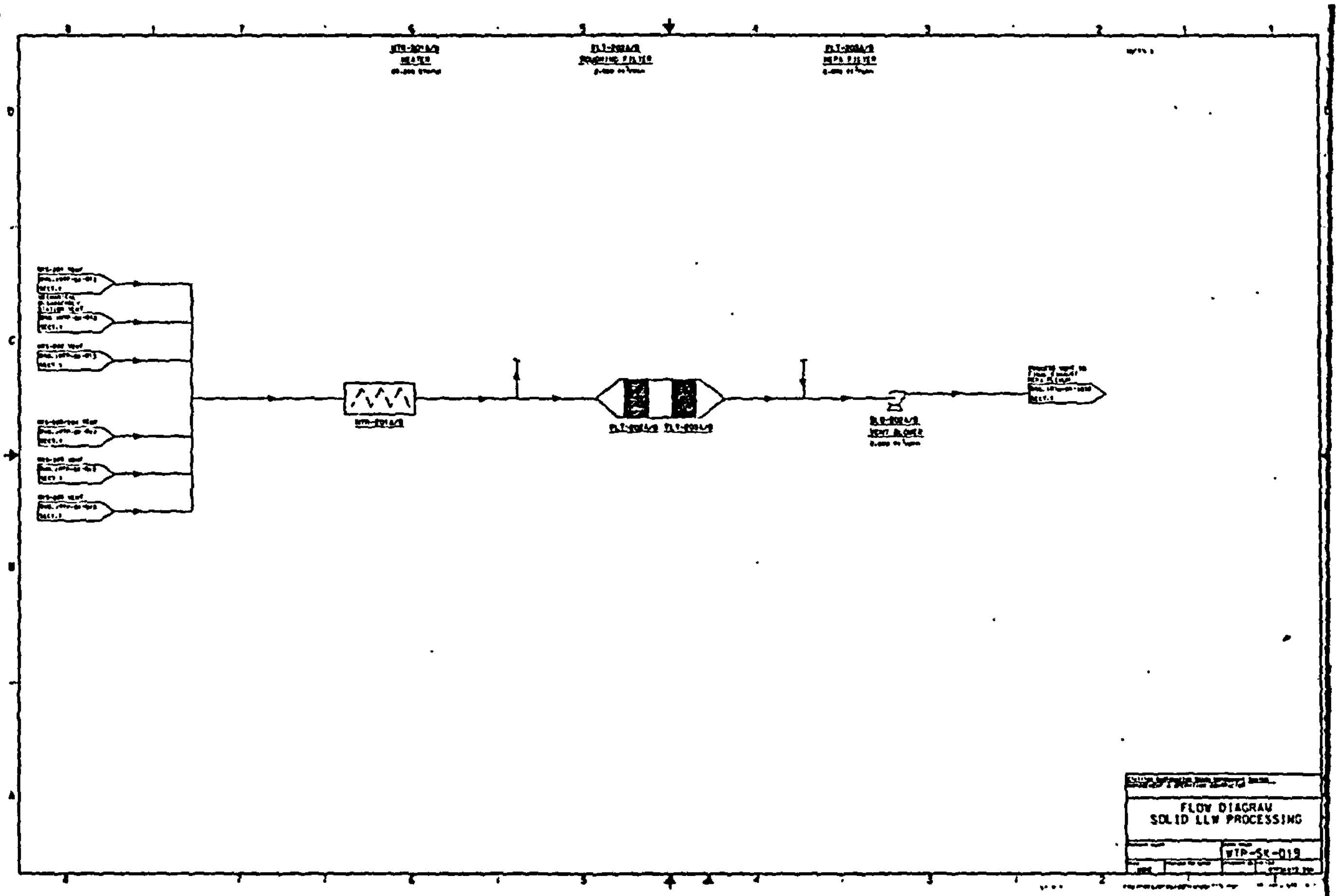

FLOW DIAGRAM
SOLID LLW PROCESSING
WTP-SK-015


FLOW DIAGRAM
SOLID LLW PROCESSING
WTP-SK-016



FLOW DIAGRAM
SOLID LLW PROCESSING
WTP-SK-017


FLOW DIAGRAM
SOLID LLW PROCESSING
WTP-SK-018


FLOW DIAGRAM
SOLID LLW PROCESSING
WTP-SK-019

LIQUID LLW PROCESSING

STREAM NO.	101	102	103	104	105	106	107	108	109	110	111	112	113	114
DESCRIPTION	FLOOR DRAIN (RECYCLABLE) FROM TNK-100	FLOOR DRAIN (RECYCLABLE) FROM CHF	FLOOR DRAIN (RECYCLABLE) FROM WHB	CASK DECON. WATER WASH FROM CHF	WASTE PACKAGE WASH FROM WHB	SMALL EQUIP./TOOL DECON. WATER FROM WHB	TRUCK/RAIL CARRIAGE WASH FROM CHF	TOTAL RECYCLABLE LIQUID LLW	FLOOR DRAIN (CHEMICAL) FROM TNK-100	FLOOR DRAIN (CHEMICAL) FROM CHF	FLOOR DRAIN (CHEMICAL) FROM WHB	CASK DECON. CHEMICAL WATER WASH FROM CHF	SMALL EQUIP./TOOLS DECON. SOLUTION FROM WHB	TOTAL CHEMICAL LIQUID LLW
GALLONS/YEAR	5,200	21,100	30,300	12,700	1,600	3,100	1,100	75,100	3,400	14,100	20,200	21,500	6,200	65,400
GALLONS/BATCH	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DRUMS/YEAR (55 GALLON)	—	—	—	—	—	—	—	—	—	—	—	—	—	—
lb/DRUM	—	—	—	—	—	—	—	—	—	—	—	—	—	—
BULK DENSITY, lb/ft^3	64.5	64.5	64.5	64.5	64.5	64.5	64.5	64.5	64	64	64	64	64	64
PRESSURE, PSIG	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
TEMPERATURE, °F	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT
GPM	—	—	—	—	—	—	—	—	—	—	—	—	—	—

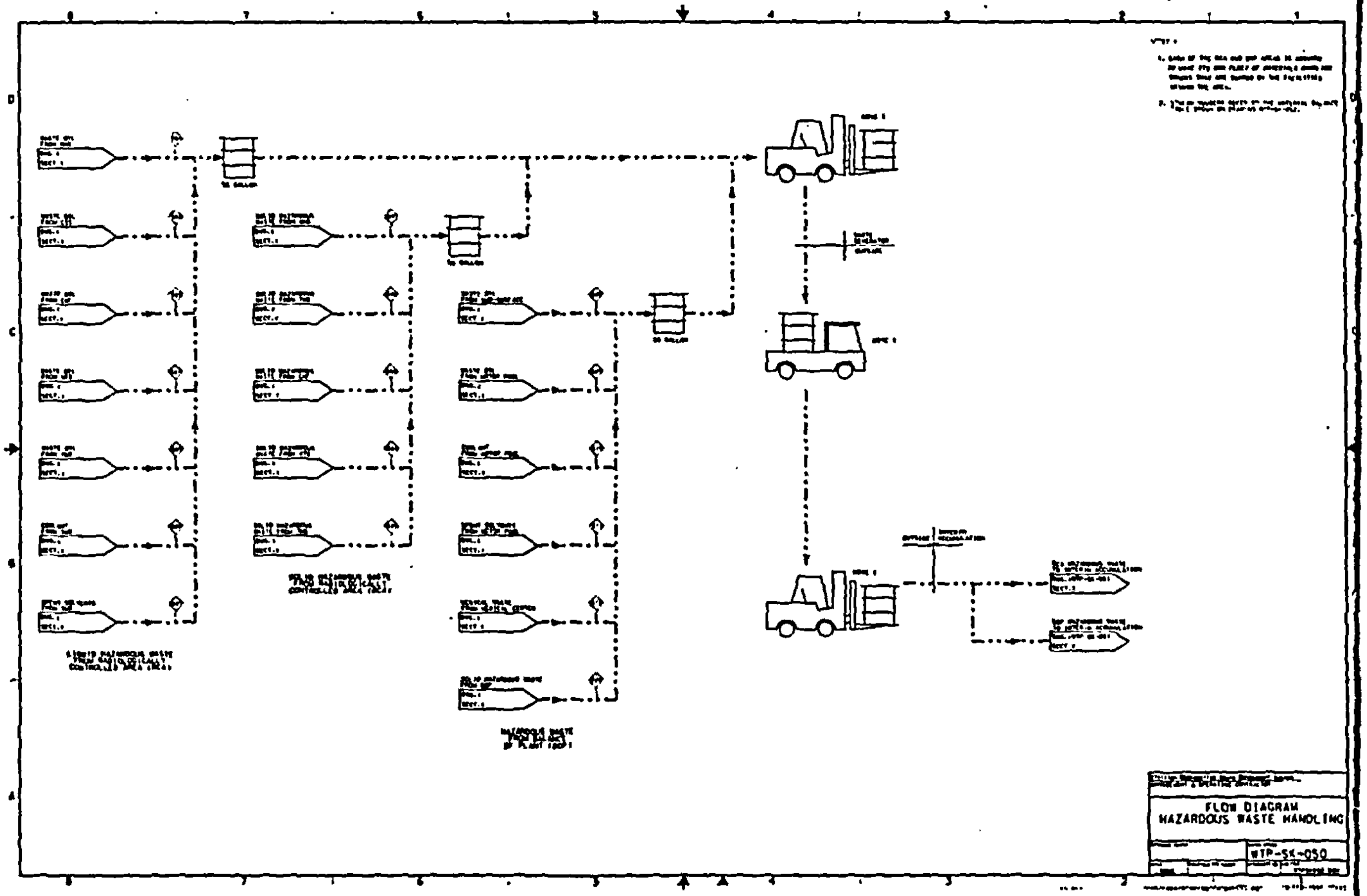
STREAM NO.	115	116	117	118	119	120	121	122	123	124	125	126	127
DESCRIPTION	CHEMICAL WASTE TO TNK-108	RECYCLABLE LIQUID WASTE TO FLT-101A/B	FILTRATE FROM FLT-101A/B	EVAPORATOR FEED TO EVP-101	EVAPORATOR OVERHEAD CONDENSATE	EVAPORATOR BOTTOMS	ION EXCHANGE FEED	RECYCLABLE WATER TO TNK-101A/B	SPENT RESIN SLURRY	CHEMICAL WASTE FROM TNK-108	DRUM CONTAINING CHEMICAL WASTE	CEMENT ADDITION TO DRUM	WATER FROM SPENT RESIN DEWATERING WIS-202
GALLONS/YEAR	65,400	75,100	—	—	—	—	—	—	1,120	—	—	—	7,011
GALLONS/BATCH	270	320	310	310	303	26	303	303	144	304	—	—	—
DRUMS/YEAR (55 GALLON)	—	—	—	—	—	—	—	—	—	—	4,370	4,370	—
lb/DRUM	—	—	—	—	—	—	—	—	—	—	343	651	—
BULK DENSITY, lb/ft^3	64	64.5	65.3	65.3	62.4	80.9	62.4	62.4	50	65.2	65.2	94	62.4
PRESSURE, PSIG	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	ATM	ATM	TBD
TEMPERATURE, °F	AMBIENT	AMBIENT	AMBIENT	AMBIENT	107	176	107	107	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT
GPM	9.3	5.3	9.3	1.6	1.4	5	1.7	1.7	5	3.4	—	—	8

SOLID LLW PROCESSING

STREAM NO.	201	202	203	204	205	206	207	208	209
DESCRIPTION	NONCOMPACTIBLE SOLID LLW GENERATED	COMPACTIBLE SOLID LLW GENERATED	SPENT RESIN DRUMS	DEWATERED SPENT RESIN DRUMS	COMPACTIBLE WASTE TO COMPACTOR	COMPACTED WASTE TO SUPERCOMPACTOR	DRY CEMENT FEED	200 LITER DRUM IN 300 LITER DRUM	300 LITER DRUM FOR ON-SITE DISPOSAL
lb/YEAR	1,347,960	267,900	77,260	13,000	267,900	267,900	824,041	—	—
ft^3/YEAR	8,986	26,790	1,545	400	24,558	6,698	8,766	—	—
DRUMS/YEAR (55 GALLON)	1,520	4,998	263	—	4,175	1,140	—	2,006	—
DRUMS/YEAR (85 GALLON)	—	—	—	—	—	—	—	—	2,005
BULK DENSITY, lb/ft^3	150	10	50	32.5	10.9	40	94	—	—
PRESSURE, PSIG	ATM	ATM	ATM	ATM	ATM	ATM	ATM	ATM	ATM
TEMPERATURE, °F	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT

LIQUID & SOLID LLW PROCESSING MATERIAL BALANCE

WTP-SK-020


FLOW DIAGRAM
HAZARDOUS WASTE HANDLING
WTP-SK-050


FLOW DIAGRAM
HAZARDOUS WASTE HANDLING
WTP-SK-051

LIQUID HAZARDOUS WASTE

STREAM NO.	501	502	503	504	505	506	507
DESCRIPTION	WASTE OIL FROM [illegible]	WASTE OIL FROM CSS	WASTE OIL FROM CMF	WASTE OIL FROM UTB	WASTE OIL FROM [illegible]	COOLANT FROM [illegible]	SPENT SOLVENTS FROM [illegible]
lb/YEAR	3,030	46	12	97	65	42	510
GALLONS/YEAR	406	6.2	1.6	13	8.7	4.8	72
DRUMS/YEAR (55 GALLON)	—	—	—	—	—	—	—
BULK DENSITY, lb/ft^3	56	56	56	56	56	66	53
PRESSURE, PSIG	ATM	ATM	ATM	ATM	ATM	ATM	ATM
TEMPERATURE, °F	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT

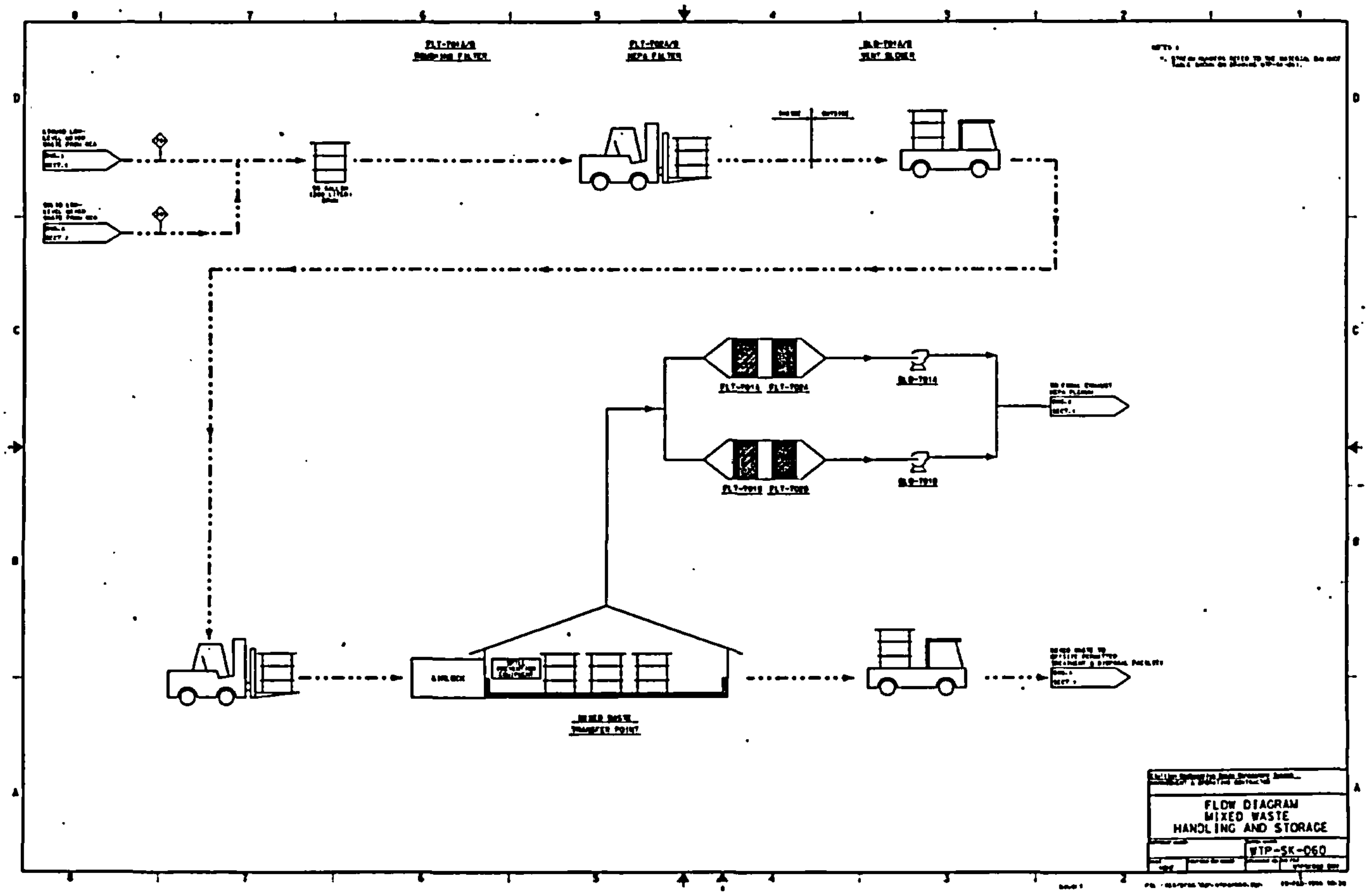
STREAM NO.	508	509	510	511	512	513	514
DESCRIPTION	WASTE OIL FROM SUB-SURFACE	WASTE OIL FROM MOTOR POOL	COOLANT FROM MOTOR POOL	SPENT SOLVENTS FROM MOTOR POOL	MEDICAL WASTE FROM MEDICAL CENTER	RCA LIQUID HW TO OFFSITE DISPOSAL	BOP LIQUID HW TO OFFSITE DISPOSAL
lb/YEAR	86,459	252	236	510	111	4,410	89,600
GALLONS/YEAR	11,616	34	27	72	12	600	12,000
DRUMS/YEAR (55 GALLON)	—	—	—	—	—	15	220
BULK DENSITY, lb/ft^3	56	56	66	53	69	—	—
PRESSURE, PSIG	ATM	ATM	ATM	ATM	ATM	ATM	ATM
TEMPERATURE, °F	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT

SOLID HAZARDOUS WASTE

STREAM NO.	601	602	603	604	605	606	607	608
DESCRIPTION	SOLID HW FROM [illegible]	SOLID HW FROM CSS	SOLID HW FROM CMF	SOLID HW FROM UTB	SOLID HW FROM [illegible]	SOLID HW FROM BOP	RCA HW TO OFFSITE DISPOSAL	BOP HW TO OFFSITE DISPOSAL
lb/YEAR	6,143	79	20	164	1,081	149,720	7,444	149,720
ft^3/YEAR	154	2	0.5	4	27	3,743	187	3,743
DRUMS/YEAR (55 GALLON)	—	—	—	—	—	—	36	510
BULK DENSITY, lb/ft^3	40	40	40	40	40	40	40	40
PRESSURE, PSIG	ATM	ATM	ATM	ATM	ATM	ATM	ATM	ATM
TEMPERATURE, °F	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT	AMBIENT

FLOW DIAGRAM
HAZARDOUS WASTE HANDLING
MATERIAL BALANCE

WTP-SK-052


FLOW DIAGRAM
MIXED WASTE
HANDLING AND STORAGE
WTP-SK-060

LIQUID MIXED WASTE

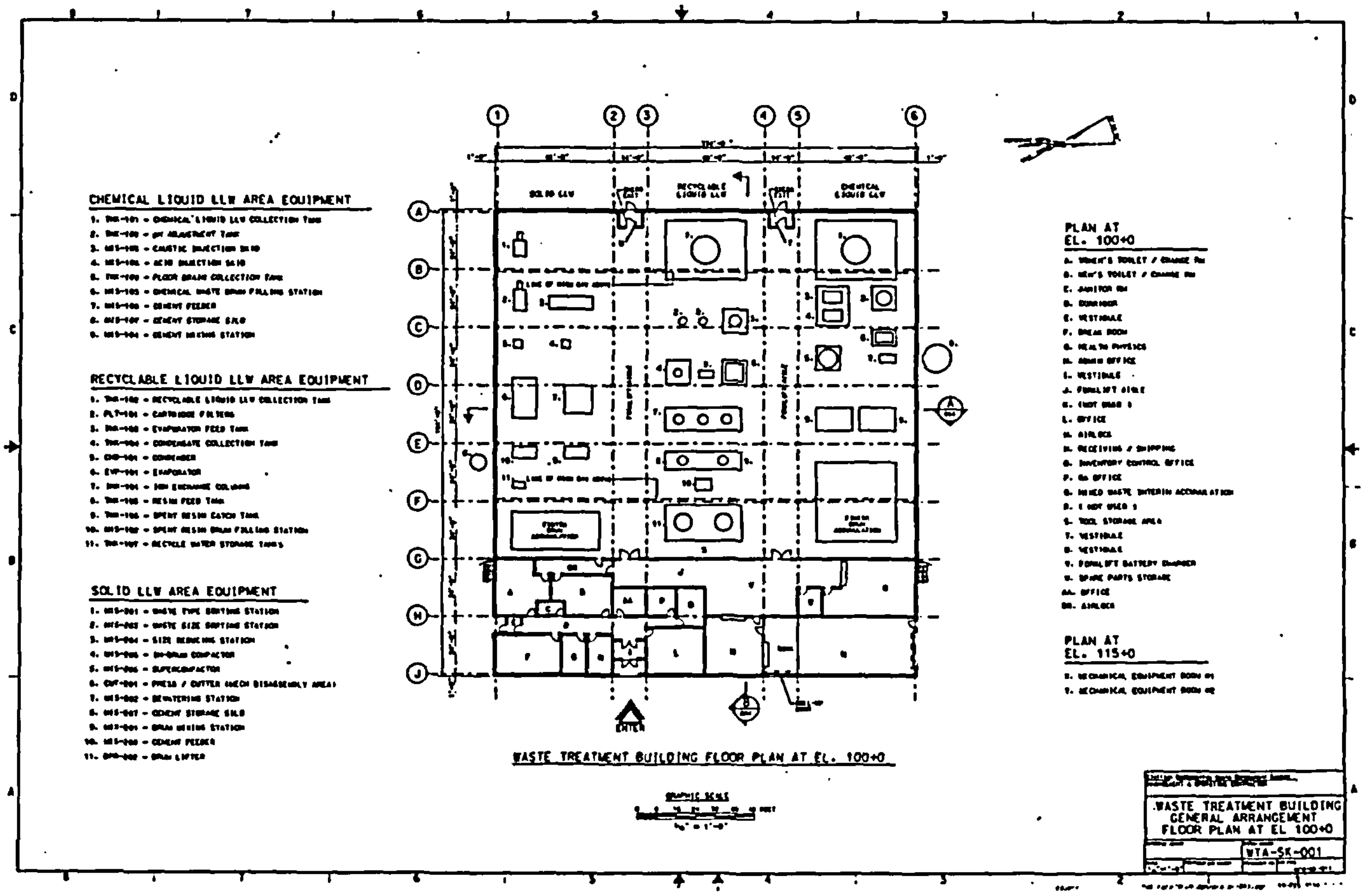
STREAM NO.	701
DESCRIPTION	LIQUID MIXED WASTE FROM RCA
lb/YEAR	243
GALLONS/YEAR	32
DRUMS/YEAR (55 GALLON)	1
BULK DENSITY, lb/ft^3	96
PRESSURE, PSIG	ATM
TEMPERATURE, °F	AMBIENT

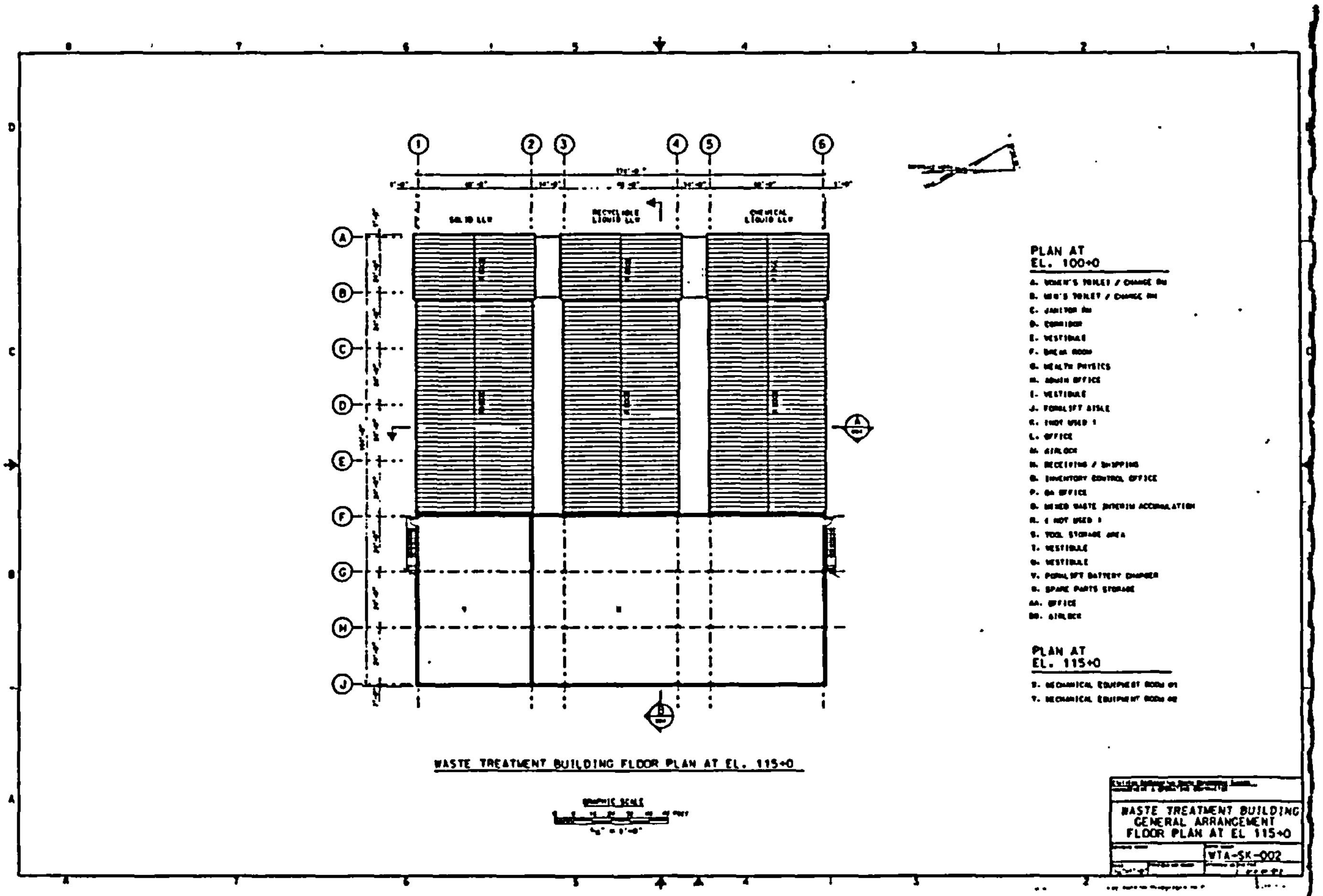
SOLID MIXED WASTE

STREAM NO.	801
DESCRIPTION	SOLID MIXED WASTE FROM RCA
lb/YEAR	440
ft^3/YEAR	11
DRUMS/YEAR (55 GALLON)	2
BULK DENSITY, lb/ft^3	40
PRESSURE, PSIG	ATM
TEMPERATURE, °F	AMBIENT

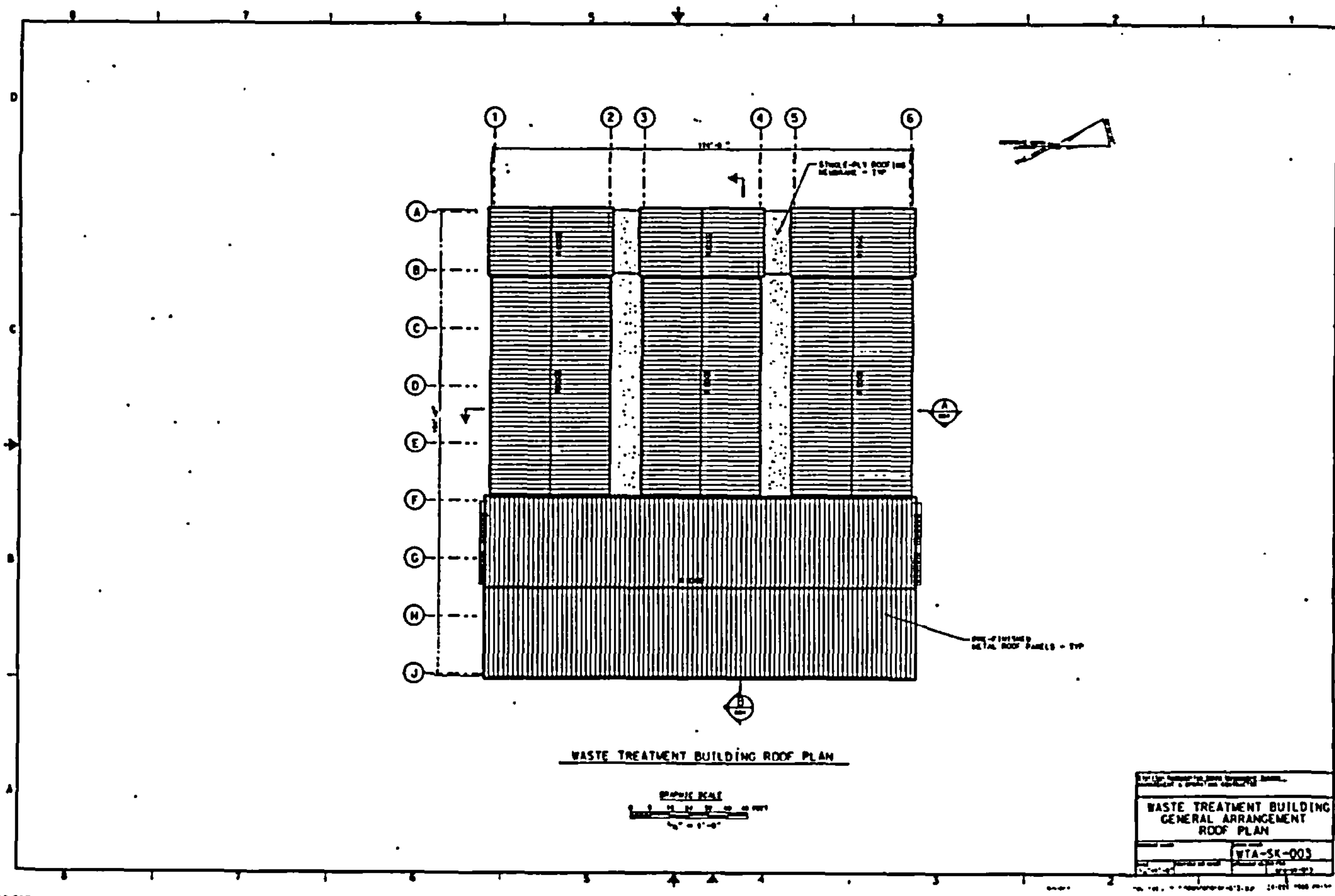
FLOW DIAGRAM
MIXED WASTE
MATERIAL BALANCE

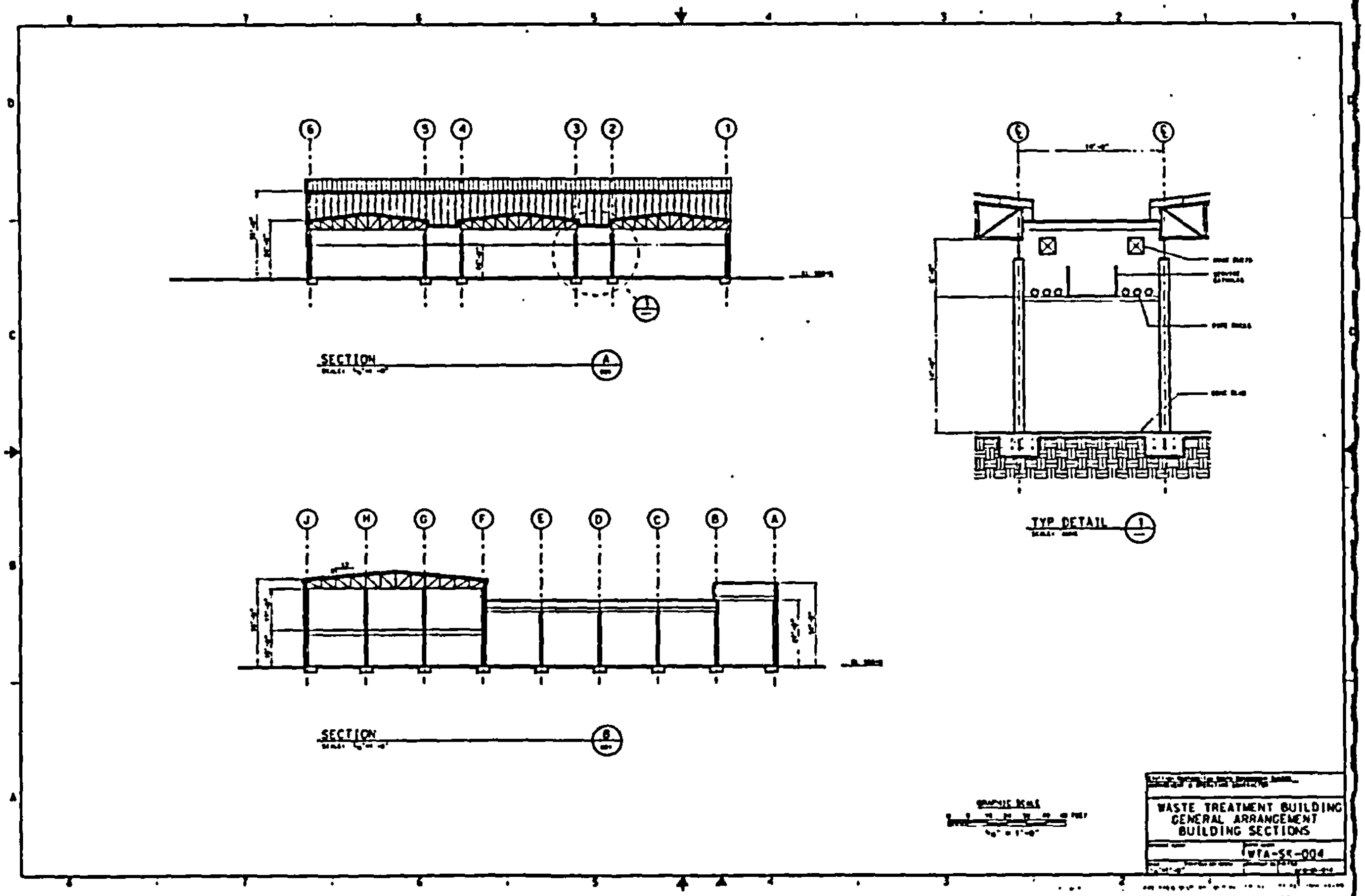
WTP-SK-061


CHEMICAL LIQUID LLW AREA EQUIPMENT
RECYCLABLE LIQUID LLW AREA EQUIPMENT
SOLID LLW AREA EQUIPMENT
PLAN AT EL. 100+0
PLAN AT EL. 115+0
ENTER
WASTE TREATMENT BUILDING FLOOR PLAN AT EL. 100+0
GRAPHIC SCALE
WASTE TREATMENT BUILDING GENERAL ARRANGEMENT FLOOR PLAN AT EL 100+0
WTA-SK-001

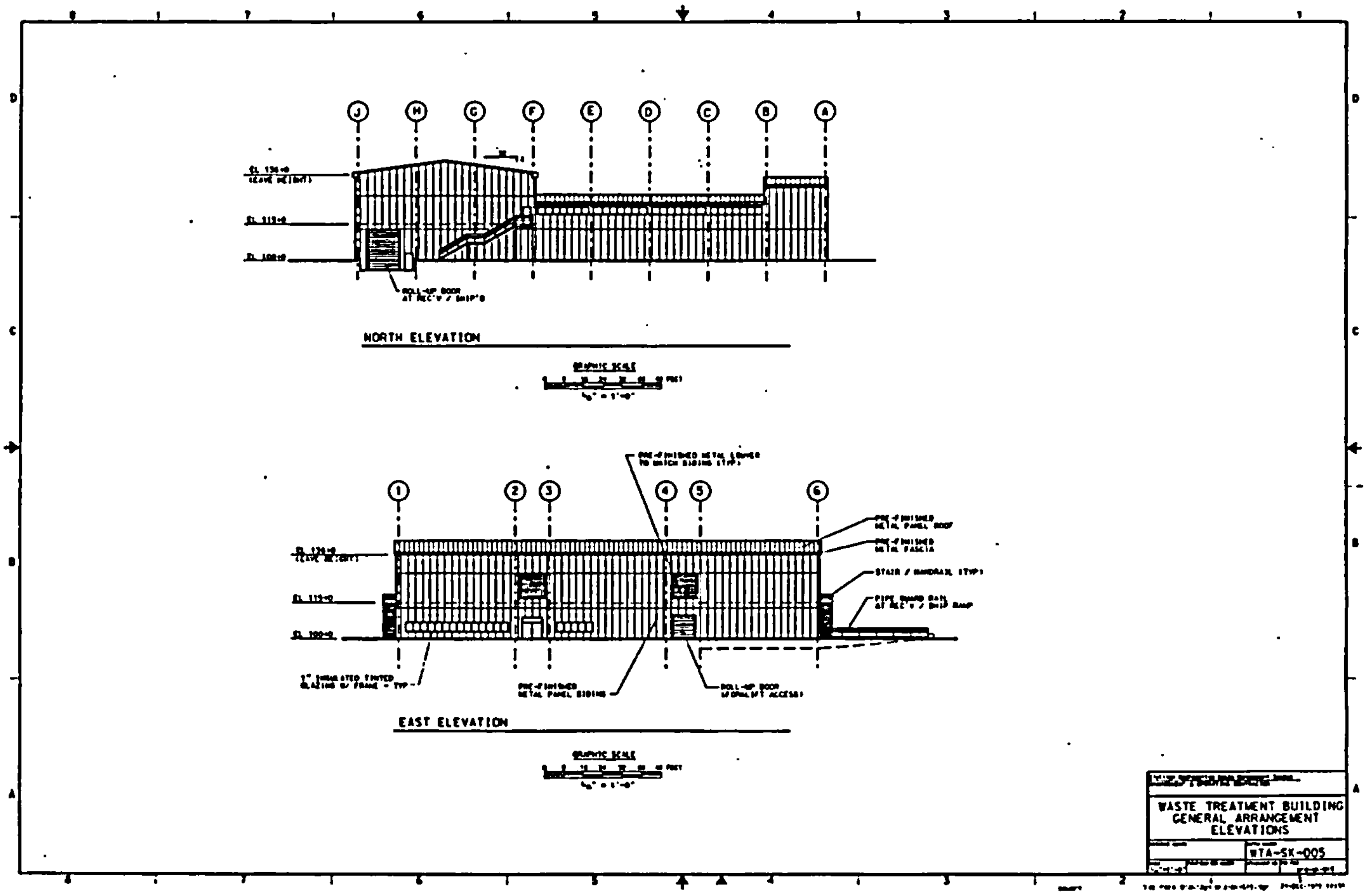


SOLID LLW
RECYCLABLE LIQUID LLW
CHEMICAL LIQUID LLW
WASTE TREATMENT BUILDING FLOOR PLAN AT EL. 115+0
GRAPHIC SCALE
PLAN AT EL. 100+0
A. WOMEN'S TOILET / CHANGE RM
B. MEN'S TOILET / CHANGE RM
C. JANITOR RM
D. CORRIDOR
E. VESTIBULE
F. BREAK ROOM
G. HEALTH PHYSICS
H. ADMIN OFFICE
I. VESTIBULE
J. FORKLIFT AISLE
K. (NOT USED)
L. OFFICE
M. AIRLOCK
N. RECEIVING / SHIPPING
O. INVENTORY CONTROL OFFICE
P. QA OFFICE
Q. MIXED WASTE INTERIM ACCUMULATION
R. (NOT USED)
S. TOOL STORAGE AREA
T. VESTIBULE
U. VESTIBULE
V. FORKLIFT BATTERY CHARGER
W. SPARE PARTS STORAGE
AA. OFFICE
BB. AIRLOCK
PLAN AT EL. 115+0
X. MECHANICAL EQUIPMENT ROOM #1
Y. MECHANICAL EQUIPMENT ROOM #2
WASTE TREATMENT BUILDING
GENERAL ARRANGEMENT
FLOOR PLAN AT EL 115+0
WTA-SK-002

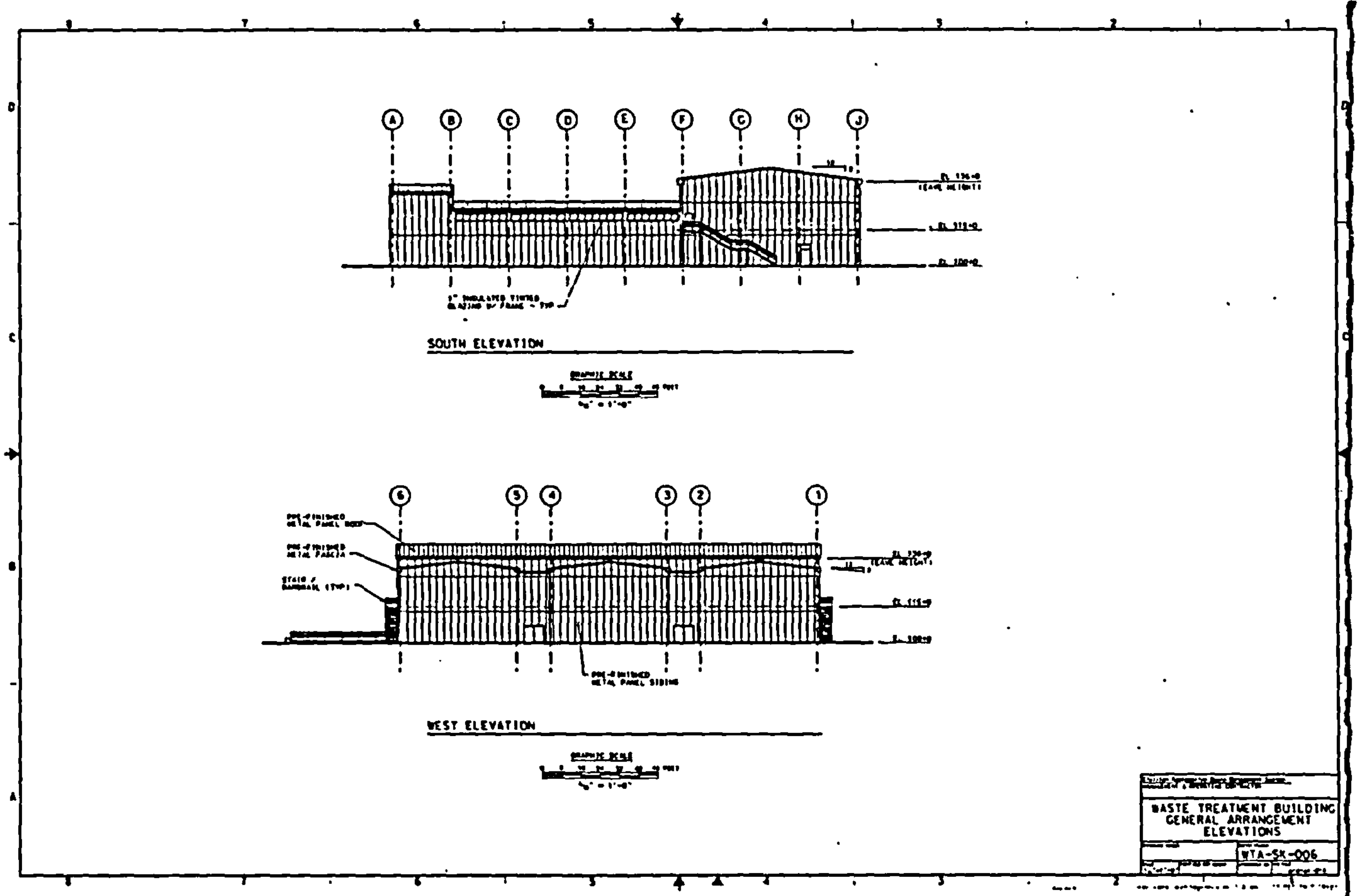

1
2
3
4
5
6
A
B
C
D
E
F
G
H
J
WASTE TREATMENT BUILDING ROOF PLAN
WASTE TREATMENT BUILDING
GENERAL ARRANGEMENT
ROOF PLAN
WTA-SK-003

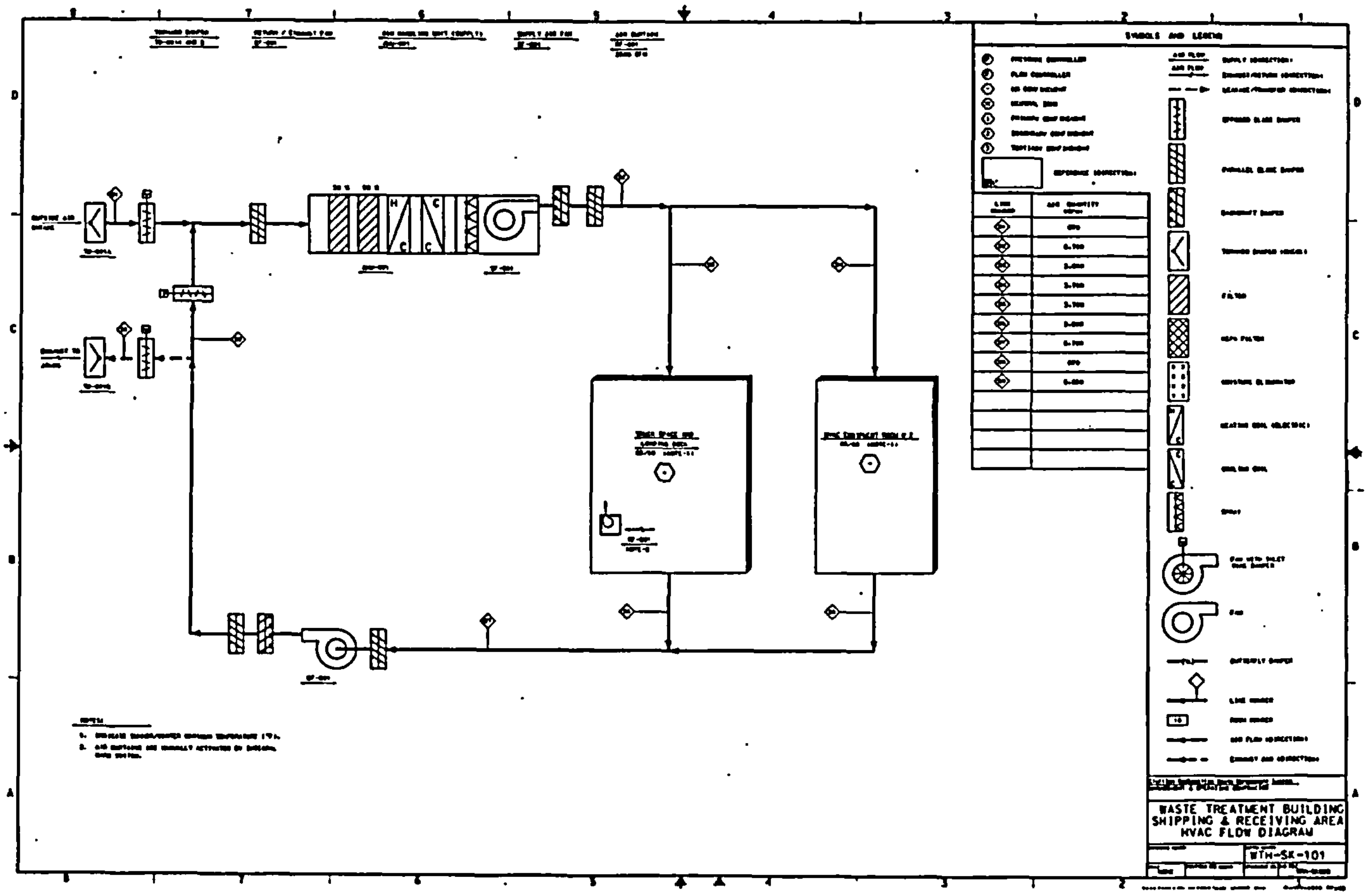


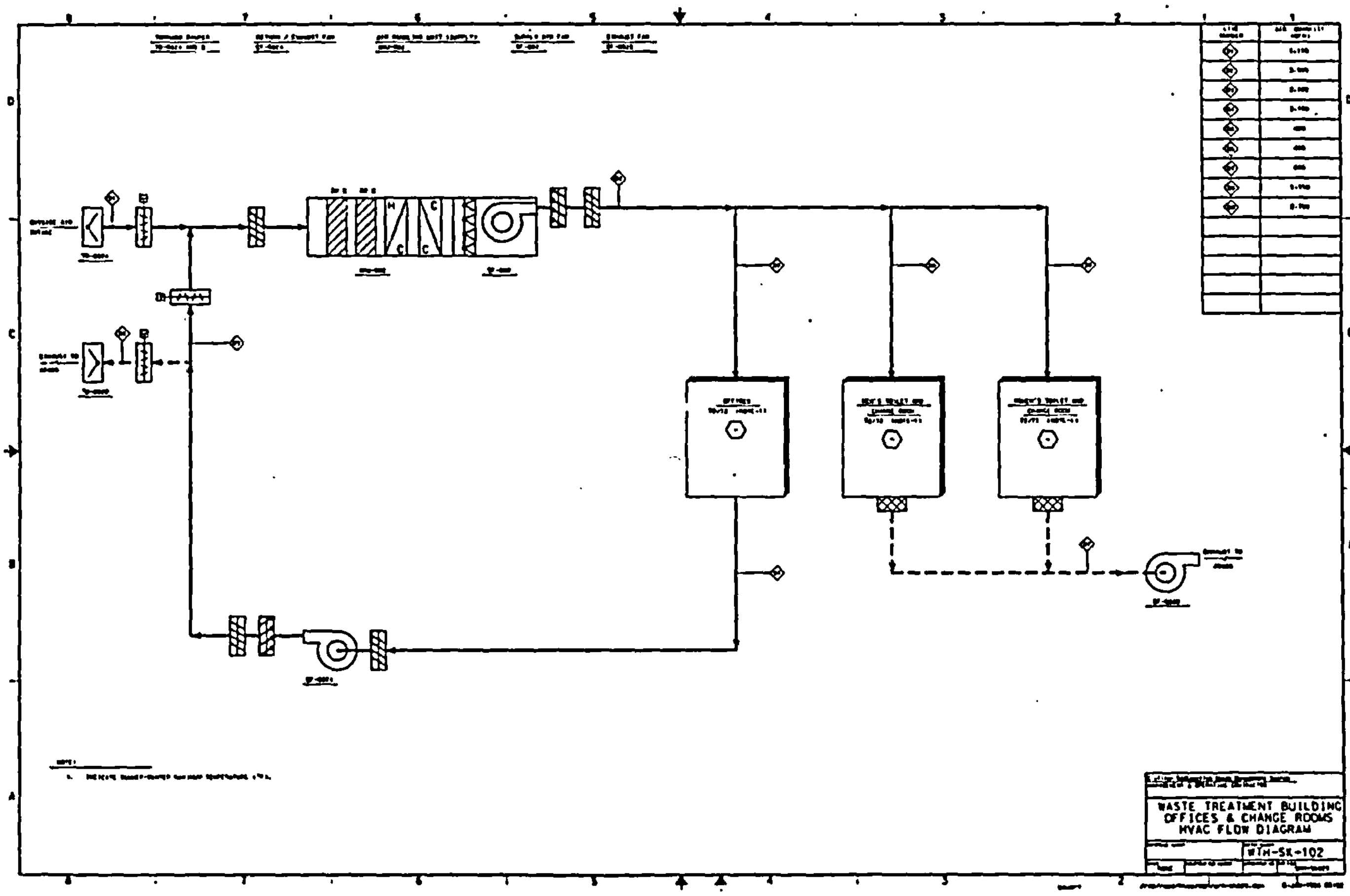
SECTION A
SECTION B
TYP DETAIL 1
WASTE TREATMENT BUILDING
GENERAL ARRANGEMENT
BUILDING SECTIONS
WTA-SK-004

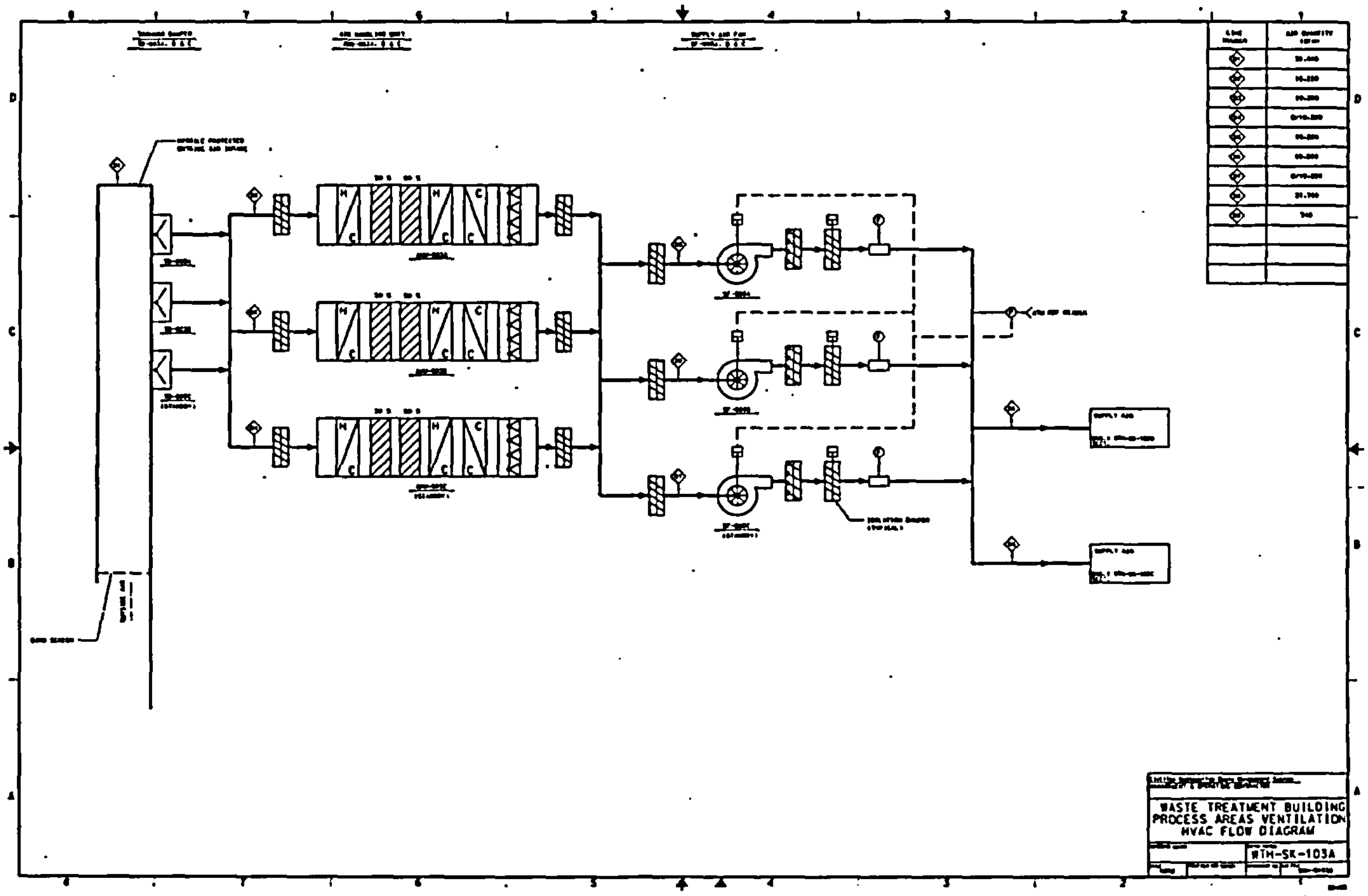


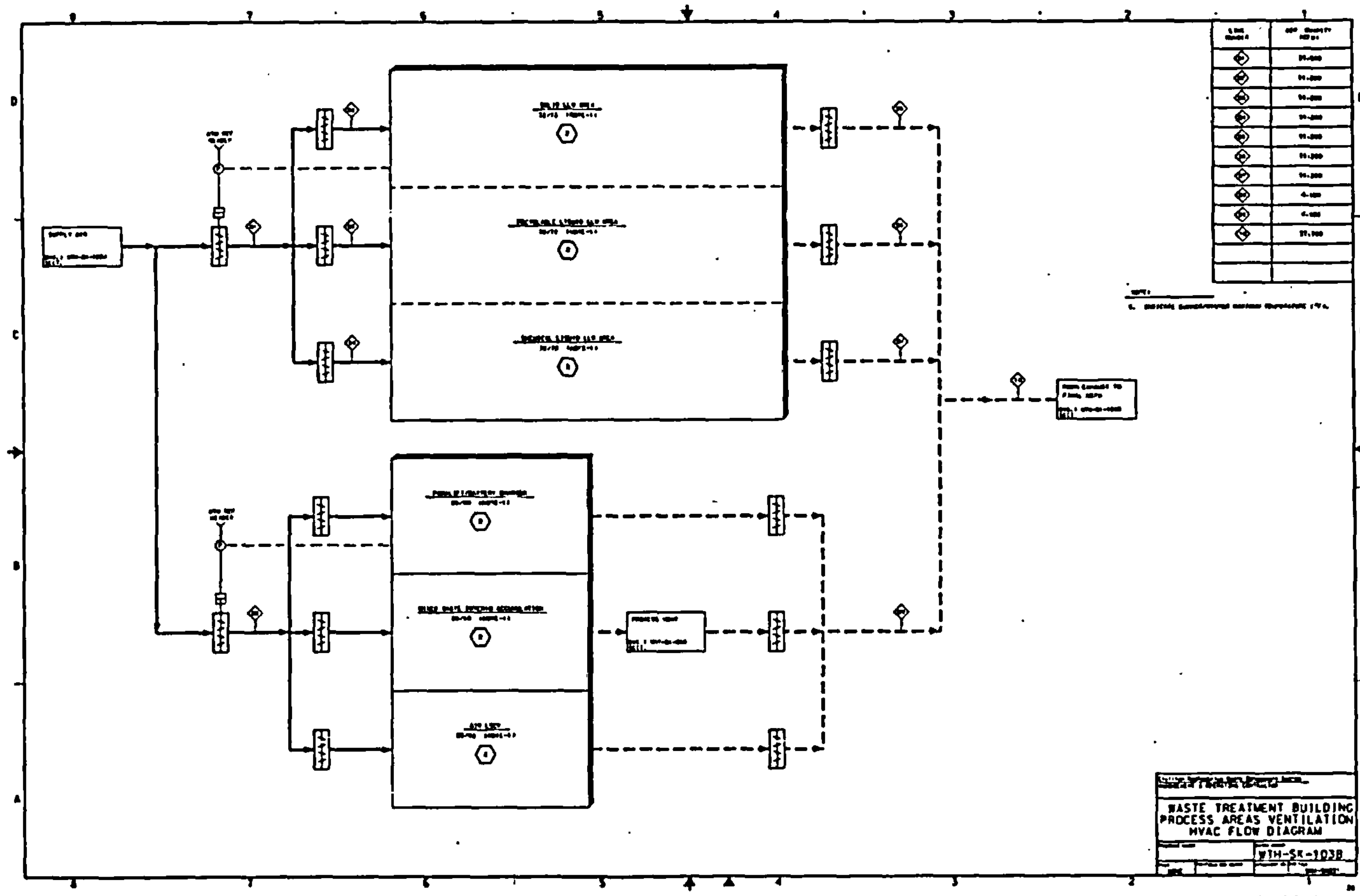
NORTH ELEVATION
ROLL-UP DOOR AT REC'V / SHIP'G
EL 100'-0
EL 115'-0
EAST ELEVATION
PRE-FINISHED METAL PANEL ROOF
PRE-FINISHED METAL FASCIA
STAIR / HANDRAIL (TYP)
PRE-FINISHED METAL PANEL SIDING
ROLL-UP DOOR
GRAPHIC SCALE
WASTE TREATMENT BUILDING
GENERAL ARRANGEMENT
ELEVATIONS
WTA-SK-005


A B C D E F G H J
SOUTH ELEVATION
6 5 4 3 2 1
WEST ELEVATION
WASTE TREATMENT BUILDING
GENERAL ARRANGEMENT
ELEVATIONS
WTA-SK-006

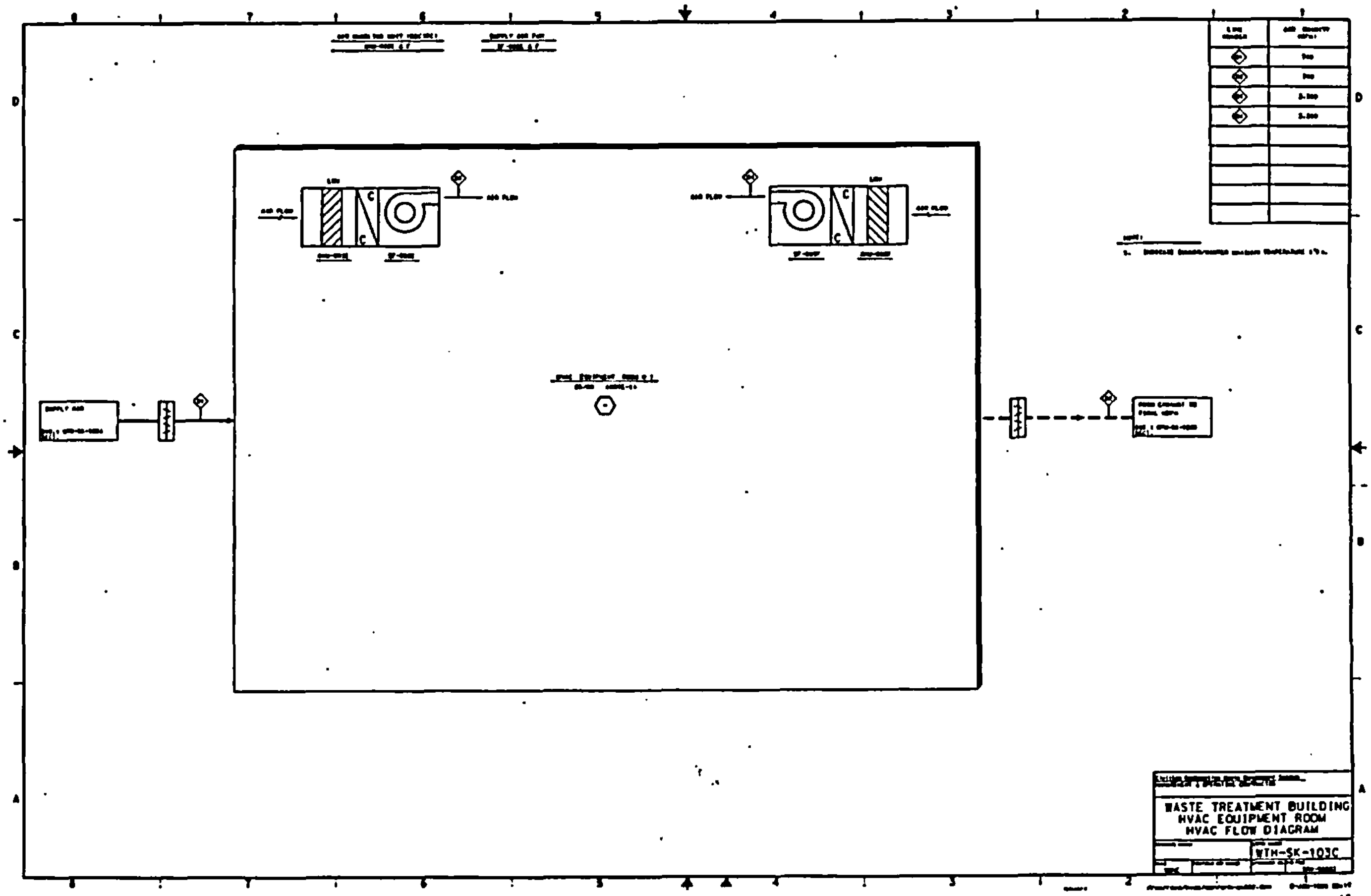

WASTE TREATMENT BUILDING
SHIPPING & RECEIVING AREA
HVAC FLOW DIAGRAM
WTH-SK-101

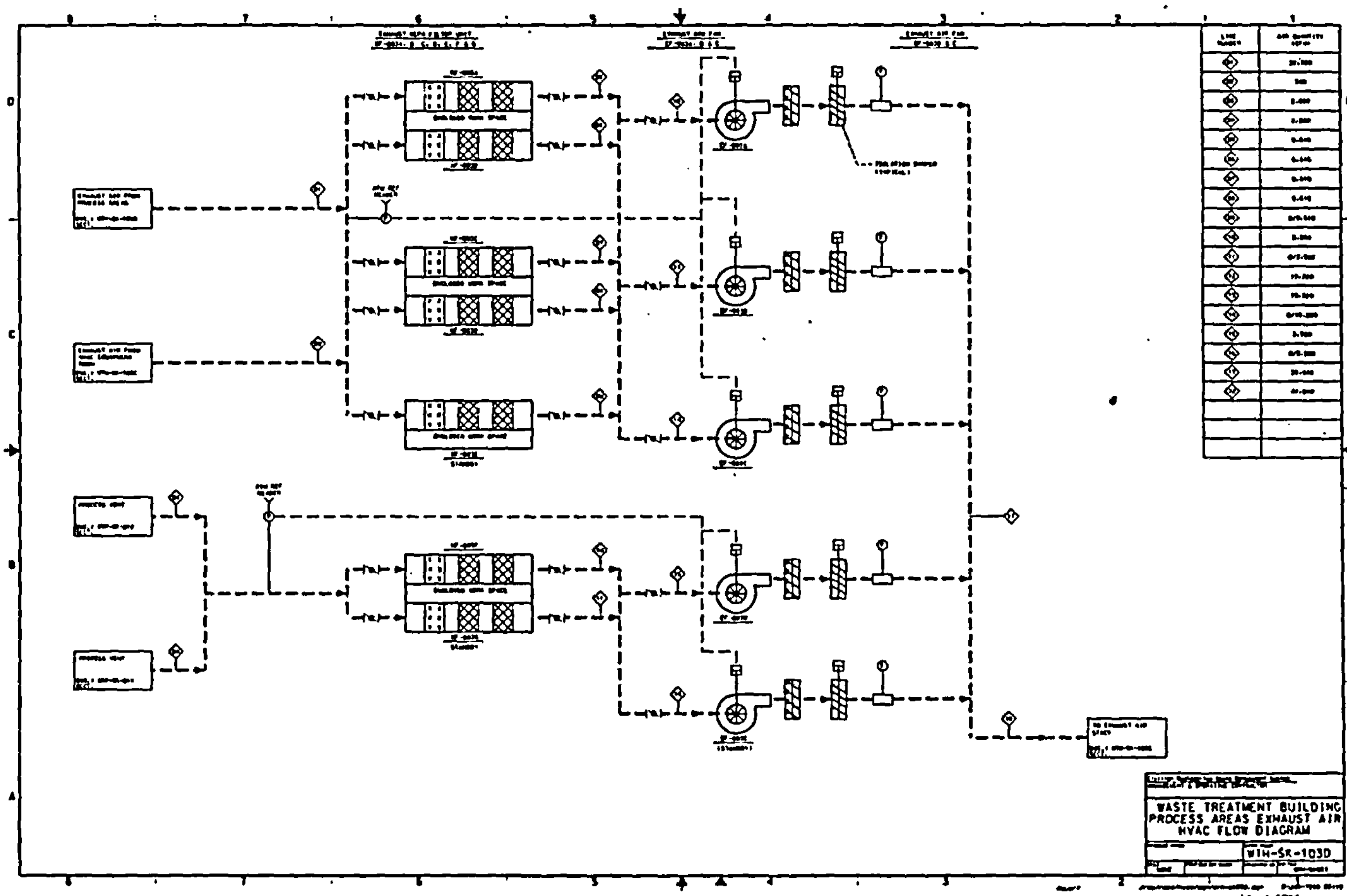

WASTE TREATMENT BUILDING
OFFICES & CHANGE ROOMS
HVAC FLOW DIAGRAM
WTH-SK-102

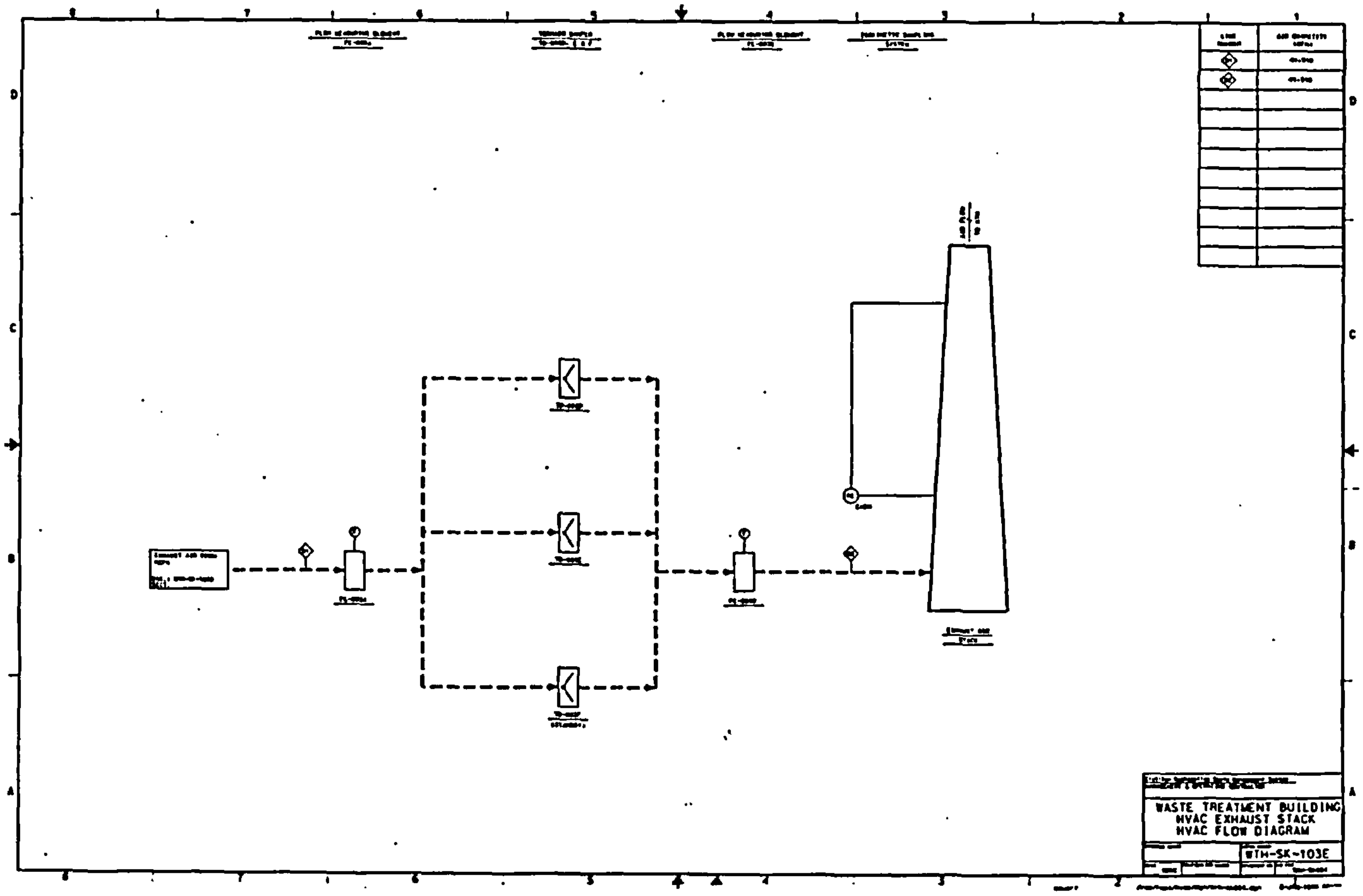

WASTE TREATMENT BUILDING
PROCESS AREAS VENTILATION
HVAC FLOW DIAGRAM
WTM-SK-103A



WASTE TREATMENT BUILDING
PROCESS AREAS VENTILATION
HVAC FLOW DIAGRAM
WTH-SK-103B


WASTE TREATMENT BUILDING
HVAC EQUIPMENT ROOM
HVAC FLOW DIAGRAM
WTH-SK-103C


WASTE TREATMENT BUILDING
PROCESS AREAS EXHAUST AIR
HVAC FLOW DIAGRAM
WTH-SK-103D



WASTE TREATMENT BUILDING
HVAC EXHAUST STACK
HVAC FLOW DIAGRAM
WTM-SK-103E

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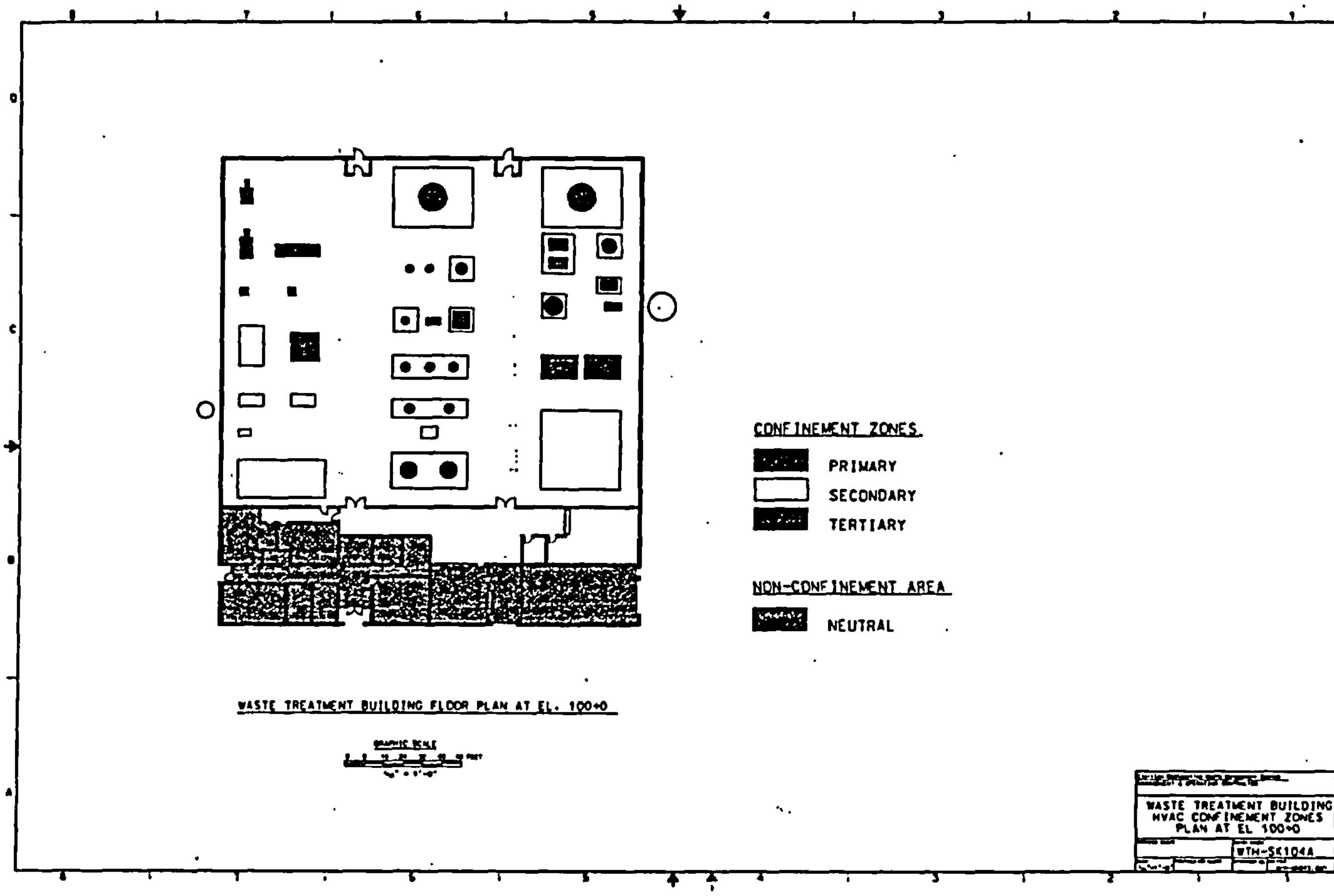

CONFINEMENT ZONES
PRIMARY
SECONDARY
TERTIARY
NON-CONFINEMENT AREA
NEUTRAL
WASTE TREATMENT BUILDING FLOOR PLAN AT EL. 100+0
WASTE TREATMENT BUILDING
HVAC CONFINEMENT ZONES
PLAN AT EL 100+0
WTH-SK104A

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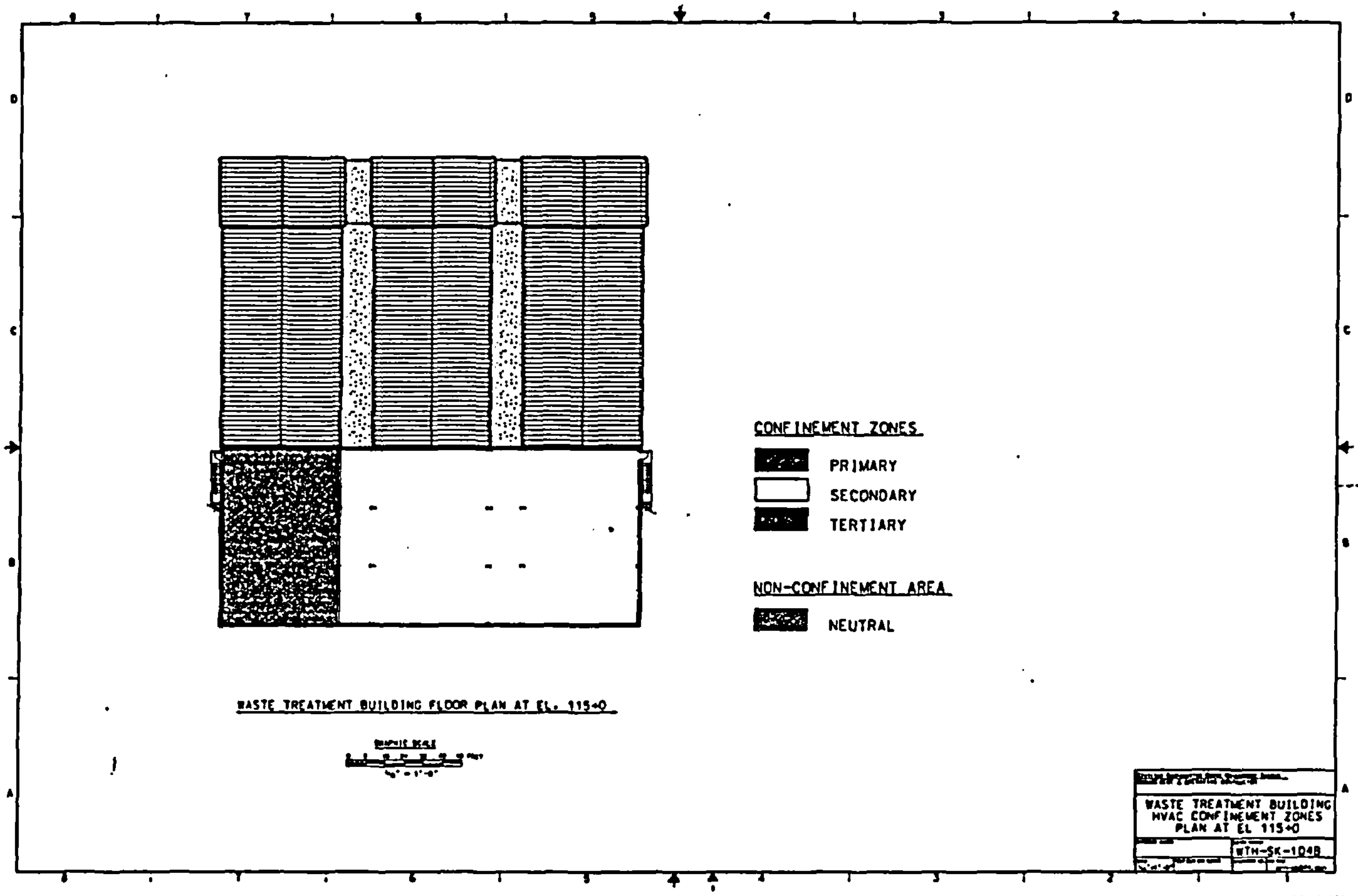
CONFINEMENT ZONES
PRIMARY
SECONDARY
TERTIARY
NON-CONFINEMENT AREA
NEUTRAL
WASTE TREATMENT BUILDING FLOOR PLAN AT EL. 115+0
WASTE TREATMENT BUILDING
HVAC CONFINEMENT ZONES
PLAN AT EL 115+0
WTH-SK-104B

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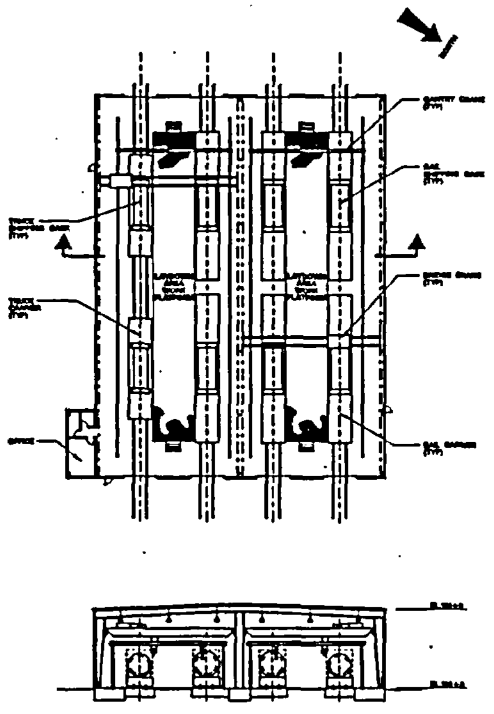


Figure 7.2.5-1. Carrier Staging Shed (Floor Plan and Building Section)

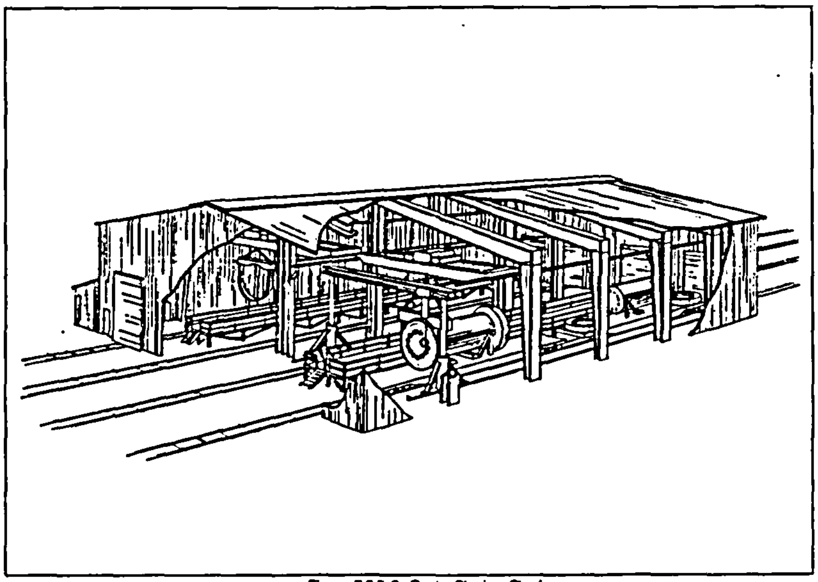


Figure 7.2.5-2. Carrier Staging Shed

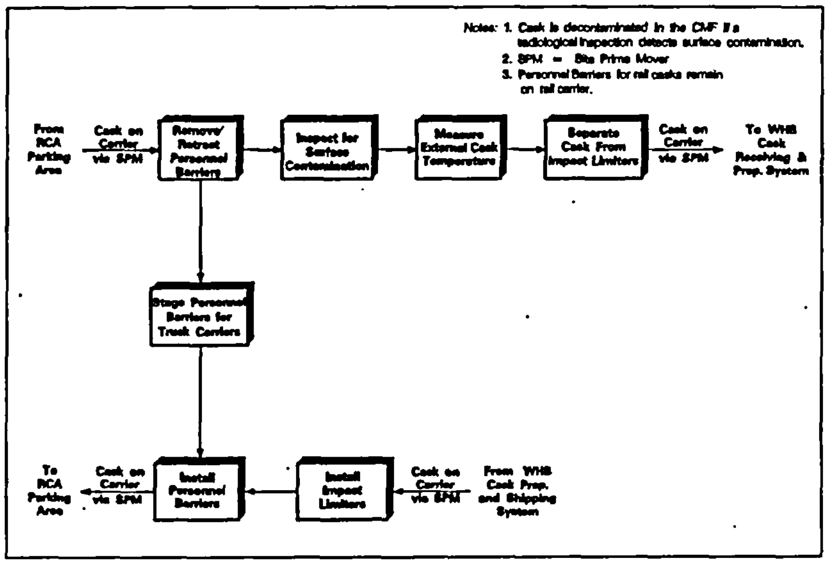
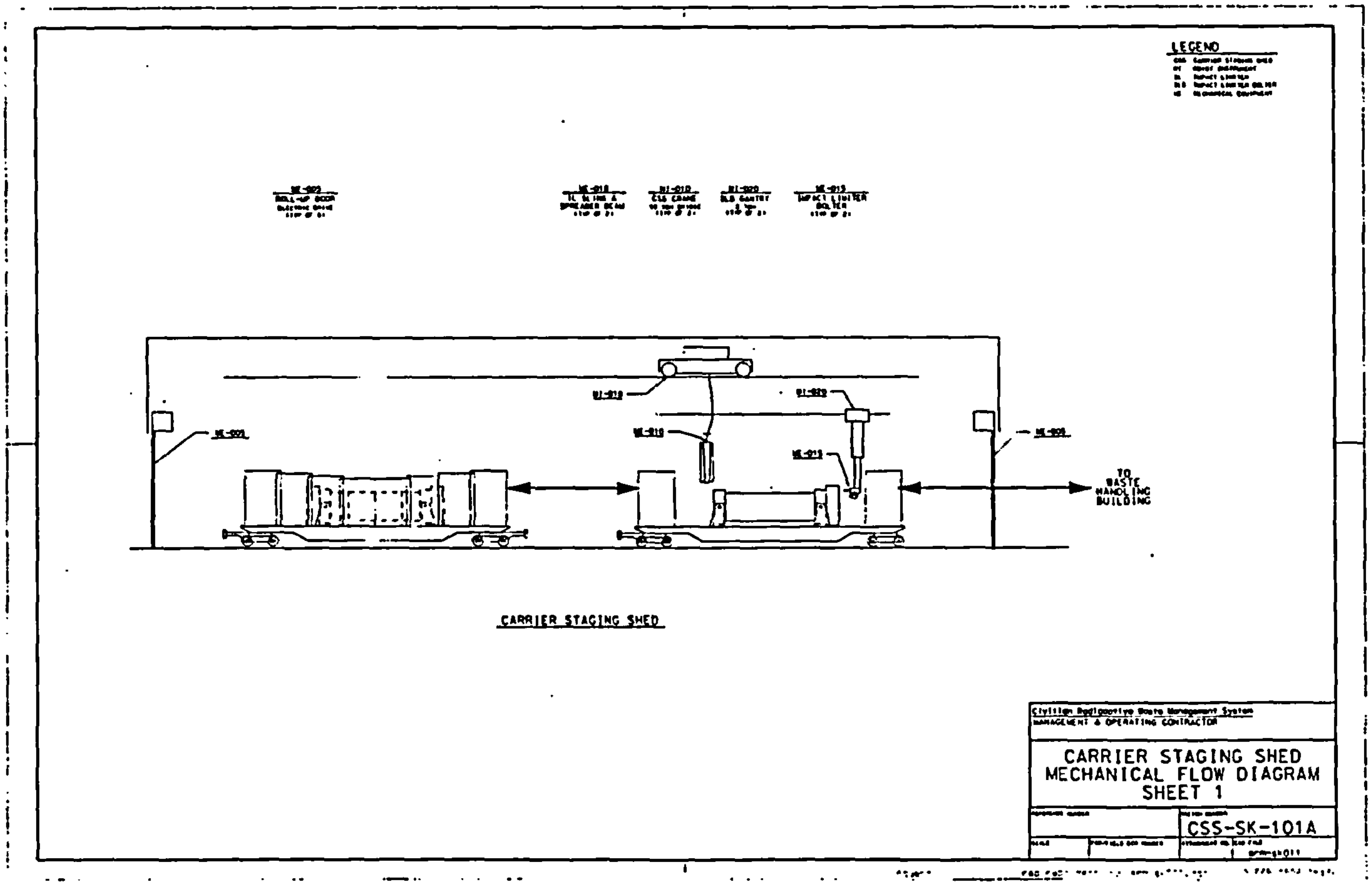
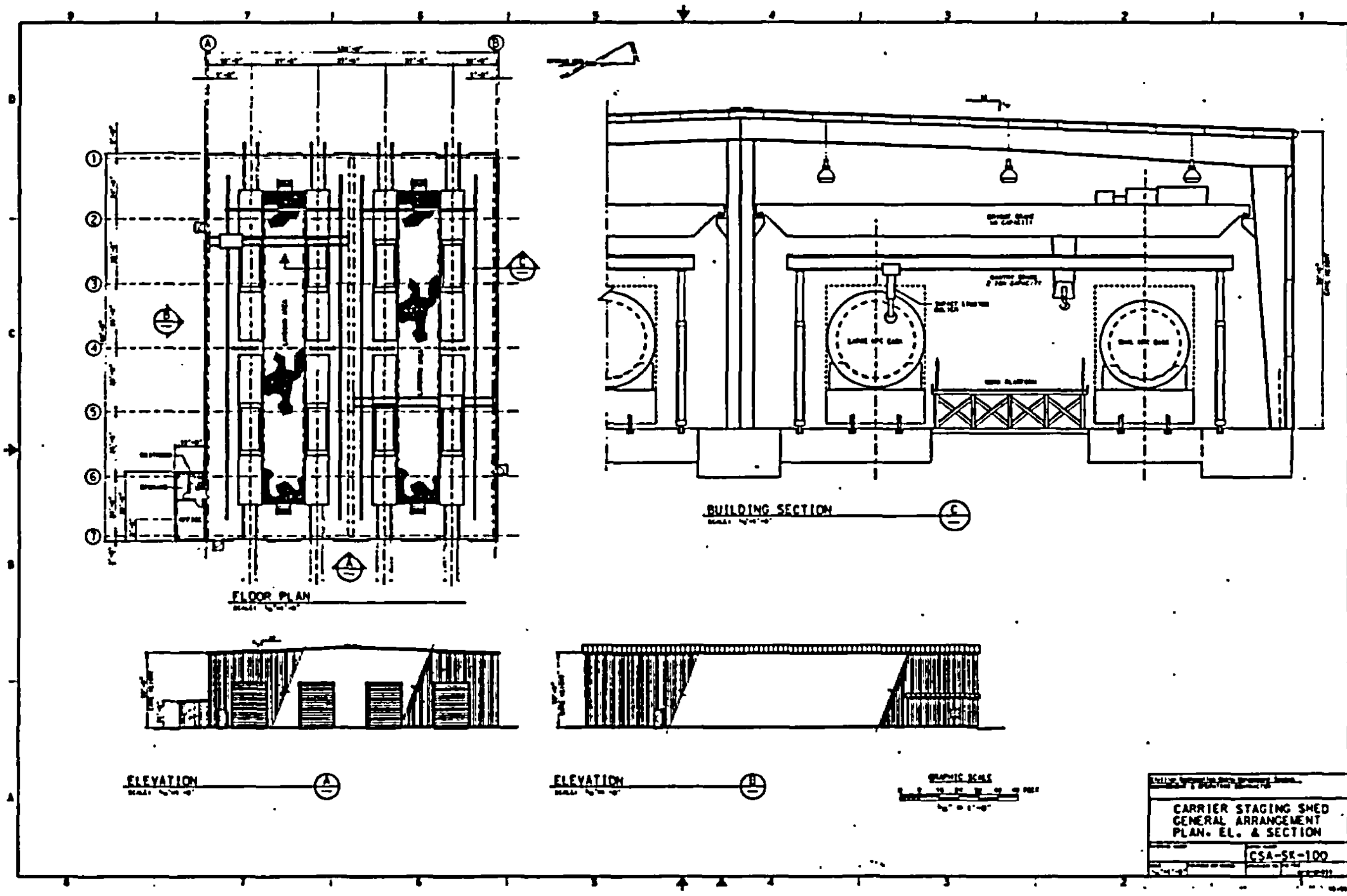


Figure 7.2.5-3. Carrier Staging System


LEGEND
TO
WASTE
HANDLING
BUILDING
CARRIER STAGING SHED
Civilian Radioactive Waste Management System
MANAGEMENT & OPERATING CONTRACTOR
CARRIER STAGING SHED
MECHANICAL FLOW DIAGRAM
SHEET 1
CSS-SK-101A


FLOOR PLAN
BUILDING SECTION
ELEVATION
ELEVATION
GRAPHIC SCALE
CARRIER STAGING SHED
GENERAL ARRANGEMENT
PLAN. EL. & SECTION
CSA-SK-100

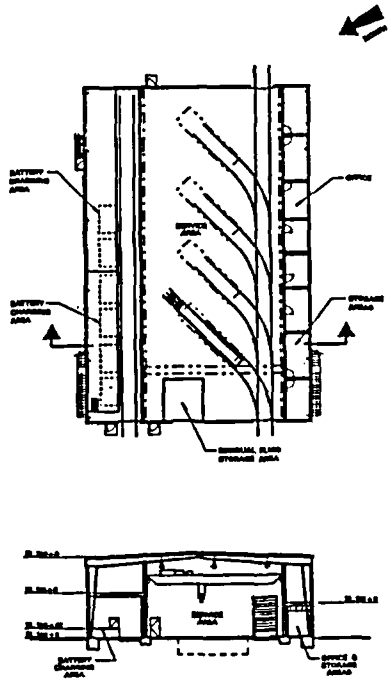
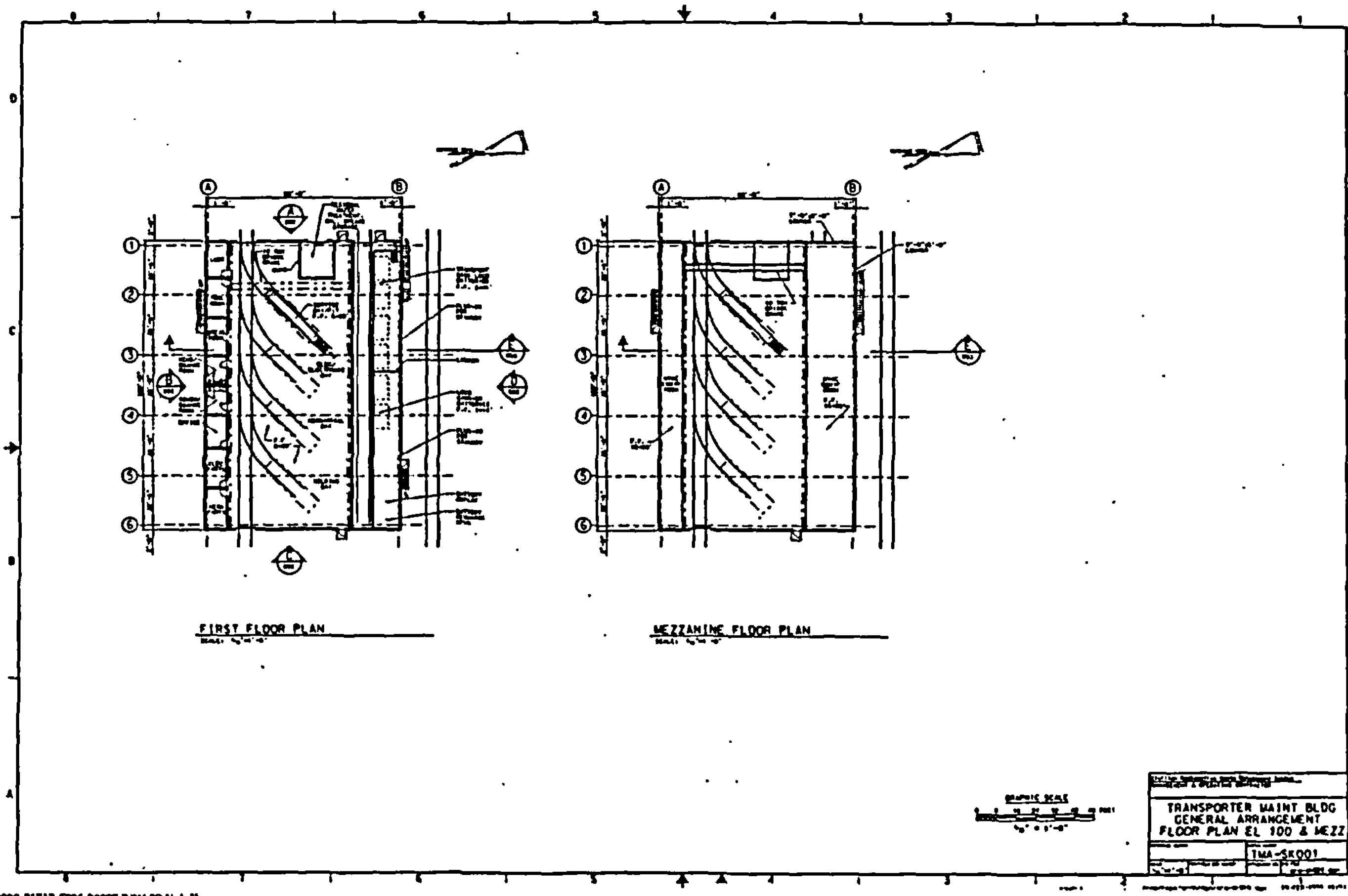
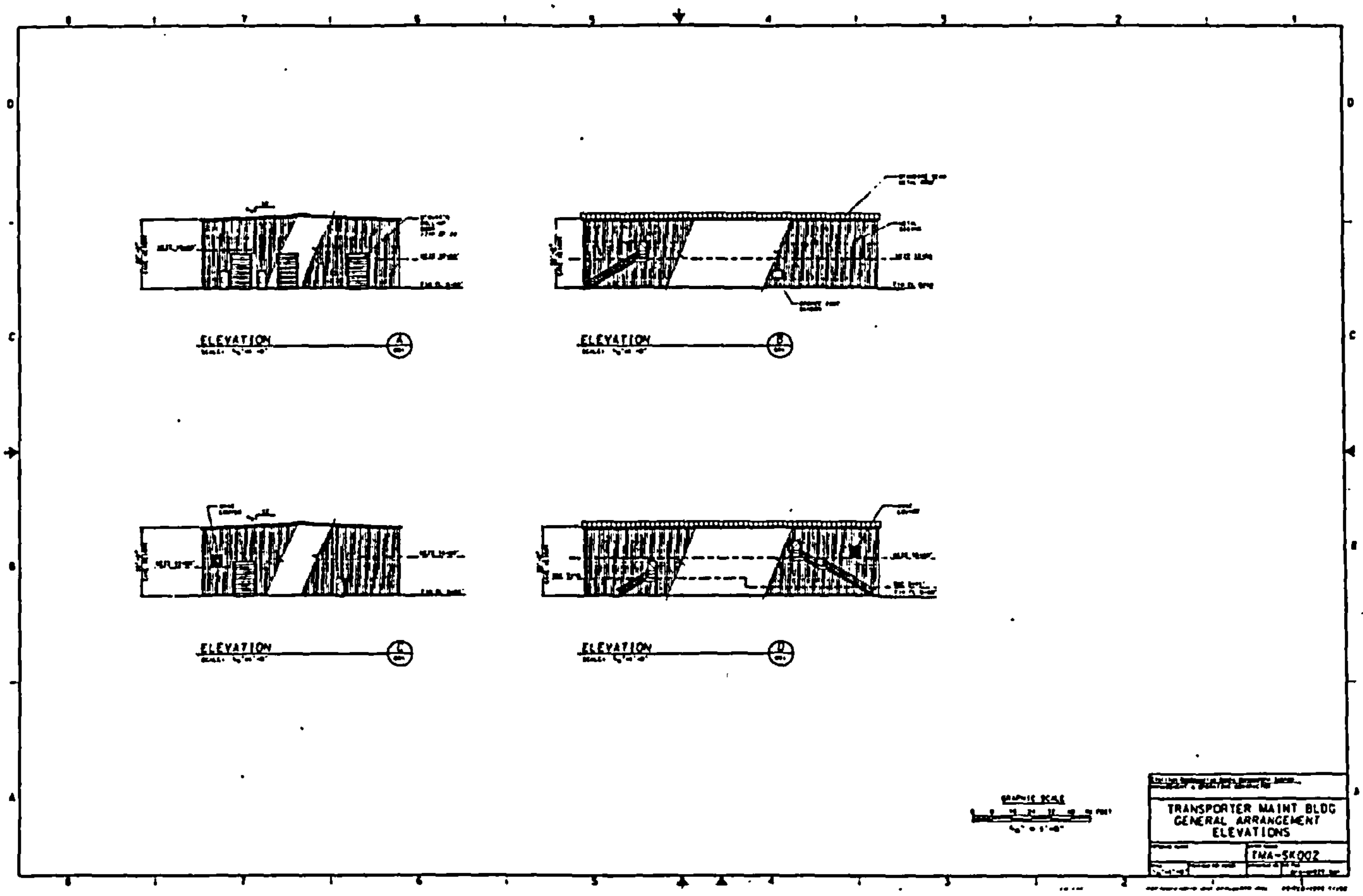
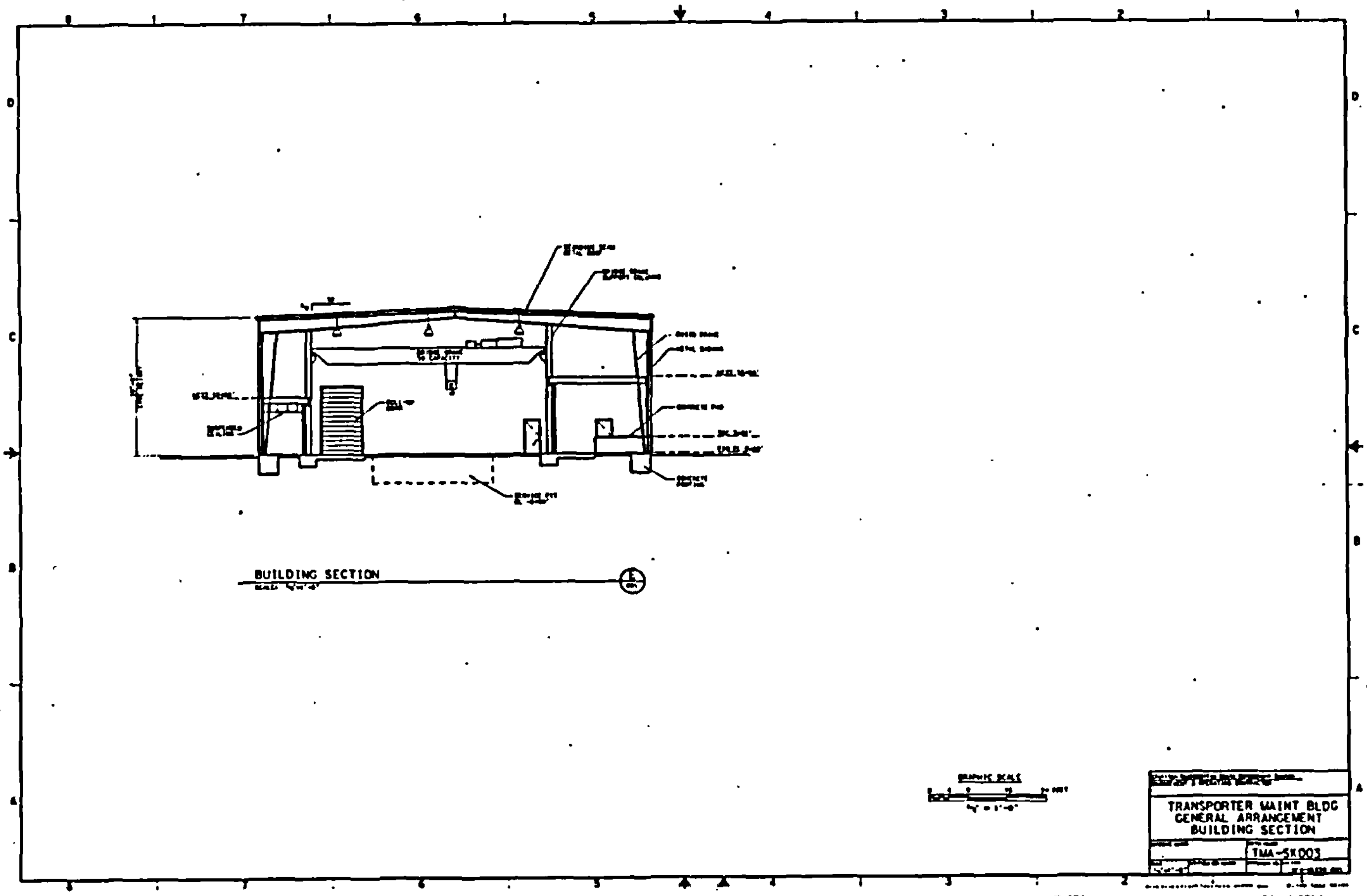
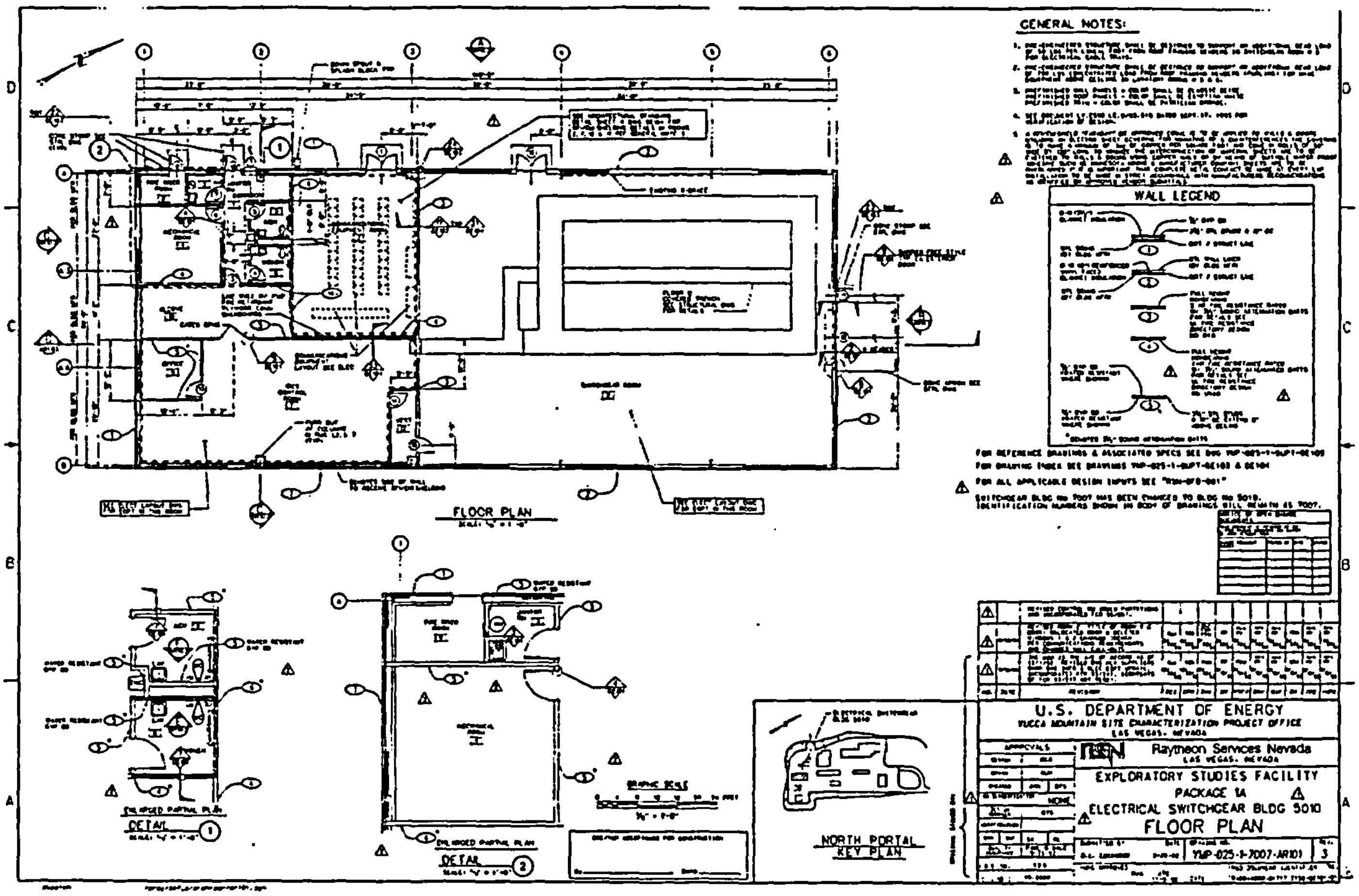


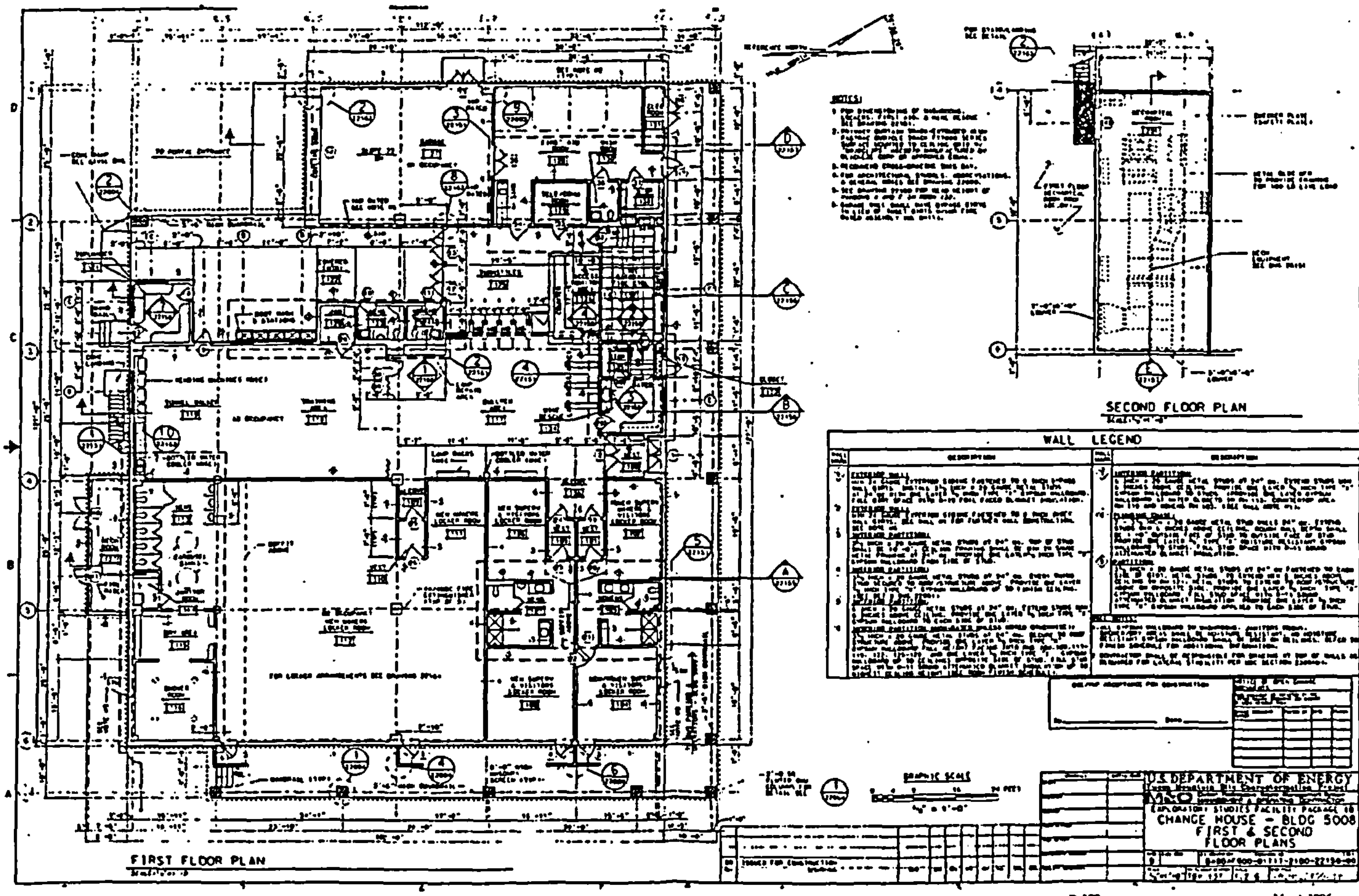
Figure 7.2.6-1. Transporter Maintenance Building (Floor Plan and Building Section)

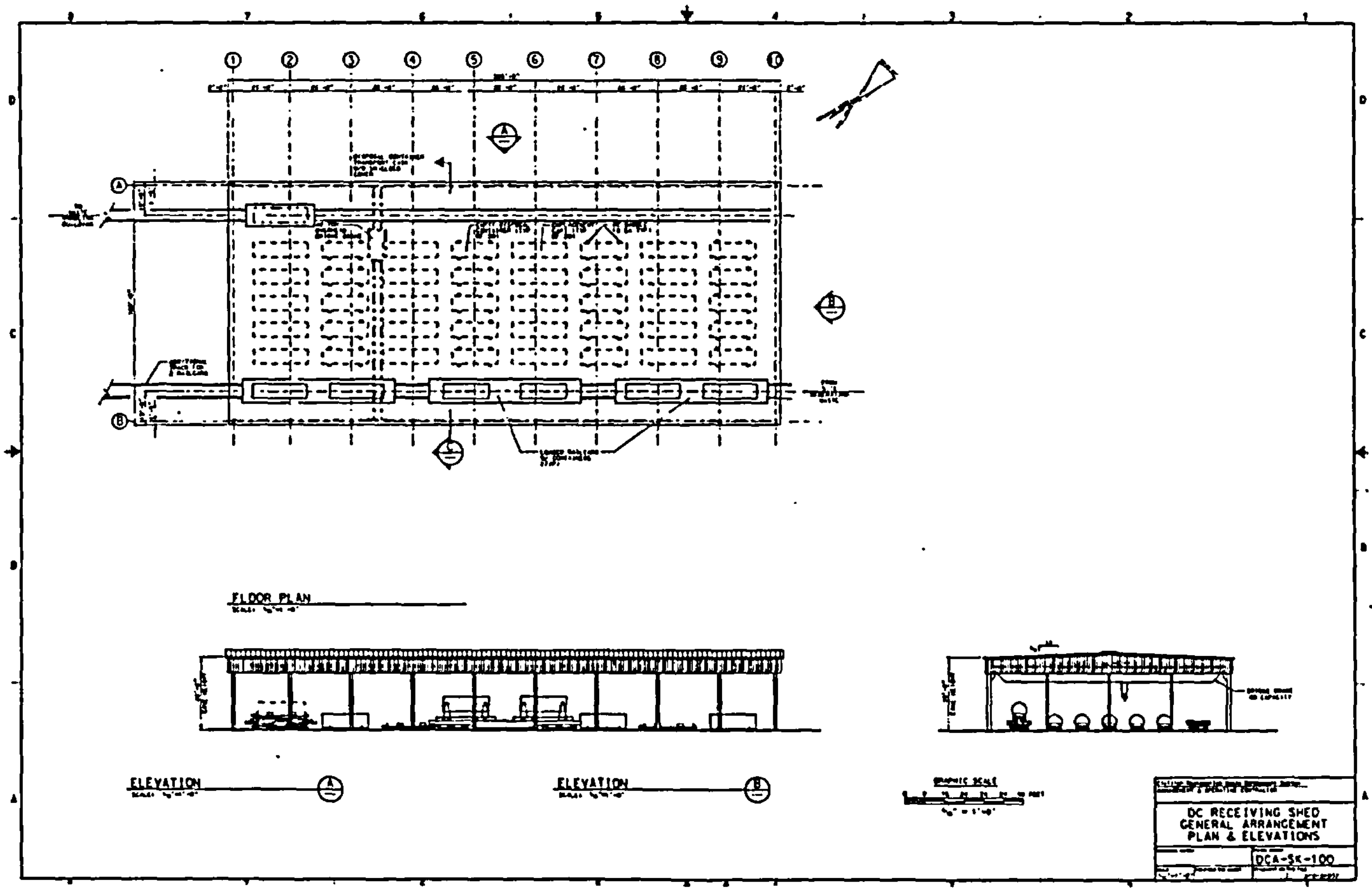

FIRST FLOOR PLAN
MEZZANINE FLOOR PLAN
TRANSPORTER MAINT BLDG
GENERAL ARRANGEMENT
FLOOR PLAN EL 100 & MEZZ
TMA-SK001


ELEVATION
ELEVATION
ELEVATION
ELEVATION
TRANSPORTER MAINT BLDG
GENERAL ARRANGEMENT
ELEVATIONS
TMA-SK002

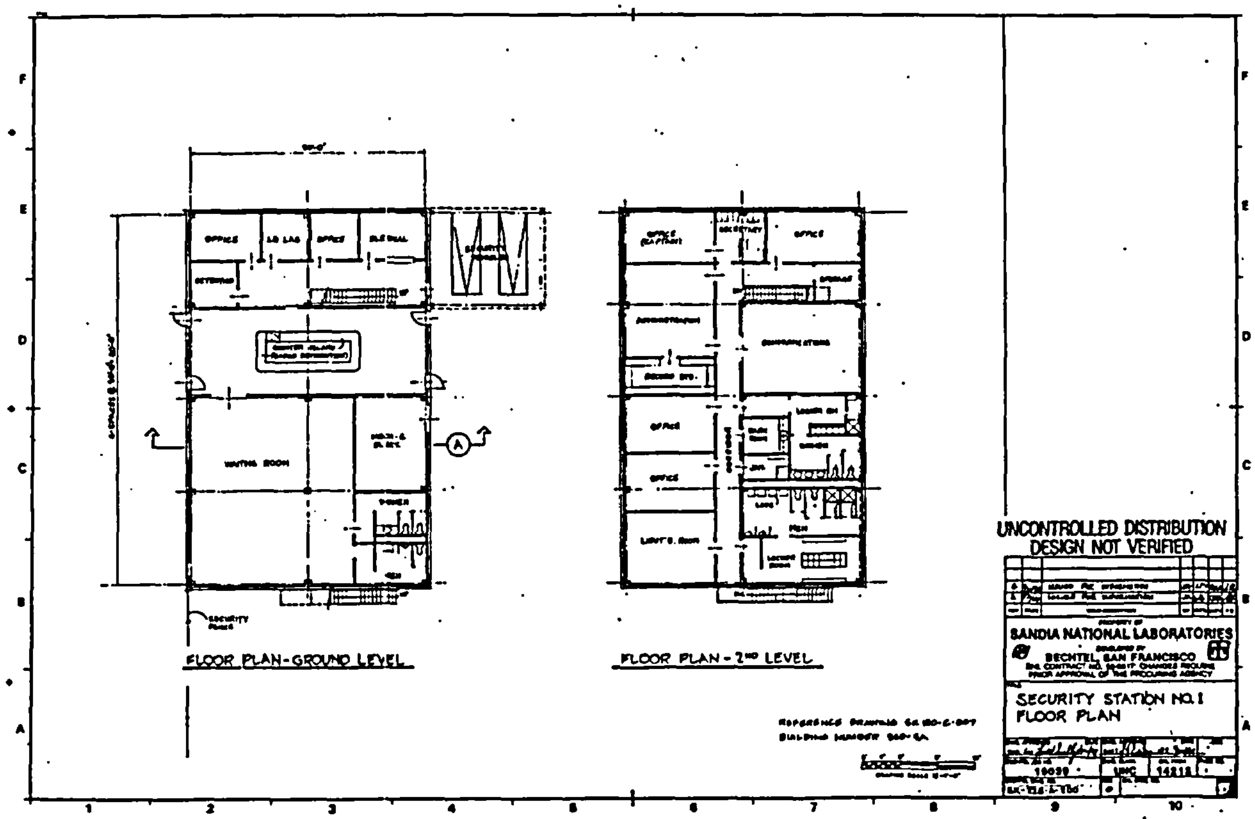

BUILDING SECTION
TRANSPORTER MAINT BLDG
GENERAL ARRANGEMENT
BUILDING SECTION
TMA-SK003

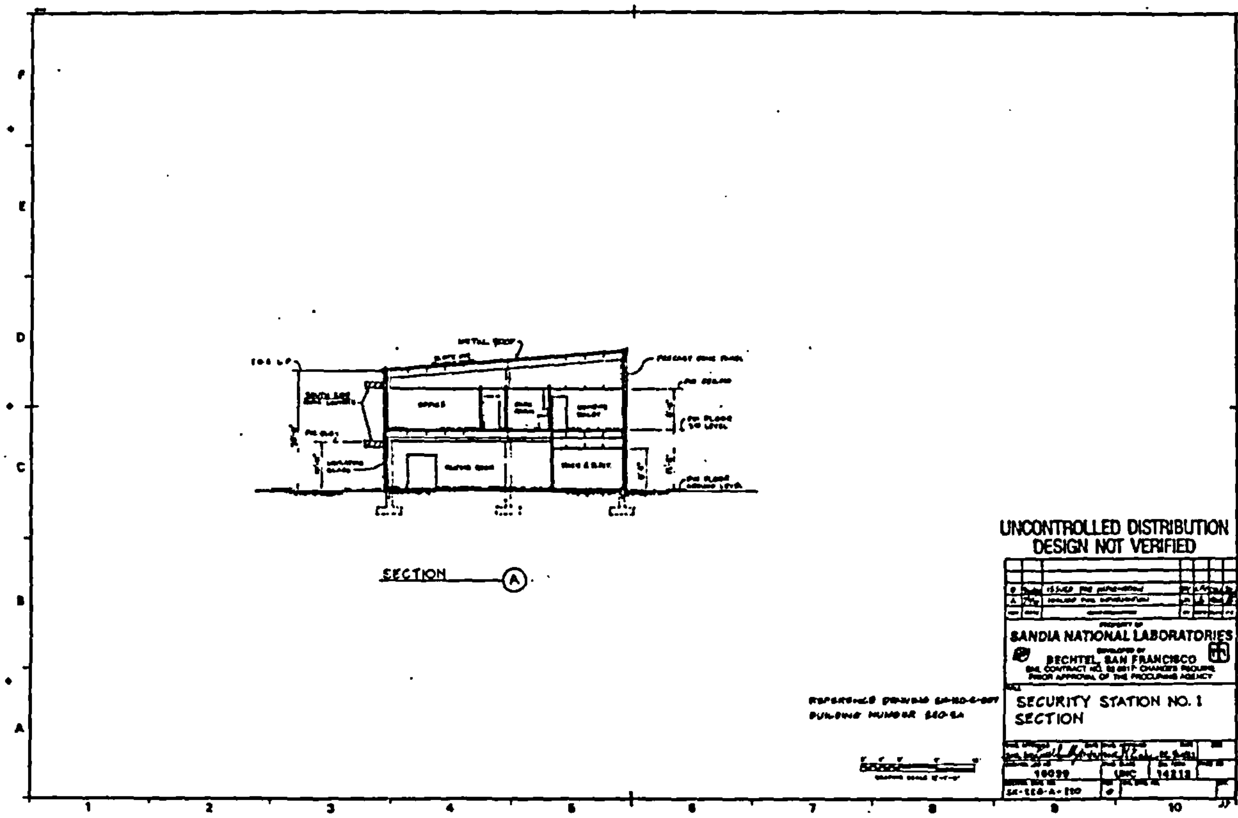

GENERAL NOTES:
WALL LEGEND
FLOOR PLAN
DETAIL 1
DETAIL 2
NORTH PORTAL KEY PLAN
U.S. DEPARTMENT OF ENERGY
YUCCA MOUNTAIN SITE CHARACTERIZATION PROJECT OFFICE
LAS VEGAS, NEVADA
Raytheon Services Nevada
LAS VEGAS, NEVADA
EXPLORATORY STUDIES FACILITY
PACKAGE 1A
ELECTRICAL SWITCHGEAR BLDG 5010
FLOOR PLAN
YMP-025-1-7007-AR101
3


NOTES:
WALL LEGEND
SECOND FLOOR PLAN
FIRST FLOOR PLAN
GRAPHIC SCALE
U.S. DEPARTMENT OF ENERGY
CHANGE HOUSE - BLDG 5008
FIRST & SECOND
FLOOR PLANS

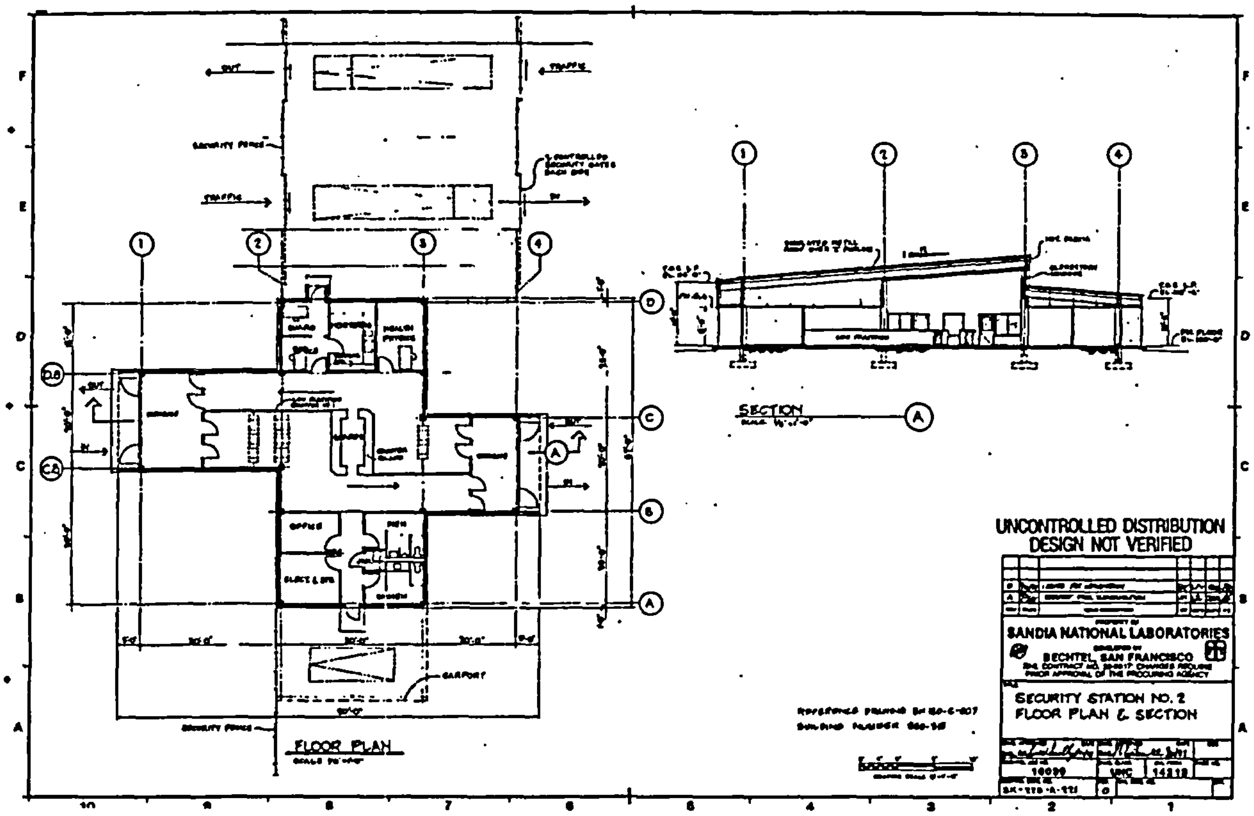


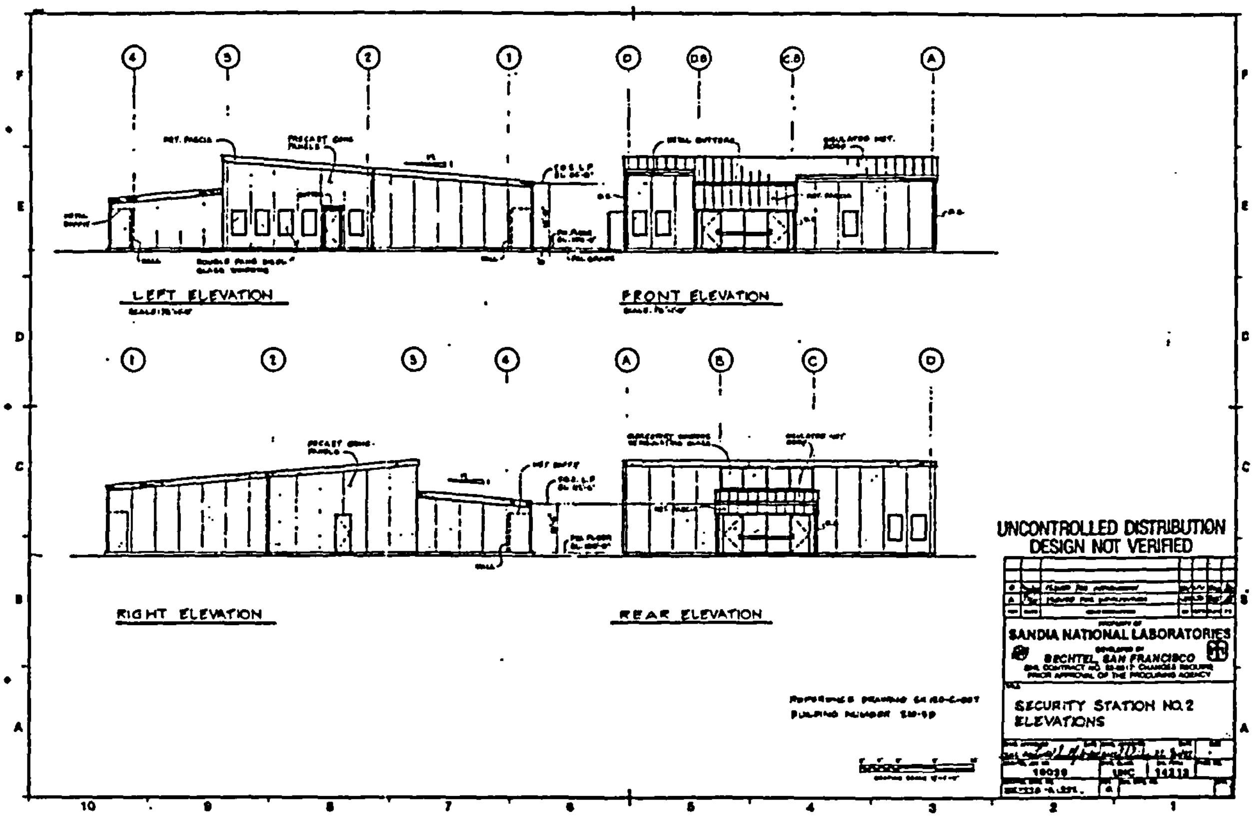
FLOOR PLAN
ELEVATION A
ELEVATION B
GRAPHIC SCALE
DC RECEIVING SHED
GENERAL ARRANGEMENT
PLAN & ELEVATIONS
DCA-SK-100

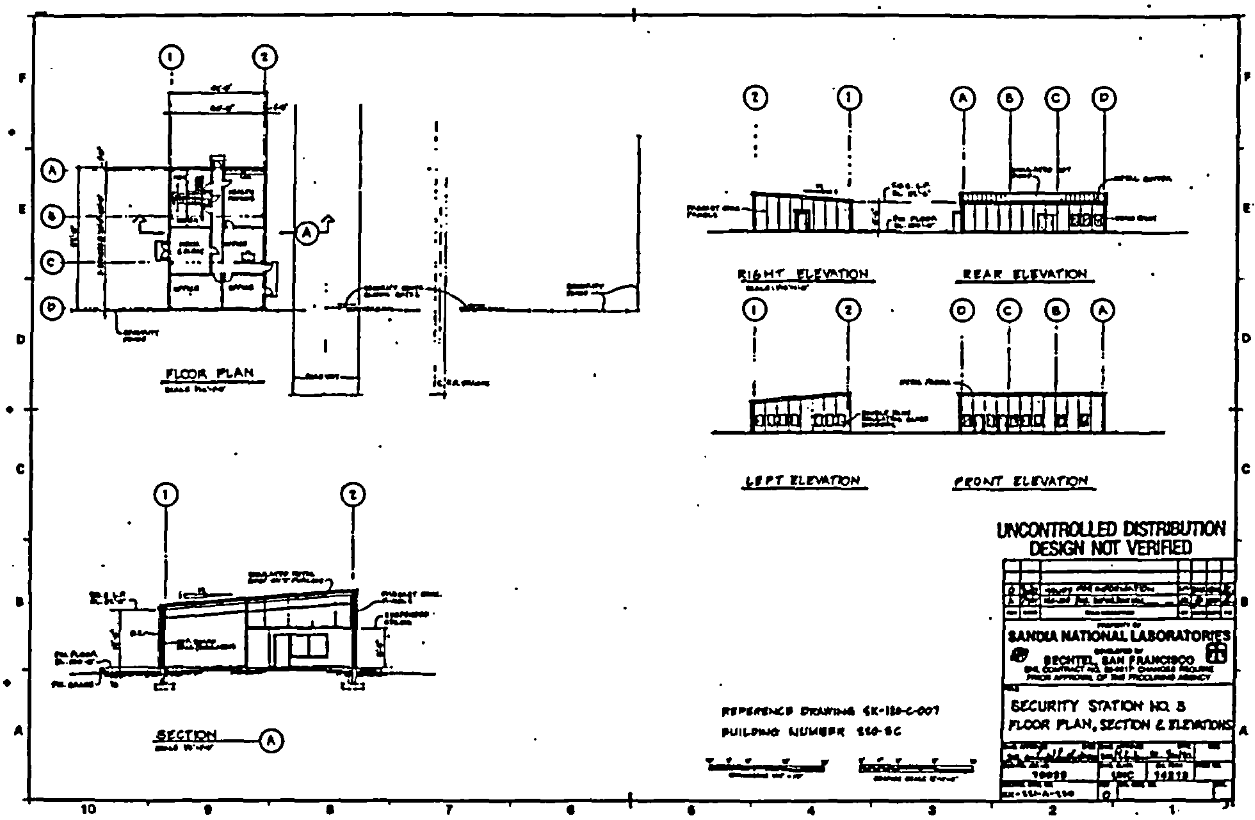

FLOOR PLAN-GROUND LEVEL
FLOOR PLAN - 2ND LEVEL
WAITING ROOM
OFFICE
UNCONTROLLED DISTRIBUTION
DESIGN NOT VERIFIED
SANDIA NATIONAL LABORATORIES
BECHTEL SAN FRANCISCO
SECURITY STATION NO. 1
FLOOR PLAN

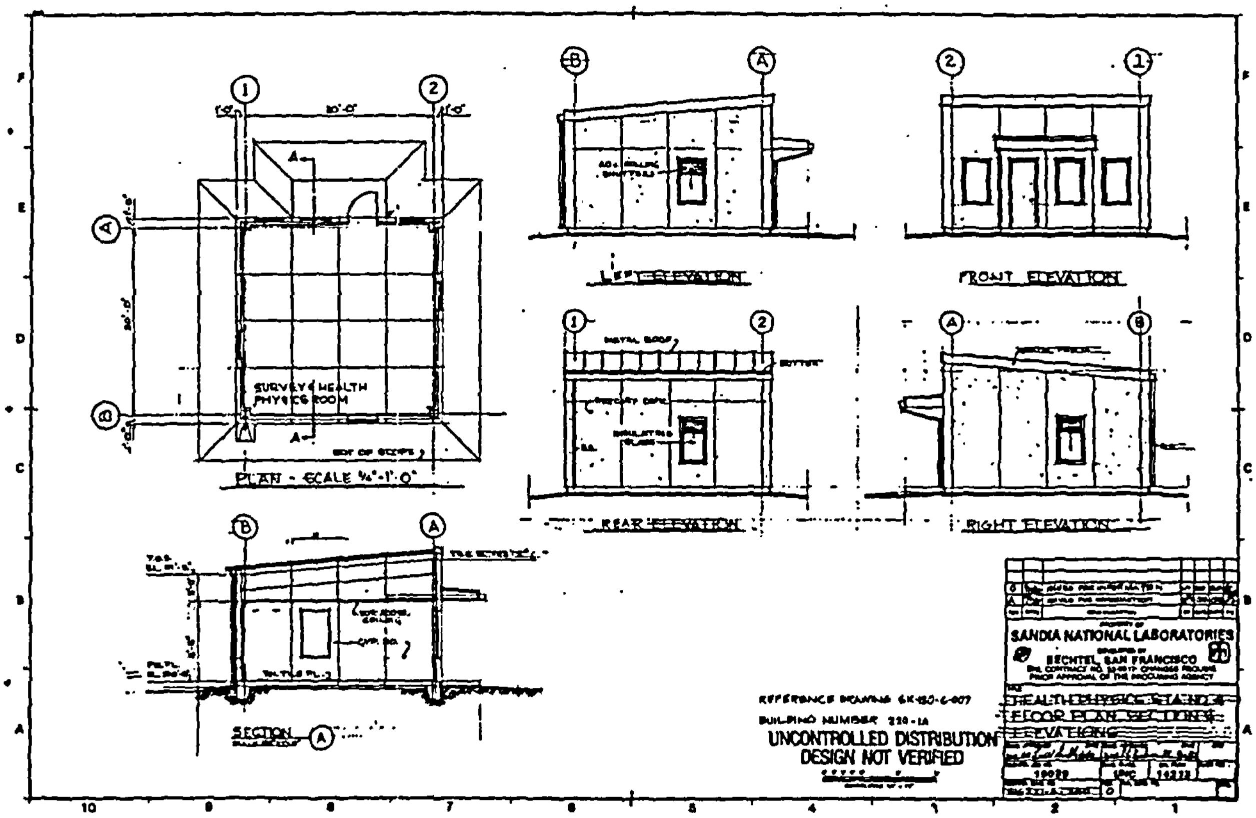


METAL ROOF
SECTION (A)
UNCONTROLLED DISTRIBUTION
DESIGN NOT VERIFIED
SANDIA NATIONAL LABORATORIES
BECHTEL, SAN FRANCISCO
SECURITY STATION NO. 1
SECTION
10099
UNC
14213

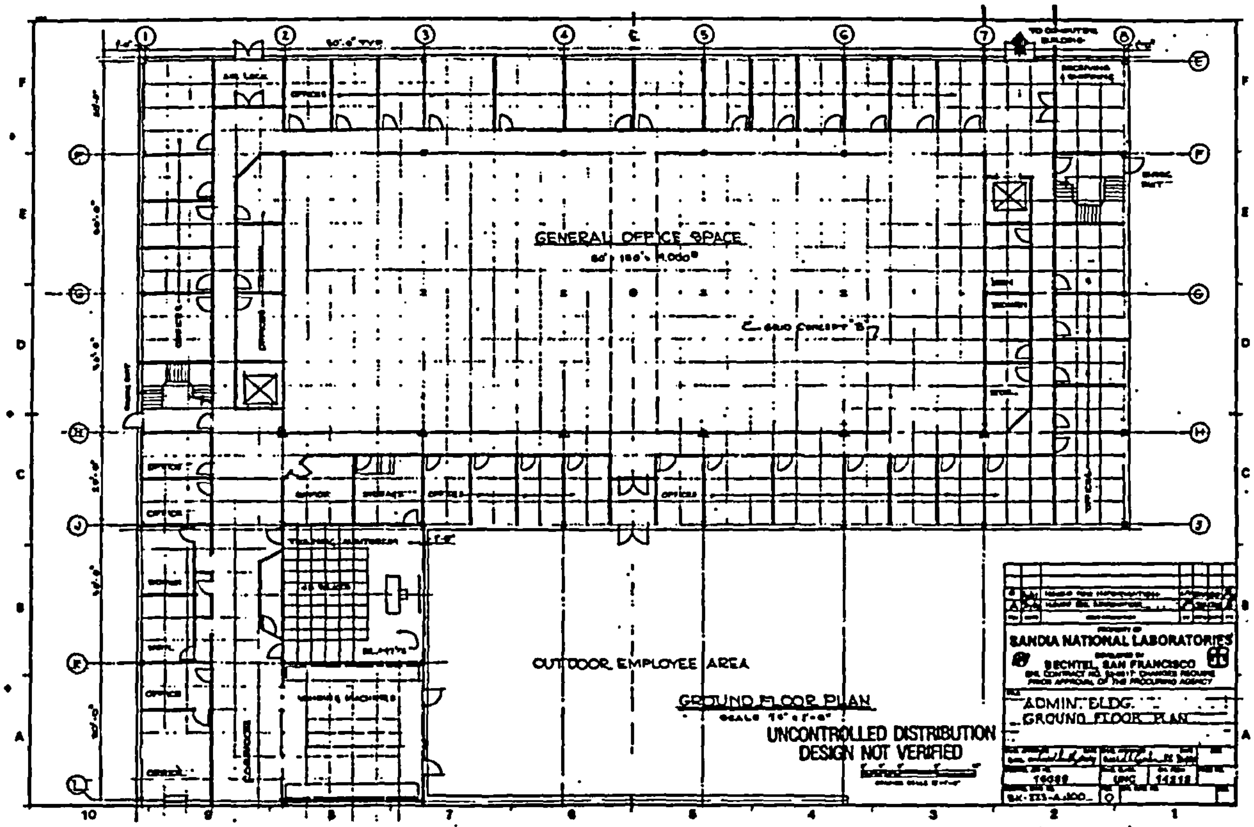

FLOOR PLAN
SECTION
UNCONTROLLED DISTRIBUTION
DESIGN NOT VERIFIED
SANDIA NATIONAL LABORATORIES
BECHTEL, SAN FRANCISCO
SECURITY STATION NO. 2
FLOOR PLAN & SECTION

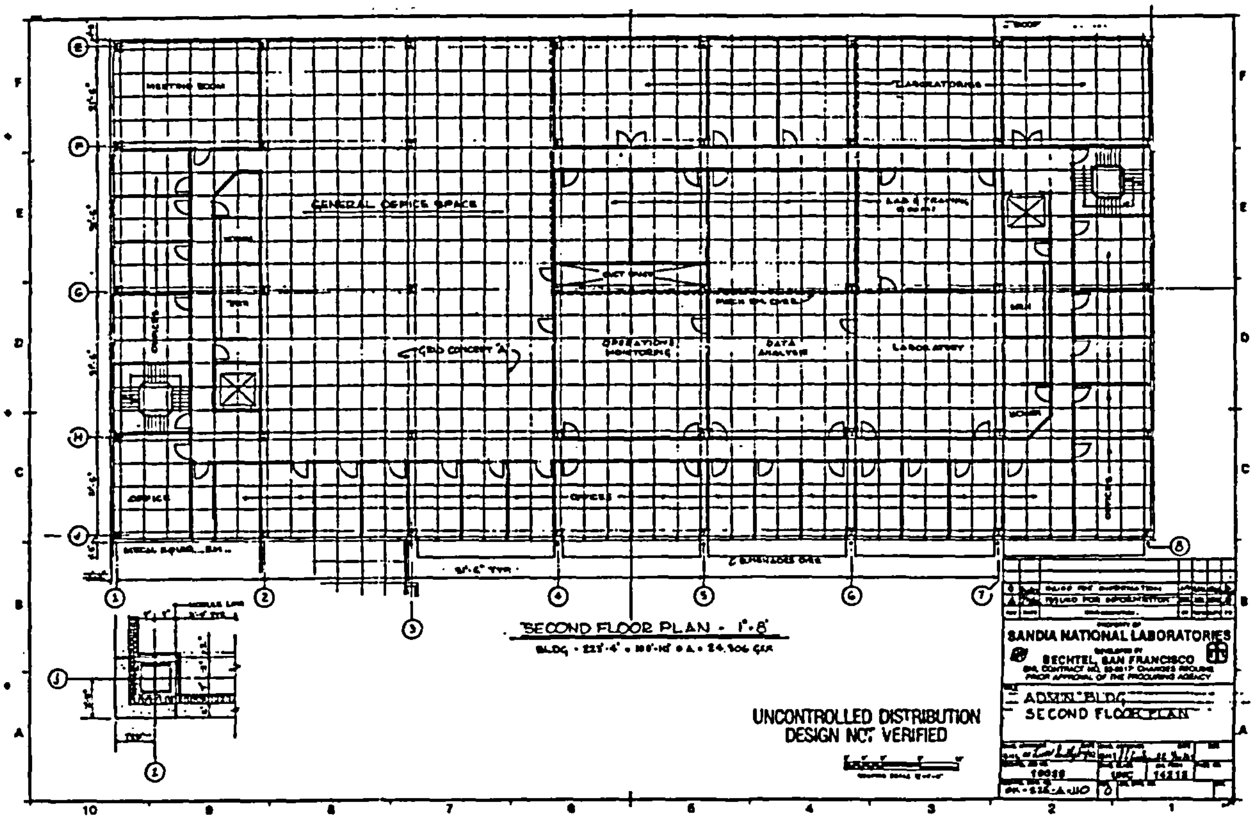

LEFT ELEVATION
FRONT ELEVATION
RIGHT ELEVATION
REAR ELEVATION
UNCONTROLLED DISTRIBUTION
DESIGN NOT VERIFIED
SANDIA NATIONAL LABORATORIES
BECHTEL, SAN FRANCISCO
SECURITY STATION NO. 2
ELEVATIONS

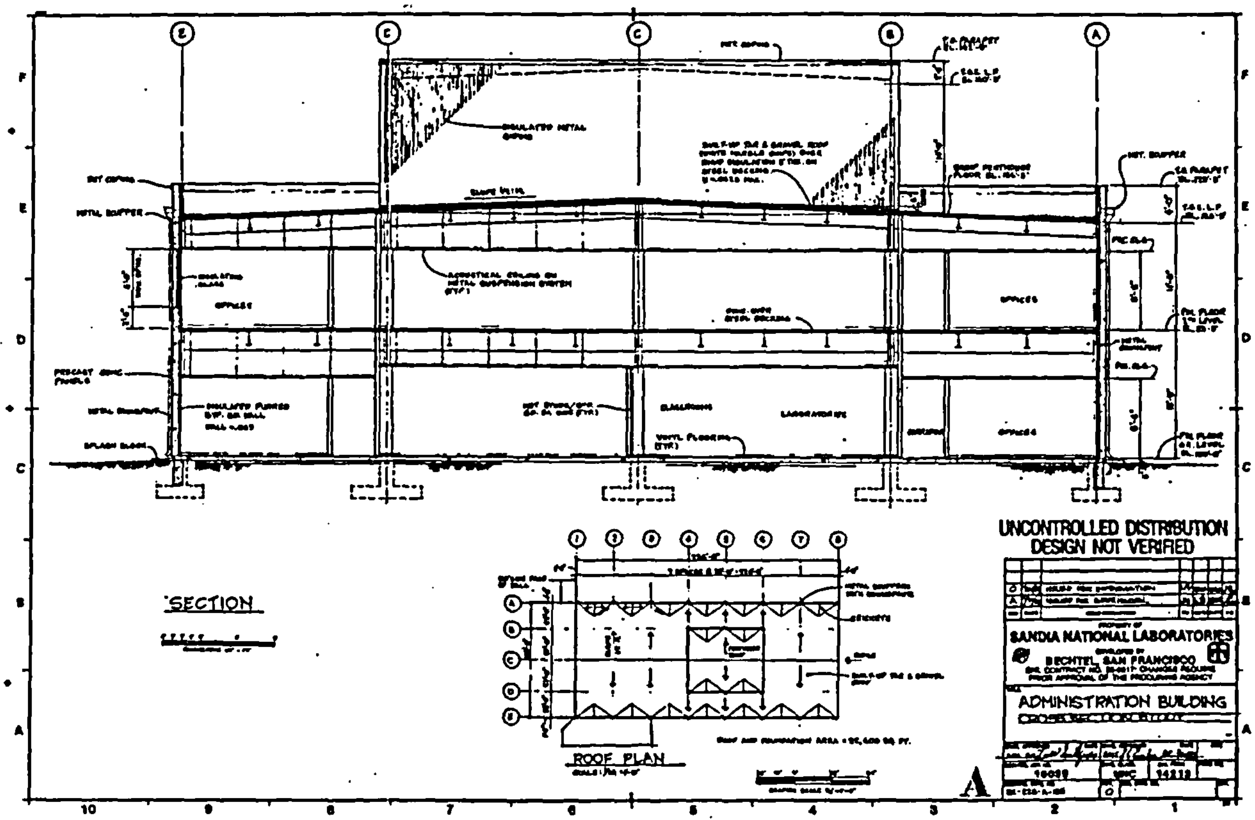

FLOOR PLAN
SECTION
RIGHT ELEVATION
REAR ELEVATION
LEFT ELEVATION
FRONT ELEVATION
UNCONTROLLED DISTRIBUTION
DESIGN NOT VERIFIED
SANDIA NATIONAL LABORATORIES
BECHTEL, SAN FRANCISCO
SECURITY STATION NO. 3
FLOOR PLAN, SECTION & ELEVATIONS

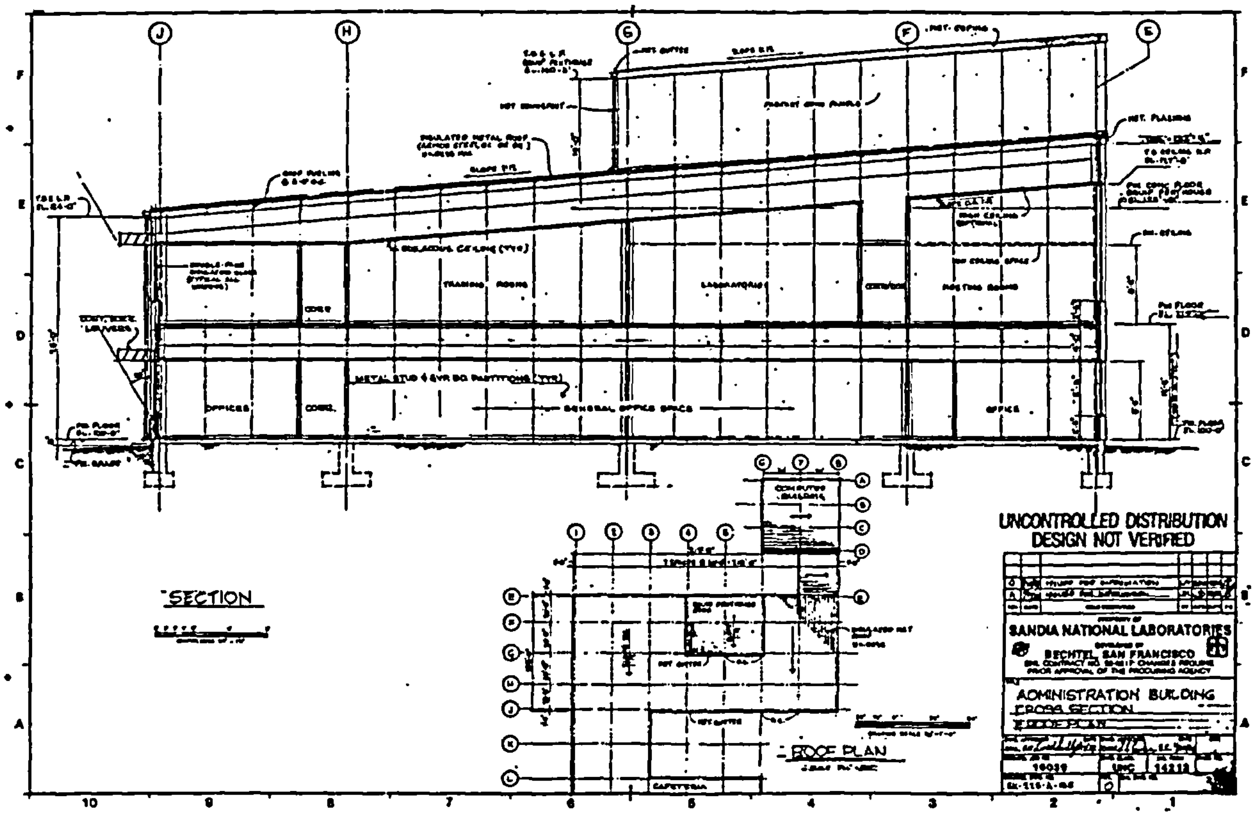


SURVEY & HEALTH PHYSICS ROOM
PLAN - SCALE 1/4"-1'-0"
LEFT ELEVATION
FRONT ELEVATION
METAL ROOF
REAR ELEVATION
RIGHT ELEVATION
SECTION A
SANDIA NATIONAL LABORATORIES
BECHTEL, SAN FRANCISCO
UNCONTROLLED DISTRIBUTION
DESIGN NOT VERIFIED

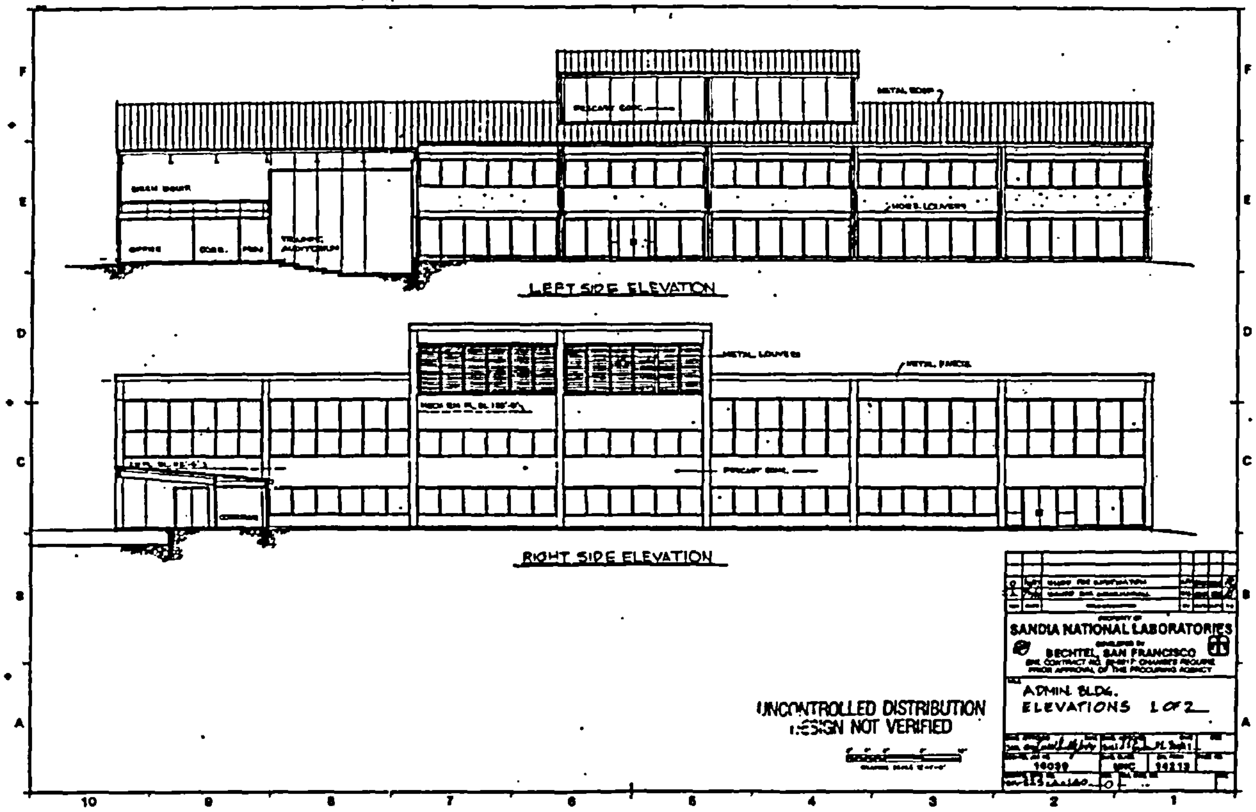

GENERAL OFFICE SPACE
OUTDOOR EMPLOYEE AREA
GROUND FLOOR PLAN
UNCONTROLLED DISTRIBUTION
DESIGN NOT VERIFIED
SANDIA NATIONAL LABORATORIES
BECHTEL, SAN FRANCISCO
ADMIN. BLDG.
GROUND FLOOR PLAN


MEETING ROOM
LABORATORIES
GENERAL OFFICE SPACE
OFFICES
OPERATIONS MONITORING
DATA ANALYSIS
LABORATORY
SECOND FLOOR PLAN - 1"=8'
SANDIA NATIONAL LABORATORIES
BECHTEL SAN FRANCISCO
ADMIN BLDG
SECOND FLOOR PLAN
UNCONTROLLED DISTRIBUTION
DESIGN NOT VERIFIED

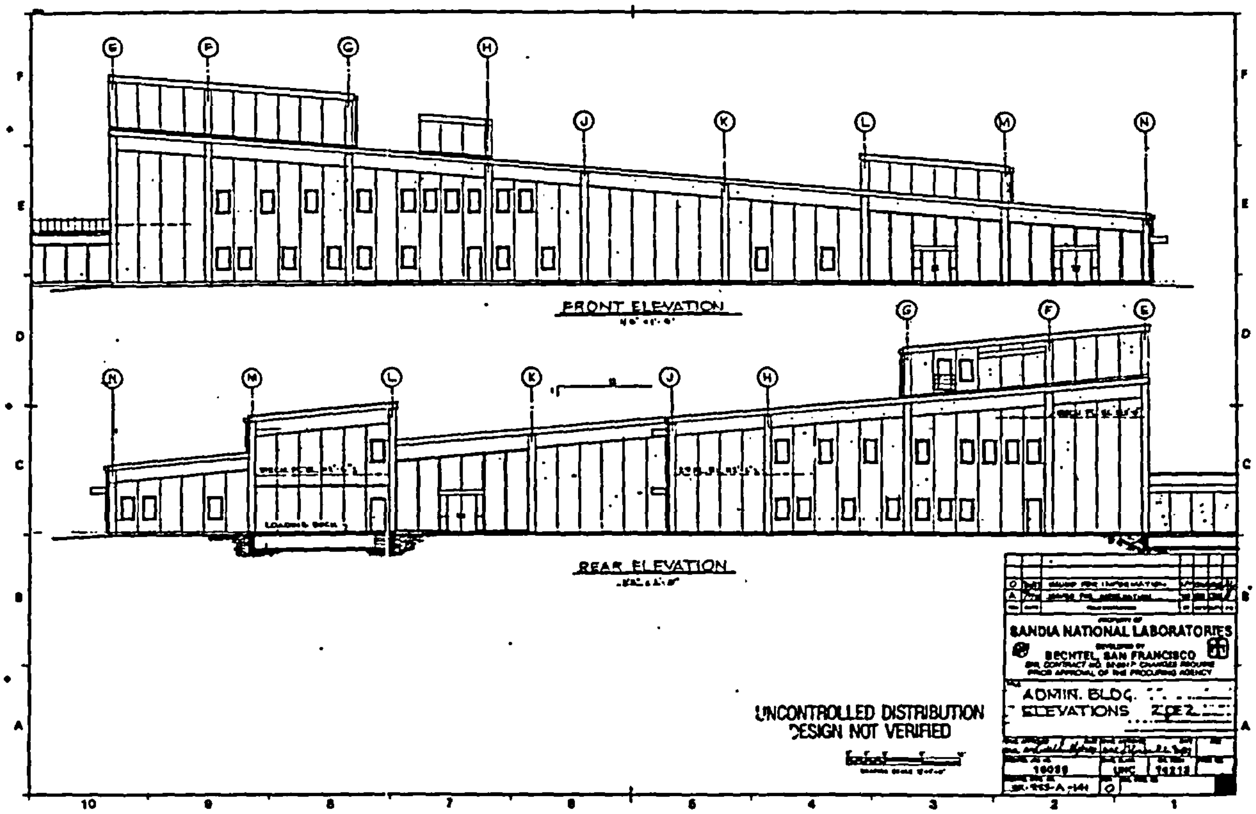

SECTION
ROOF PLAN
UNCONTROLLED DISTRIBUTION
DESIGN NOT VERIFIED
SANDIA NATIONAL LABORATORIES
BECHTEL, SAN FRANCISCO
ADMINISTRATION BUILDING

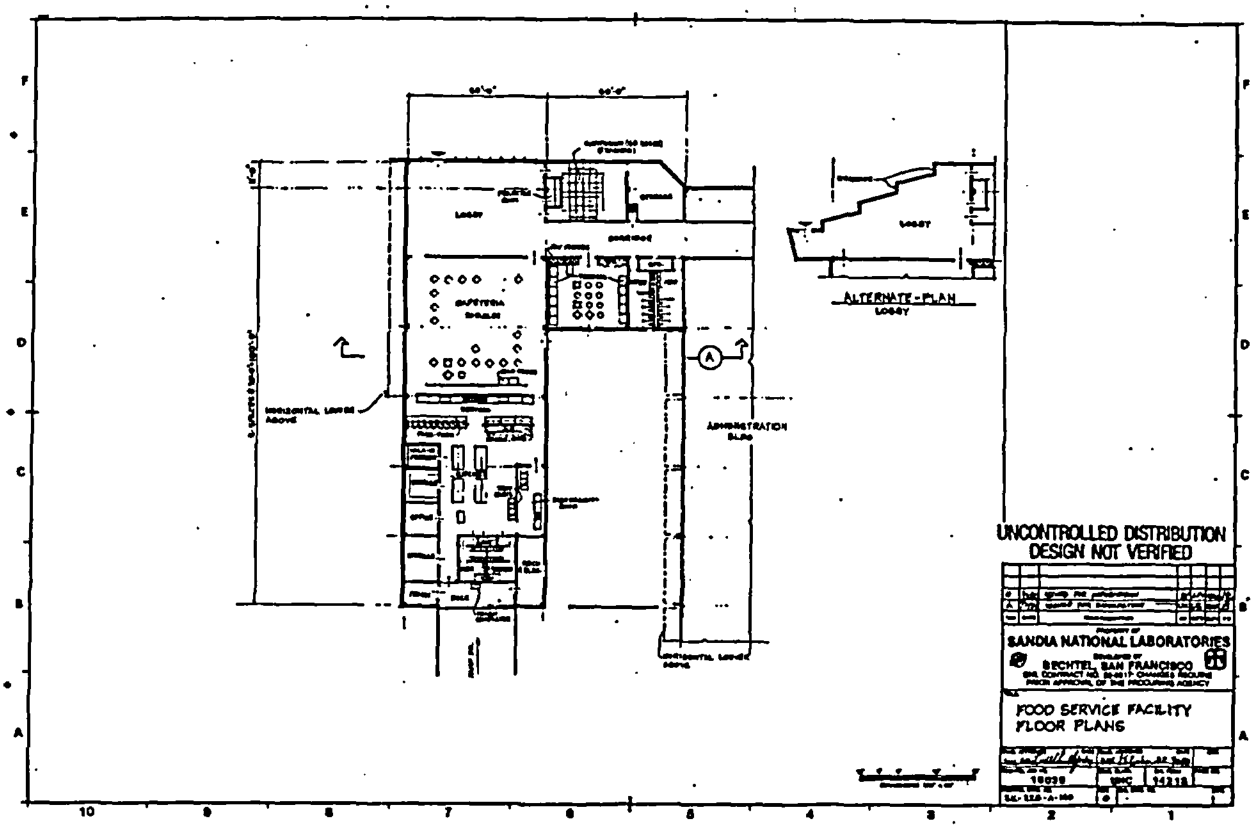


SECTION
ROOF PLAN
OFFICES
CORE
GENERAL OFFICE SPACE
OFFICE
TRAINING ROOMS
LABORATORIES
CORRIDOR
MEETING ROOMS
METAL STUD & GYP BD PARTITIONS (TYP)
UNCONTROLLED DISTRIBUTION
DESIGN NOT VERIFIED
SANDIA NATIONAL LABORATORIES
BECHTEL SAN FRANCISCO
ADMINISTRATION BUILDING
CROSS SECTION
& ROOF PLAN

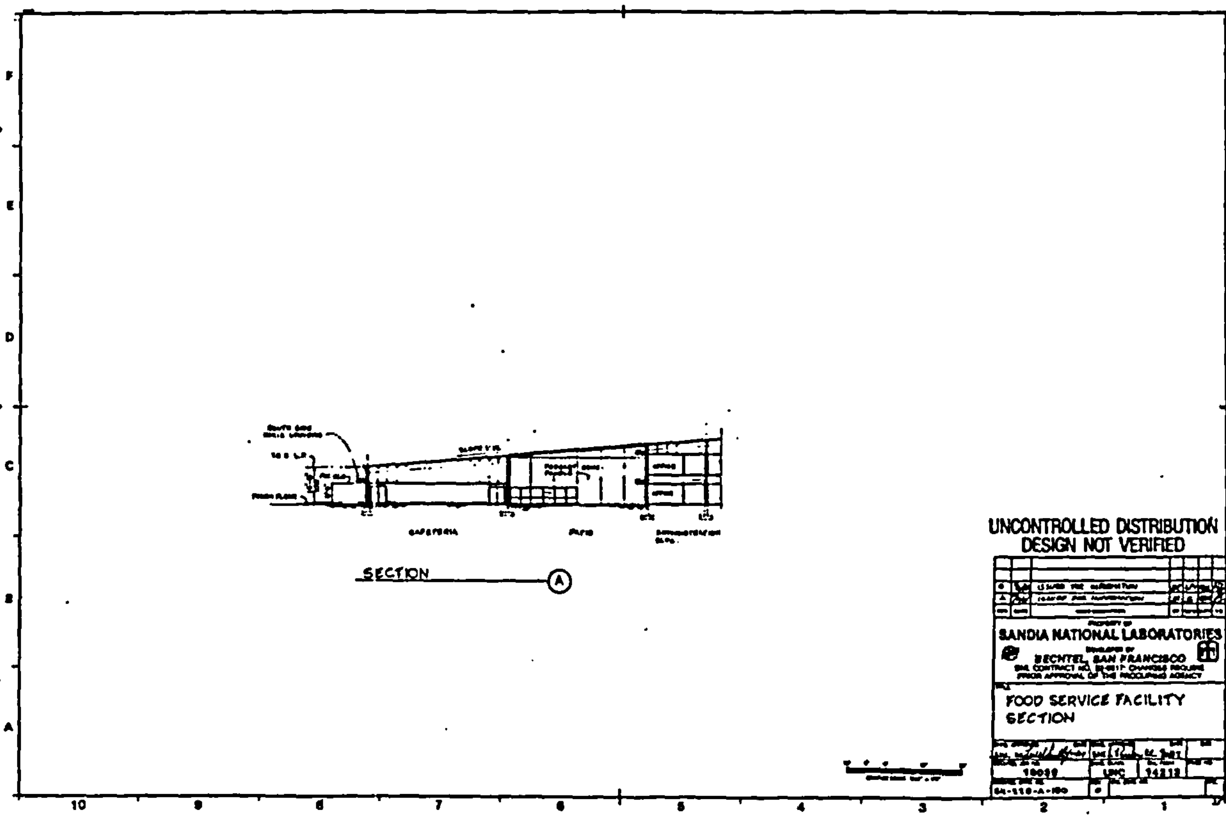


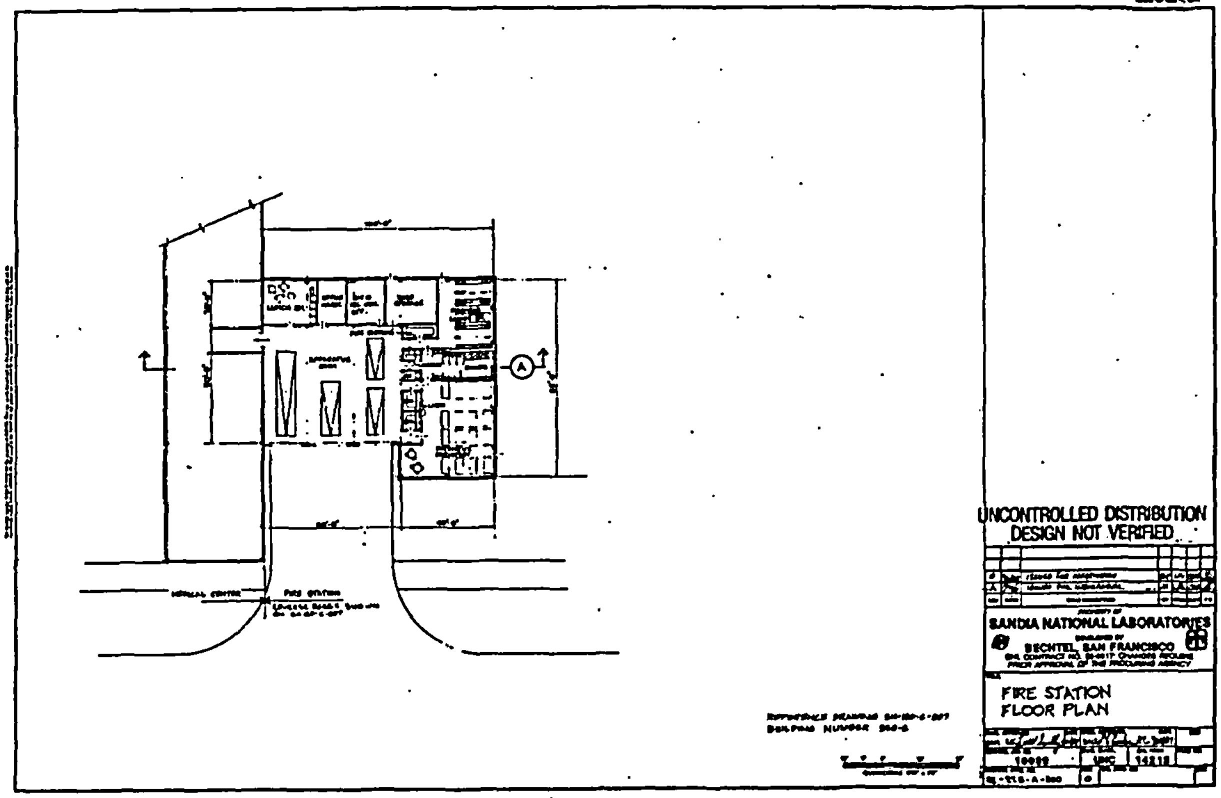
LEFT SIDE ELEVATION
RIGHT SIDE ELEVATION
SANDIA NATIONAL LABORATORIES
BECHTEL, SAN FRANCISCO
ADMIN. BLDG.
ELEVATIONS 1 OF 2
UNCONTROLLED DISTRIBUTION
DESIGN NOT VERIFIED

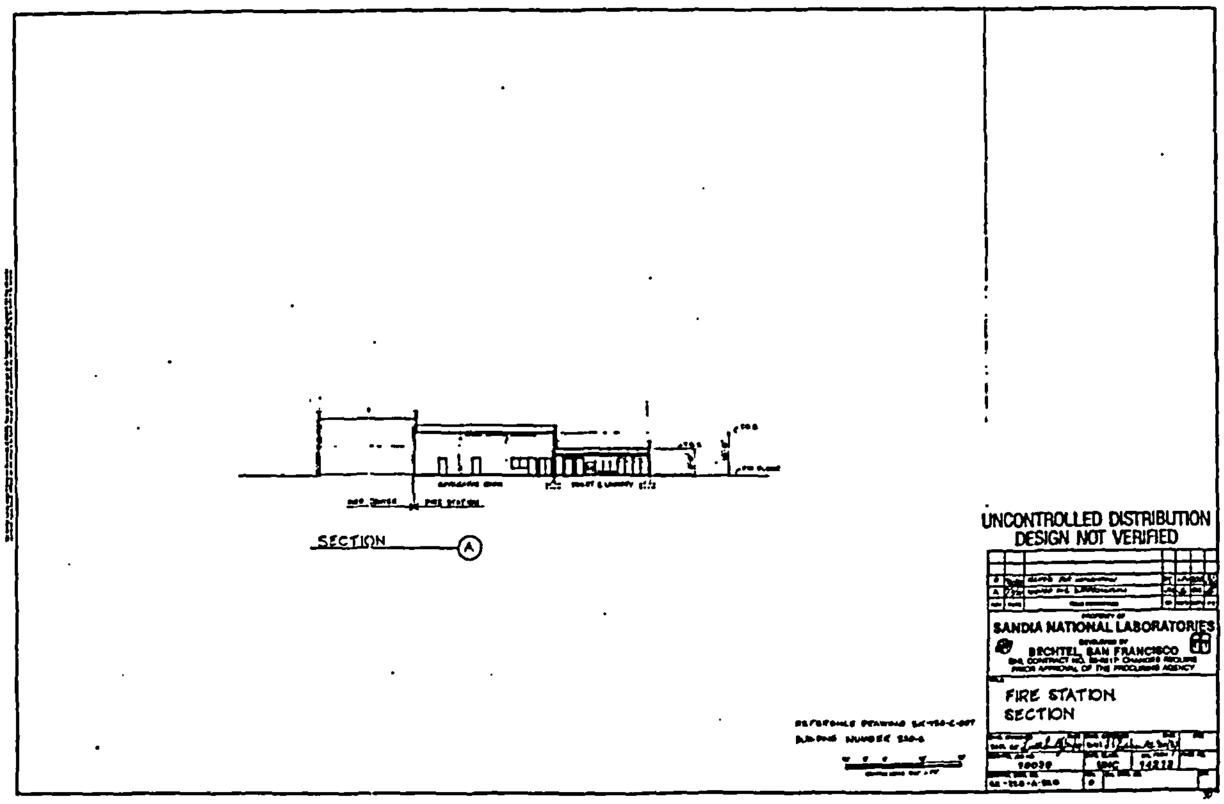

FRONT ELEVATION
REAR ELEVATION
LOADING DOCK
SANDIA NATIONAL LABORATORIES
BECHTEL, SAN FRANCISCO
ADMIN. BLDG.
ELEVATIONS 2 OF 2
UNCONTROLLED DISTRIBUTION
DESIGN NOT VERIFIED



ALTERNATE-PLAN
ADMINISTRATION BLDG
UNCONTROLLED DISTRIBUTION
DESIGN NOT VERIFIED
SANDIA NATIONAL LABORATORIES
BECHTEL, SAN FRANCISCO
FOOD SERVICE FACILITY
FLOOR PLANS


SECTION
A
CAFETERIA
UNCONTROLLED DISTRIBUTION
DESIGN NOT VERIFIED
SANDIA NATIONAL LABORATORIES
BECHTEL, SAN FRANCISCO
FOOD SERVICE FACILITY
SECTION


UNCONTROLLED DISTRIBUTION
DESIGN NOT VERIFIED
SANDIA NATIONAL LABORATORIES
BECHTEL, SAN FRANCISCO
FIRE STATION
FLOOR PLAN



SECTION (A)
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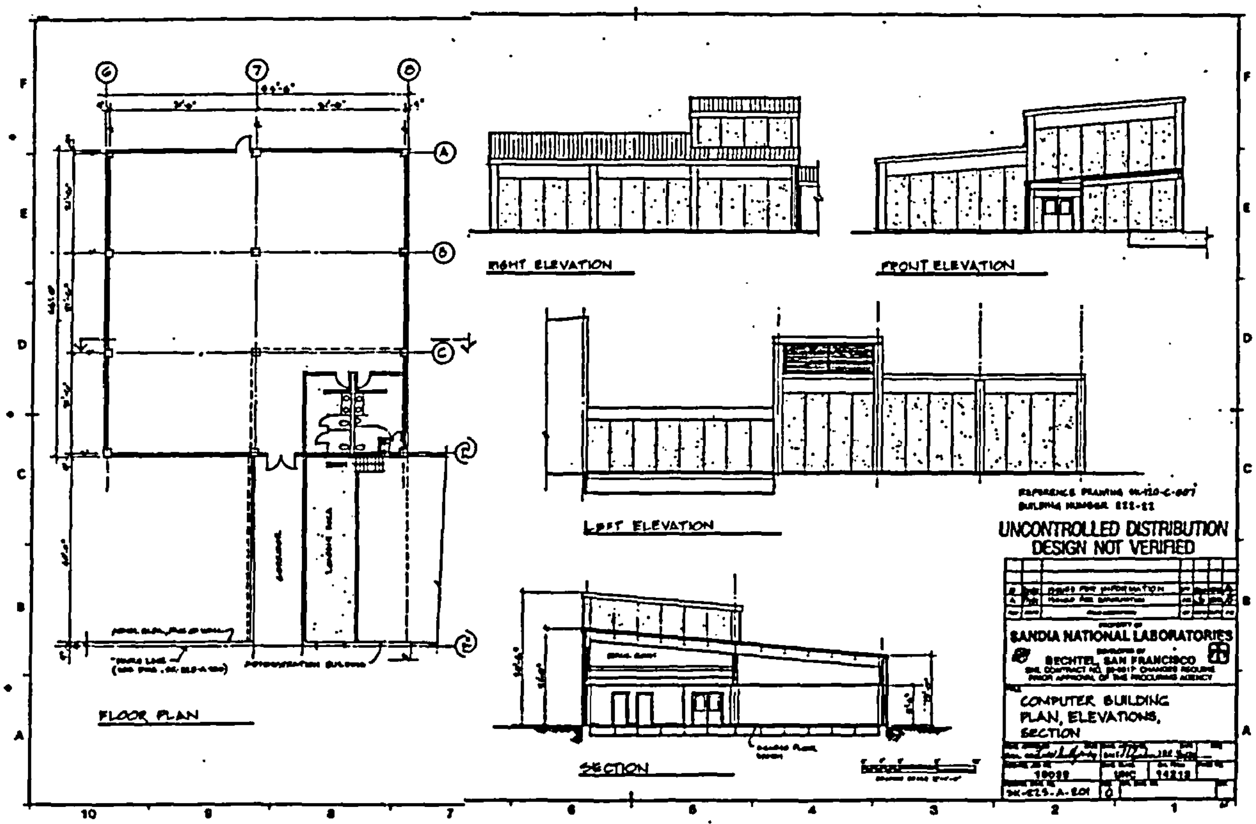
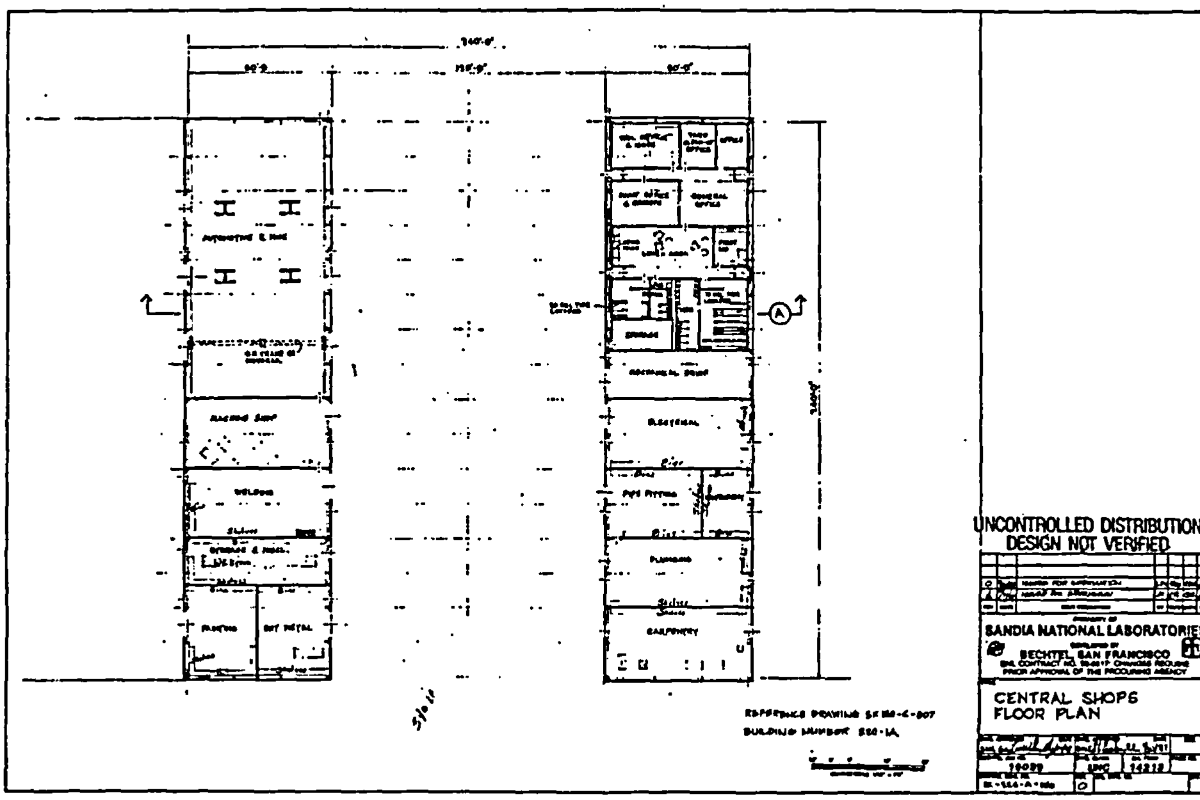
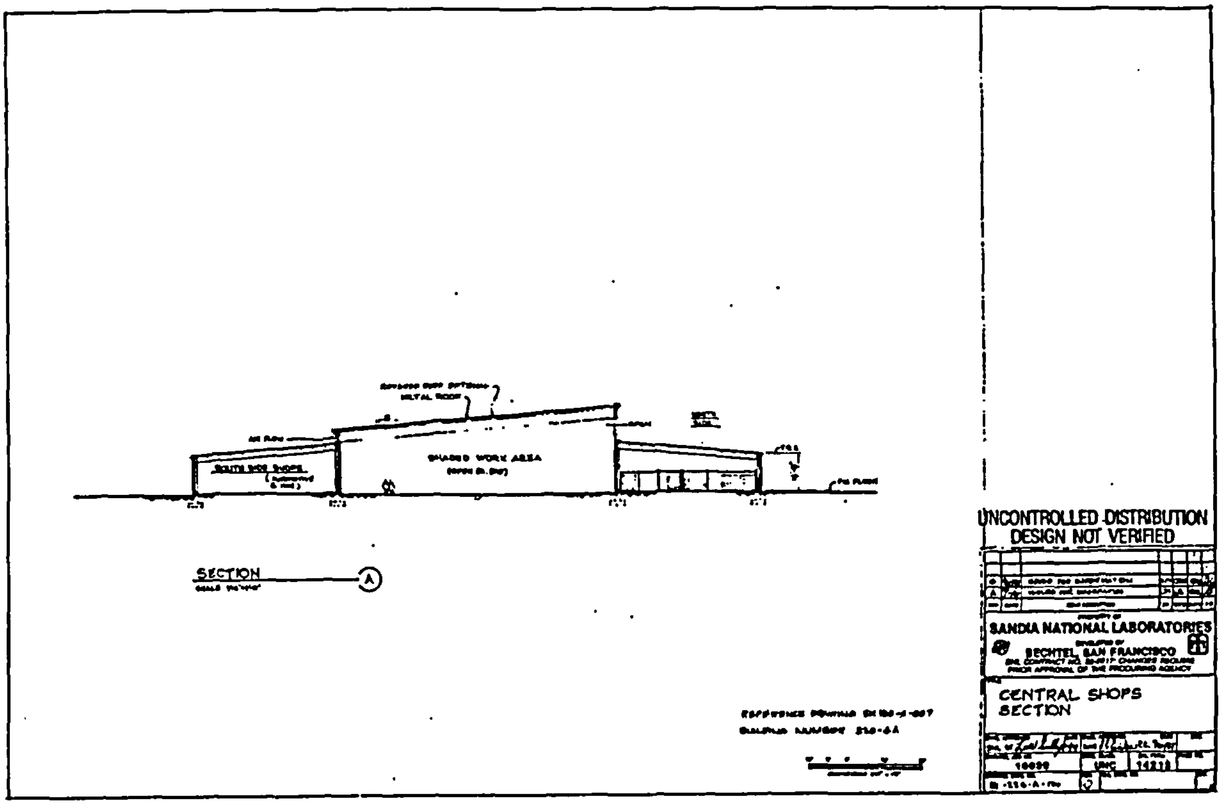
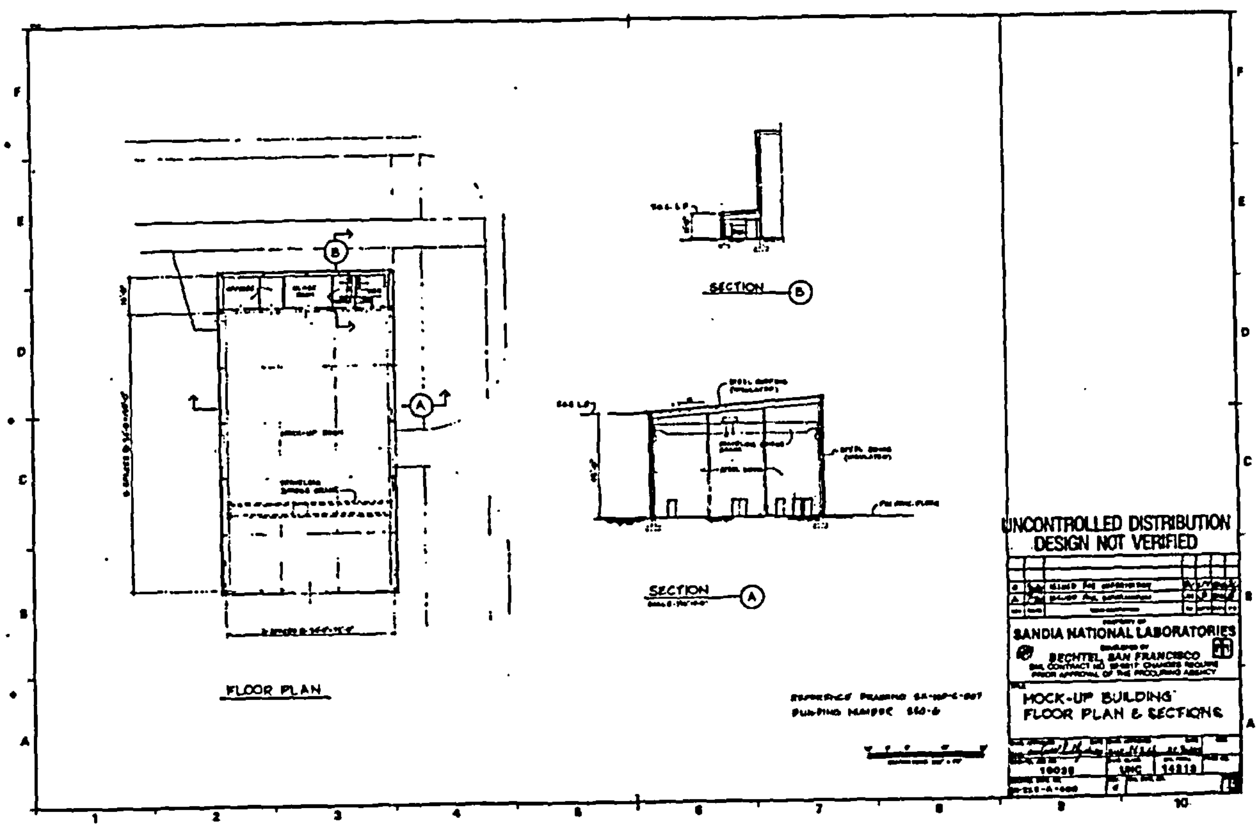
DESIGN NOT VERIFIED
SANDIA NATIONAL LABORATORIES
BECHTEL SAN FRANCISCO
FIRE STATION
SECTION

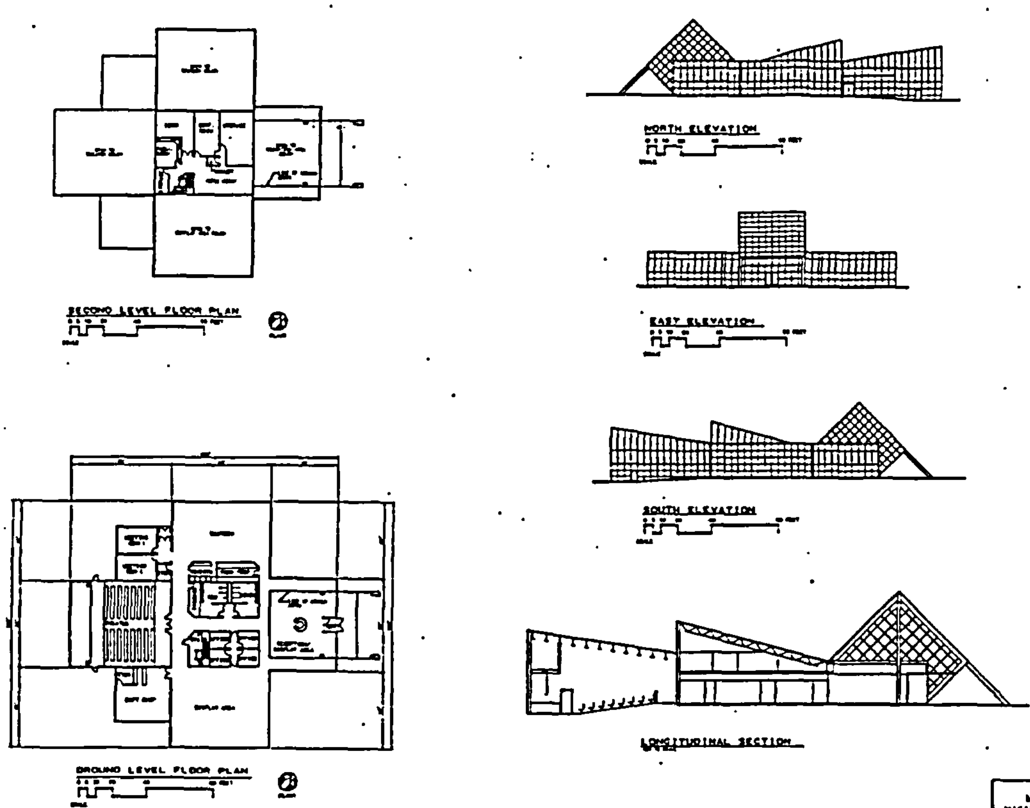

FLOOR PLAN
RIGHT ELEVATION
FRONT ELEVATION
LEFT ELEVATION
SECTION
UNCONTROLLED DISTRIBUTION
DESIGN NOT VERIFIED
SANDIA NATIONAL LABORATORIES
BECHTEL SAN FRANCISCO
COMPUTER BUILDING
PLAN, ELEVATIONS,
SECTION


UNCONTROLLED DISTRIBUTION
DESIGN NOT VERIFIED
SANDIA NATIONAL LABORATORIES
BECHTEL, SAN FRANCISCO
CENTRAL SHOPS
FLOOR PLAN


SECTION
UNCONTROLLED DISTRIBUTION
DESIGN NOT VERIFIED
SANDIA NATIONAL LABORATORIES
BECHTEL, SAN FRANCISCO
CENTRAL SHOPS
SECTION



SECTION B
SECTION A
FLOOR PLAN
UNCONTROLLED DISTRIBUTION
DESIGN NOT VERIFIED
SANDIA NATIONAL LABORATORIES
BECHTEL, SAN FRANCISCO
MOCK-UP BUILDING
FLOOR PLAN & SECTIONS



Volume II. C

MRS/MPC FACILITY
VISITORS & MEDIA CENTER
GENERAL ARRANGEMENT
PLANS, SECTION & ELEV.

FIGURE: 4.2.2.21-G1

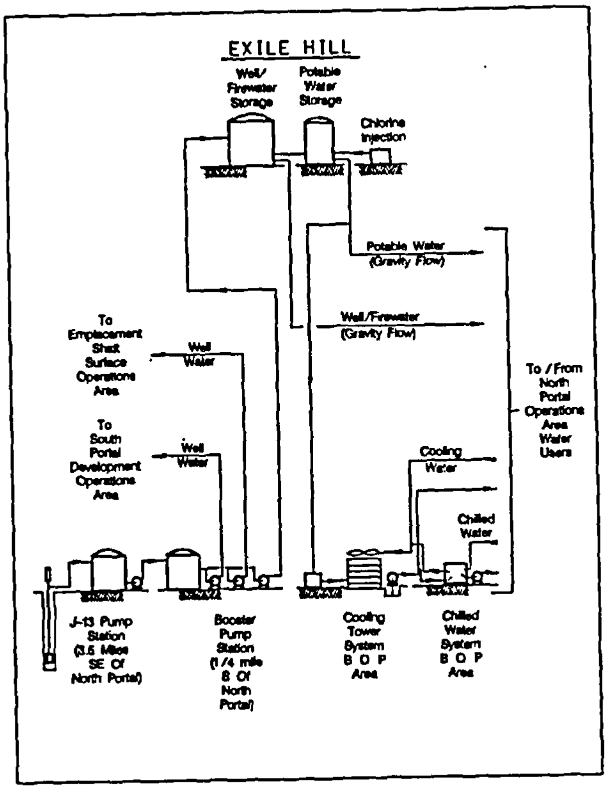


Figure 7.2.8-1. North Portal Water Systems

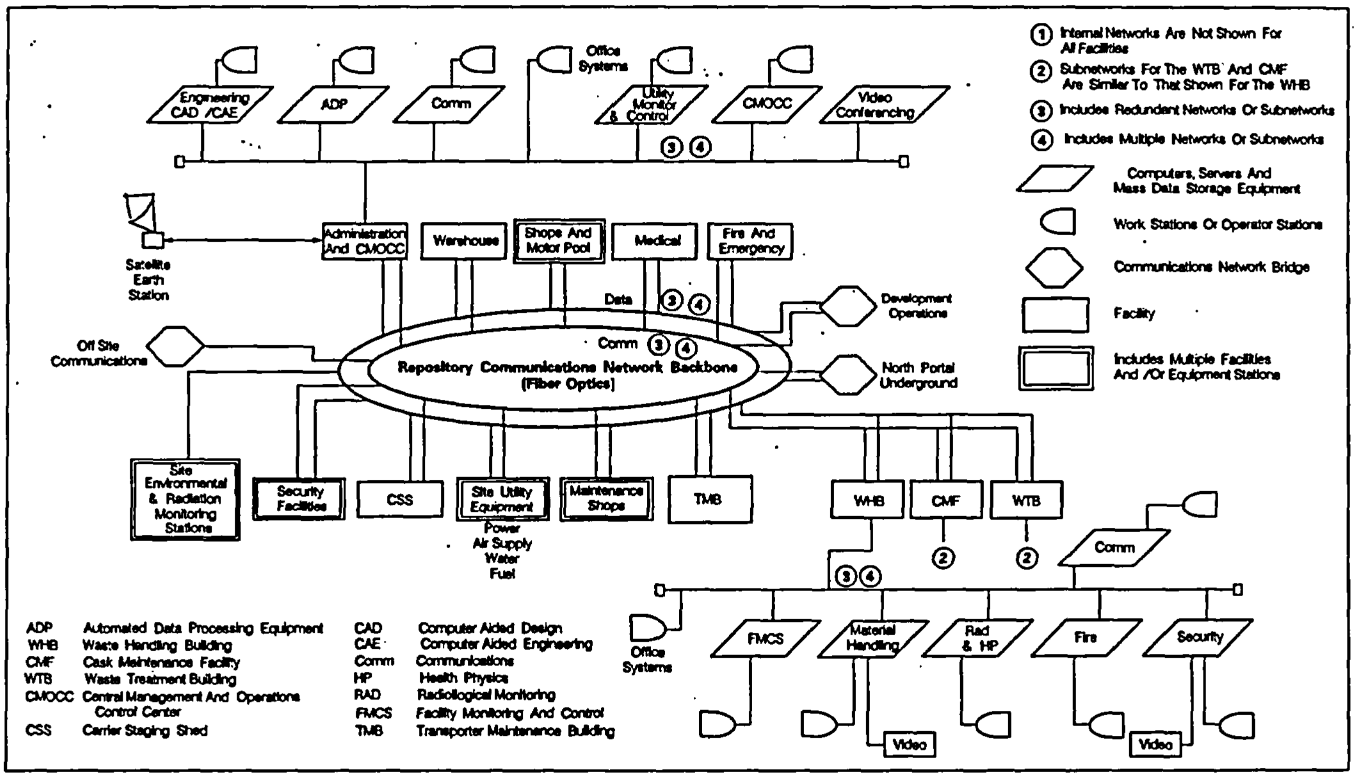


Figure 7.2.6-2. North Portal Communications Monitoring And Controls System

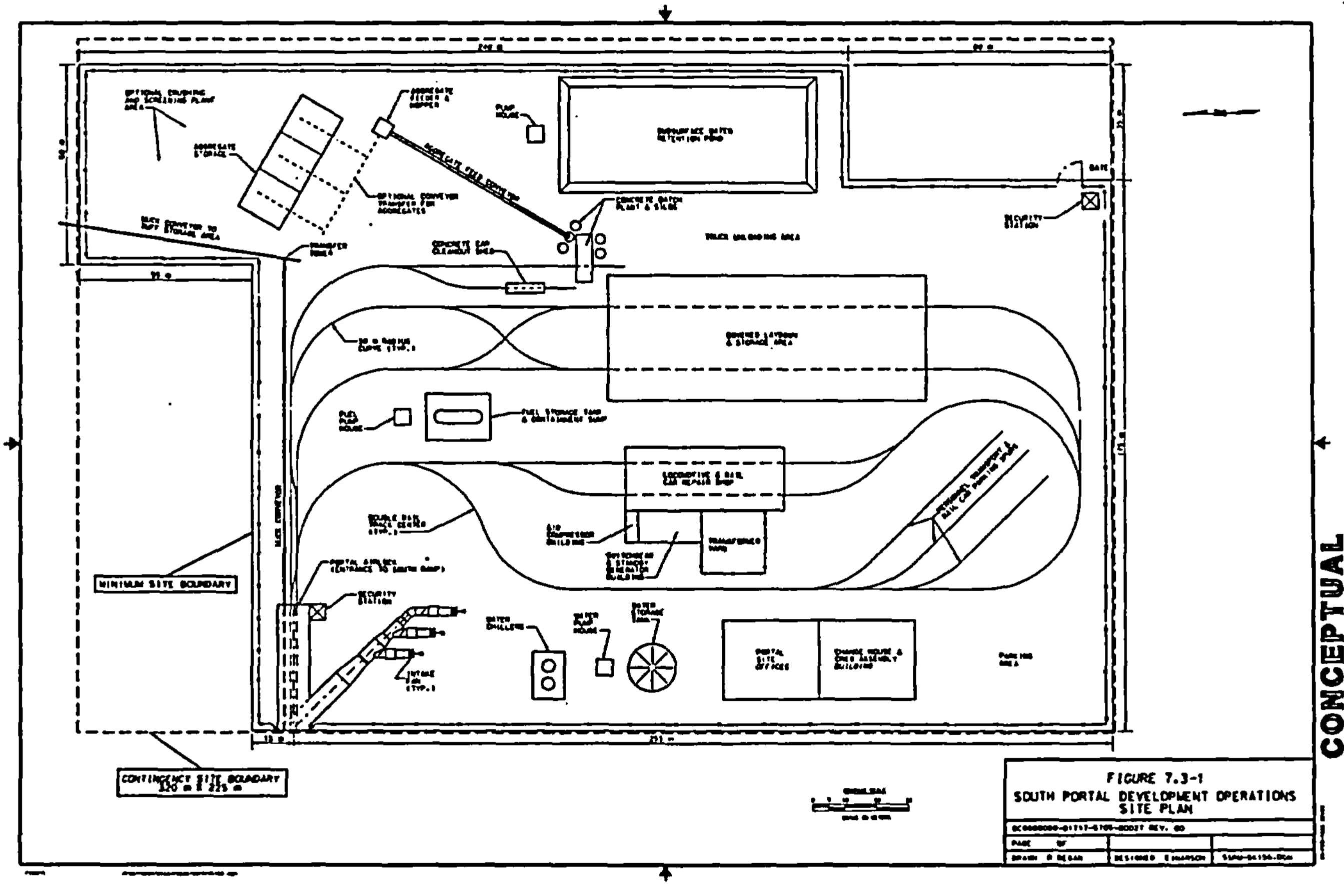


FIGURE 7.3-1
SOUTH PORTAL DEVELOPMENT OPERATIONS
SITE PLAN

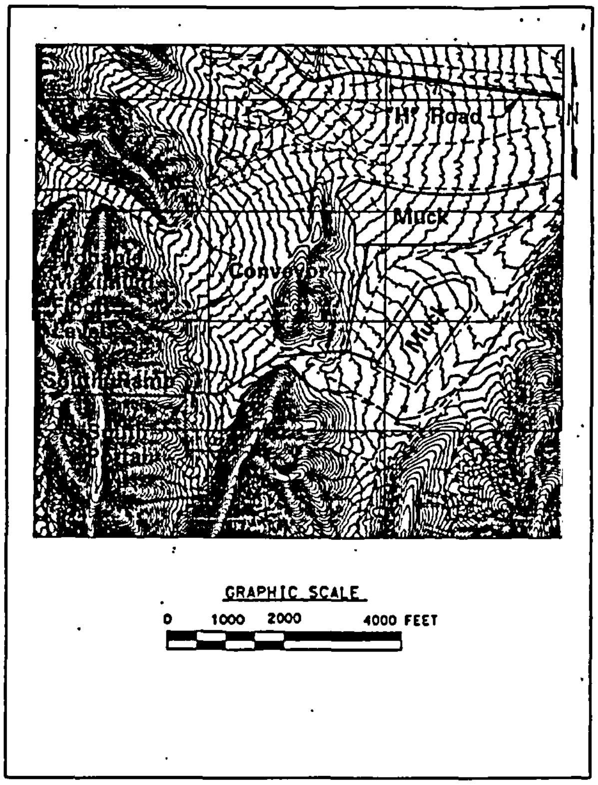


Figure 7.3-2. South Portal Development Operations
Muck Storage And Transfer

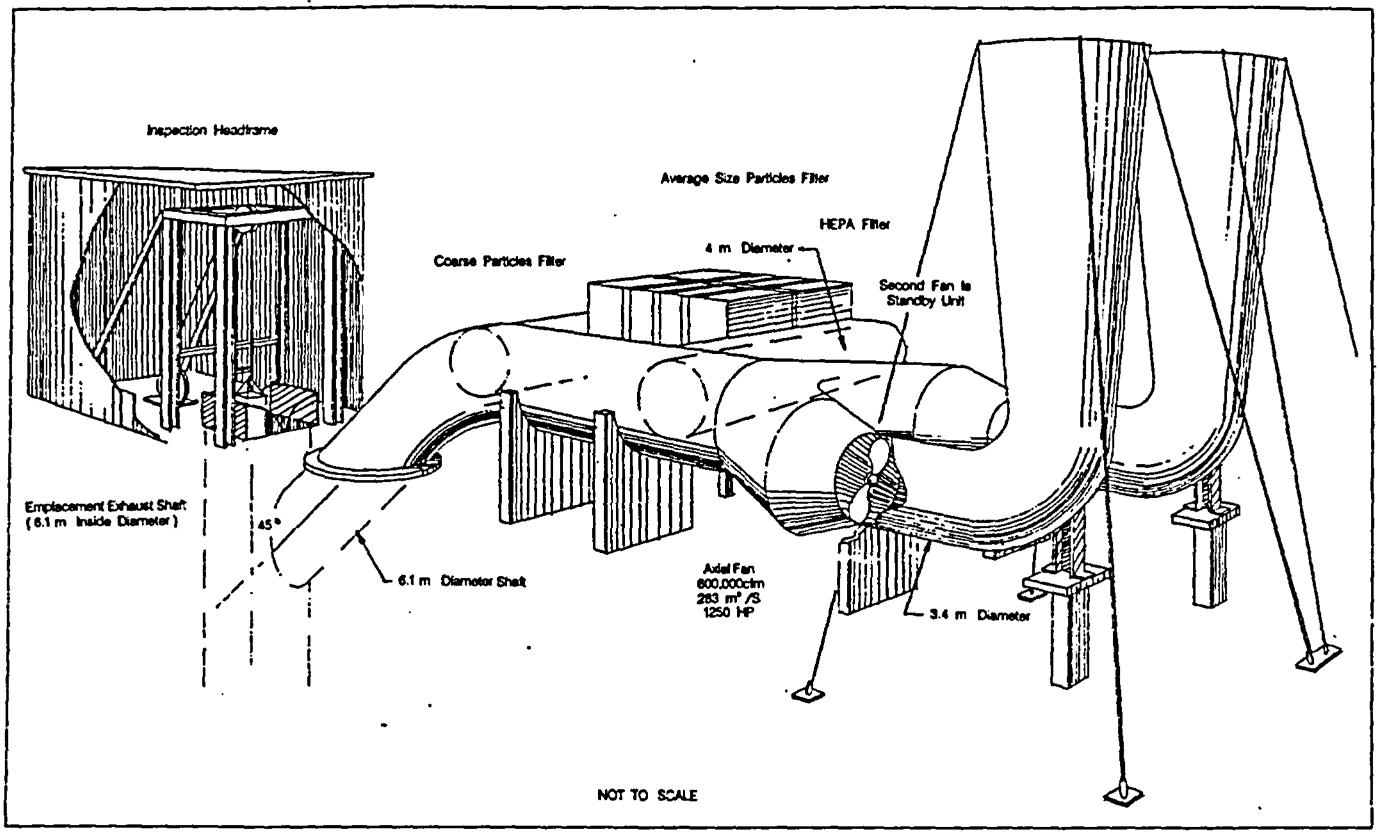


Figure 7.4-1.
Emplacement Side Exhaust Shaft
Fans & HEPA Filters Schematic

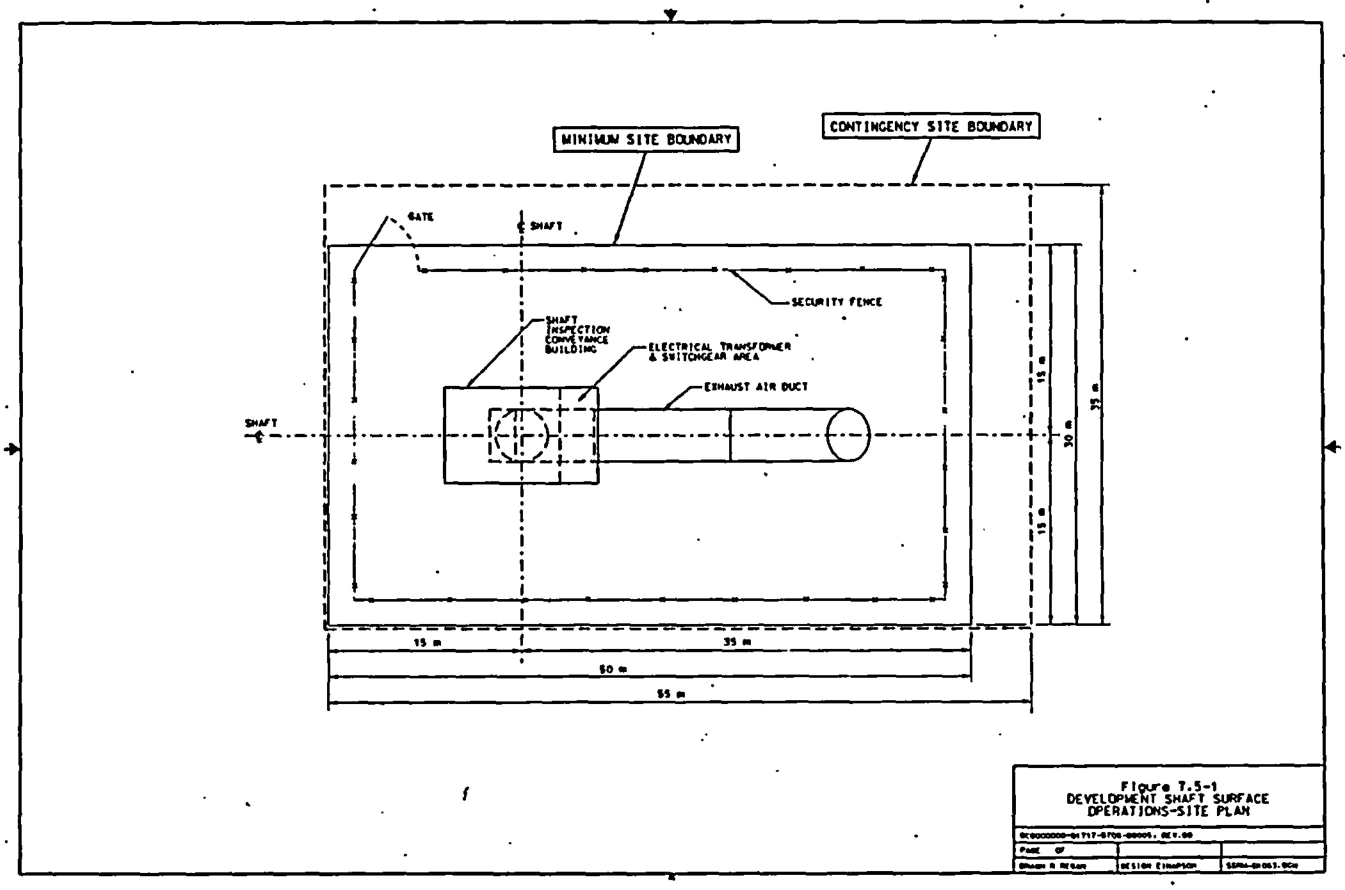
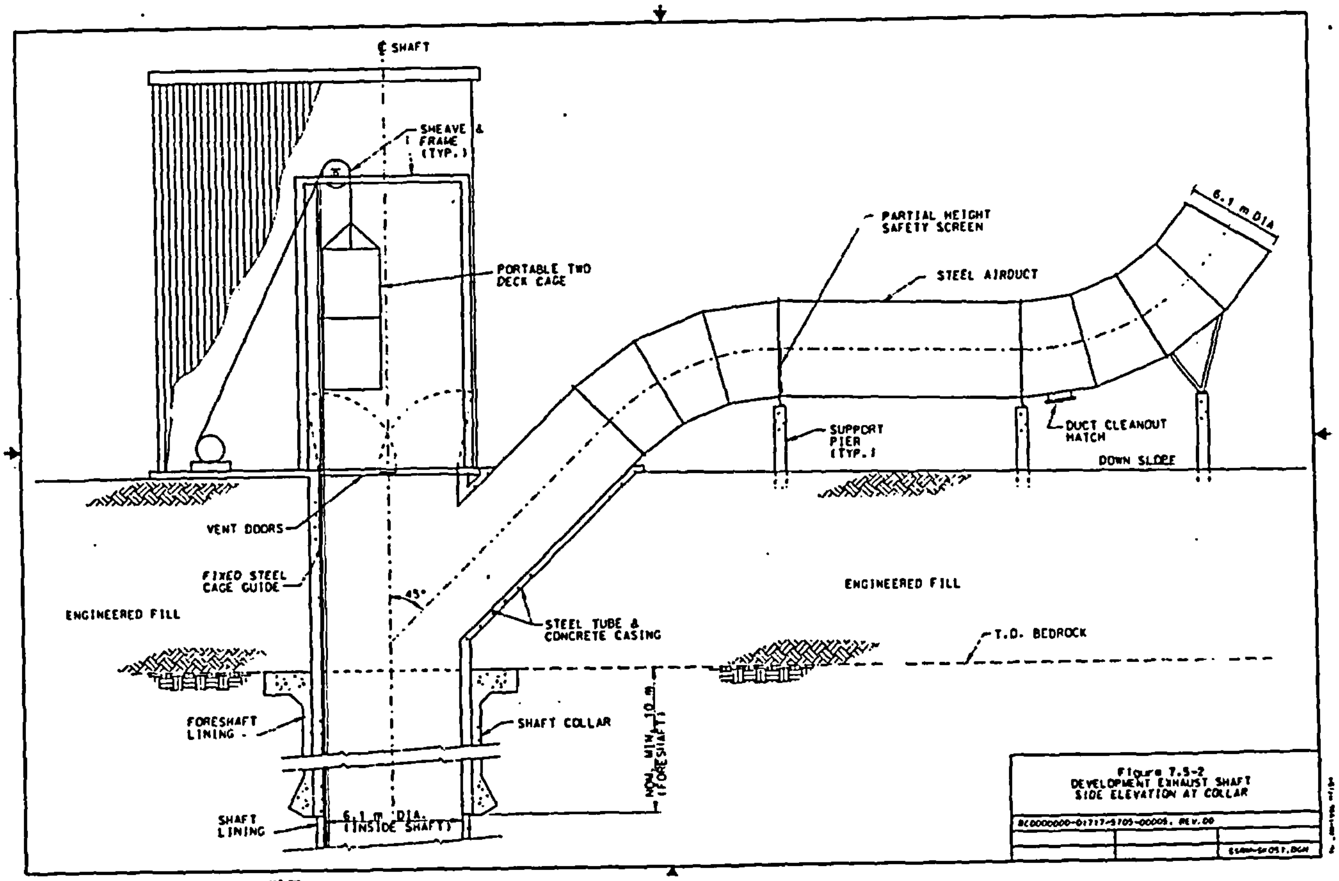


Figure 7.5-1
DEVELOPMENT SHAFT SURFACE
OPERATIONS-SITE PLAN



℄ SHAFT
SHEAVE & FRAME (TYP.)
PORTABLE TWO DECK CAGE
PARTIAL HEIGHT SAFETY SCREEN
STEEL AIRDUCT
6.1 m DIA
SUPPORT PIER (TYP.)
DUCT CLEANOUT HATCH
DOWN SLOPE
VENT DOORS
FIXED STEEL CAGE GUIDE
ENGINEERED FILL
ENGINEERED FILL
45°
STEEL TUBE & CONCRETE CASING
T.O. BEDROCK
FORESHAFT LINING
SHAFT COLLAR
NOM. MIN. 10 m (FORESHAFT)
SHAFT LINING
6.1 m DIA. (INSIDE SHAFT)
Figure 7.5-2
DEVELOPMENT EXHAUST SHAFT
SIDE ELEVATION AT COLLAR
BC0000000-01717-5705-00005, REV.00

APPENDIX E

SUBSURFACE EQUIPMENT DATA

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Equipment Data Sheets:

Transport Locomotive
Transfer Locomotive
Emplacement Locomotive
WP Transporter

Locomotive Selection Data:

Transport Locomotive
Transfer Locomotive
Emplacement Locomotive

Rail Size Selection Data:

Emplacement Drift Rail
Main Drift and Crosscut/Turnout Rail

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PRELIMINARY DATA SHEET NO. 1

Name: Transport Locomotive

Service: A single locomotive to move a WP transporter from the Waste Handling Building (at surface) to Emplacement Drifts (below surface). Tandem locomotives to move a loaded WP transporter from the Emplacement Drift to the Waste Handling Building.

Operating Conditions:

1.	Working Environment:	At surface and below surface in tunnels and drifts
2.	Temperature Range:	26°C to 50°C (79°F to 122°F)
3.	Elevation:	Approximately 1,000 m to 1,200 m (3,300 to 4,000 ft) above sea level
4.	Tunnel/Drift Dimensions:	
	a. Diameter:	5.0 m (16 ft) minimum
	b. Grade:	Tunnel +1.5% to -2.5%, Drifts ±0.75%
5.	Worst Case Load:	
	a. Type:	Waste package and WP transporter with two truck suspension
	b. Weight:	225 MT (250 tons) maximum
6.	Wheel Bearings:	Roller
7.	Locomotive Dimensions:	Approximately 6.7 m L x 1.8 m W x 2.4 m H
8.	Minimum Turning Radius:	25 m (82 ft) for both locomotive and WP transporter
9.	Track Gauge:	1.44 m (56½ in.)
10.	Rail:	57.05 kg/m (115 lb/yd) American Railroad Engineering Associates (AREA), on steel ties and concrete inverts
11.	Rail Condition:	Dry and in good condition
12.	Power Source:	Overhead trolley (250 volts D.C.) for travel in main drifts, and battery pack for limited travel in cross cuts or turnouts
13.	Battery Operation:	4 hours per day maximum
14.	Operation:	Two round trips per 8-hour day

15. Travel Distance: 4,000 m to 6,000 m one-way in main drifts, and 100 m (approx.) one-way in cross cuts or turnouts

Equipment Requirements:

1. Description: Two electric mine service type locomotives, for both trolley and battery operation with provisions, for single or tandem operations.

2. Maximum Design Grade: Single locomotive +2% to -3%
   Tandem locomotives ±3%

3. Maximum Speed: 8 km/hr (5 mph)

4. Control: Manual and remote for operation in areas of high radioactivity

5. Coupler: Standard with remote operation

6. Approximately Dimensions and Weight:
   a. No. wheels: Four (4)
   b. Wheelbase: 2.54 m
   c. Coupler to coupler center: 7.7 m
   d. Overall length: 6.7 m
   e. Overall width: 1.83 m
   f. Overall height: 2.44 m above rail
   g. Coupler height: 0.79 m above rail
   h. Operating weight: 32 MT (35 tons)

Features:

1. Removable battery pack

2. Self-contained battery charger

3. Remote control operation (possibly wireless)

4. Closed circuit TV for remote operation

5. Remote control operation for coupler and air brake connections to WP transporter

Note: Above weights and dimensions are based on preliminary estimates and assumptions for approximate sizing of the mobile equipment for ACD. These weights and dimensions may change during subsequent design phases.

U.S. Suppliers:

1. Goodman Equipment Corporation
   (708) 496-1188 Fax: (708) 496-3939
   Contact: Scott Rife

2. Jeffery Division of Dresser Industries
   (614) 297-3123 Fax: (614) 297-3036
   Contact: Randy Morris

3. Balco, Inc.
   (412) 459-6814 Fax: (412) 459-0793
   Contact: Jess Bartholow

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PRELIMINARY DATA SHEET NO. 2

Name: Transfer Locomotive

Service: To move emplacement locomotive on locomotive carrier from main drift to emplacement drift.

Operating Conditions:

1.	Location:	Below surface in tunnels and drifts
2.	Temperature Range:	26°C to 50°C (79°F to 122°F)
3.	Elevation:	Approximately 1,000 m to 1,200 m (3,300 to 4,000 ft) above sea level
4.	Tunnel/Drift Dimensions:	
	a. Diameter:	5.0 m (16 ft) minimum
	b. Grade:	Tunnel +1.5% to -2.5% Drifts ±0.75%
5.	Worst Case Load:	
	a. Type:	Locomotive carrier with emplacement locomotive
	b. Weight:	30 MT (33 tons) maximum
6.	Wheel Bearings:	Roller
7.	Locomotive Dimensions:	Approximately 4.4 m L x 2.0 m W x 1.6 m H
8.	Minimum Turning Radius:	25 m (82 ft) for both locomotive carrier and locomotive
9.	Track Gauge:	1.44 m (56½ in.)
10.	Rail:	57.05 kg/m (115 lb/yd) AREA, on steel ties and concrete inverts
11.	Rail Condition:	Dry and in good condition
12.	Power Source:	Replaceable battery packs (one in locomotive, one on charger)
13.	Battery Operation:	8 hrs per day, maximum
14.	Operation:	Two round trips per 8-hour day
15.	Travel Distance:	4,000 m to 6,000 m one-way in main drifts, and 100 m (approx.) one-way in cross cuts or turnouts

Equipment Requirements:

1. Description: An electric mine service-type locomotive for battery operation

2. Maximum Design Grade: ±3%

3. Maximum Speed: 5 km/hr (3.1 mph)

4. Control: Manual and remote for operation in areas of high radioactivity

5. Coupling: Standard with remote operation

6. Approximately Dimensions and Weight:
   a. No. wheels: Four (4)
   b. Wheelbase: 1.5 m
   c. Coupler to coupler truck center: 4.8 m
   d. Overall length: 4.4 m
   e. Overall width: 2.0 m
   f. Overall height: 1.6 m above rail
   g. Coupler height: 0.79 m above rail
   h. Operating weight: 10 MT (11 tons)

Features:

1. Removable battery pack

2. Self-contained battery charger

3. Remote control operation (possibly wireless)

4. Closed circuit TV for remote operation

5. Remote control for coupler and air brake connectors to railcars

Note: Above weights and dimensions are based on preliminary estimates and assumptions for approximate sizing of the mobile equipment for ACD. These weights and dimensions may change during subsequent design phases.

U.S. Suppliers:

1. Goodman Equipment Corporation
   (708) 496-1188 Fax: (708) 496-3939
   Contact: Scott Rife

2. Jeffery Division of Dresser Industries
   (614) 297-3123 Fax: (614) 297-3036
   Contact: Randy Morris

3. Balco, Inc.
   (412) 459-6814 Fax: (412) 459-0793
   Contact: Jess Bartholow

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PRELIMINARY DATA SHEET NO. 3

Name:	Emplacement Locomotive
Service:	To move emplacement railcar loaded with waste package into emplacement drift.

Operating Conditions:

1.	Location:	Below surface in emplacement drifts
2.	Temperature Range:	26°C to 50°C (79°F to 122°F)
3.	Elevation:	Approximately 1,000 m to 1,200 m (3,300 to 4,000 ft) above sea level
4.	Drift Dimensions:	
	a. Diameter:	5.0 m (16 ft) minimum
	b. Grade:	±0.75%
5.	Worst Case Load:	
	a. Type:	Waste package and emplacement railcar
	b. Weight:	79 MT (87 ton) maximum
6.	Wheel bearing:	Sleeve
7.	Locomotive Dimensions:	4.4 m L x 2.0 m W x 1.6 m H
8.	Minimum Turning Radius:	25 m (82 ft)
9.	Track Gauge:	1.44 m (56½.)
10.	Rail:	44.64 kg/m (90 lb/yd), American Society of Civil Engineers (ASCE) on steel ties and compacted tuffaceous fill
11.	Rail Condition:	Dry and in good condition
12.	Power Source:	Replaceable battery packs (one in locomotive, one on charger)
13.	Battery Operation:	8 hrs per day, maximum
14.	Operation:	Two round trips per 8-hour day
15.	Travel Distance:	600 m maximum, one-way

Equipment:

1. Description: An electric mine service-type locomotive for battery operation

2. Maximum Design Grade: ±0.75%

3. Maximum Speed: 5 km/hr (3.1 mph)

4. Control: Manual and remote for operation in areas of high radioactivity

5. Coupling: Standard with remote operation

6. Approximately Dimensions and Weight:
   a. No. wheels: Four (4)
   b. Wheelbase: 1.5 m
   c. Coupler to coupler center: 4.8 m
   d. Overall length: 4.4 m
   e. Overall width: 2.0 m
   f. Overall height: 1.6 m above rail
   g. Coupler height: 0.38 m above rail
   h. Operating weight: 10 MT (11 tons)

Features:

1. Removable battery pack

2. Self-contained battery charger

3. Remote control operation (possibly wireless)

4. Closed circuit TV for remote operation

5. Remote control for coupler and air brake connectors to railcar

Note: Above weights and dimensions are based on preliminary estimates and assumptions for approximate sizing of the mobile equipment for ACD. These weights and dimensions may change during subsequent design phases.

U.S. Suppliers:

1. Goodman Equipment Corporation
   (708) 496-1188 Fax: (708) 496-3939
   Contact: Scott Rife

2. Jeffery Division of Dresser Industries
   (614) 297-3123 Fax: (614) 297-3036
   Contact: Randy Morris

3. Balco, Inc.
   (412) 459-6814 Fax: (412) 459-0793
   Contact: Jess Bartholow

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PRELIMINARY DATA SHEET NO. 4

Name: WP Transporter

Service: To provide for shielded transport of waste package from Waste Handling Building (at surface) to waste package emplacement drift (below surface).

Operating Conditions:

1. Working Environment:	Above surface and below surface in tunnels and drifts
2. Temperature Range:	26°C to 50°C (79°F to 122°F)
3. Elevation:	Approximately 1,000 m to 1,200 m (3,300 to 4,000 ft) above sea level
4. Tunnel/Drift Dimensions:	
a. Diameter:	5.0 m (16 ft) minimum
b. Grade:	Tunnel ±2.5% Drifts ±0.75%
5. Load:	
a. Type:	Waste package railcar
b. Weight:	79 MT (87 tons) maximum
6. Minimum Turning Radius:	25 m (82 ft) for both locomotive and WP transporter
7. Track Gauge:	1.44 m (56½ in.)
8. Rail:	57.05 kg/m (115 lb/yd) AREA, on steel ties and concrete inverts
9. Rail Condition:	Dry and in good condition
10. Operation:	Two round trips per 8-hour day
11. Travel Distance:	4,000 m to 6,000 m one-way

Equipment:

1.	Description:	A rail-mounted shielded WP transporter for the transfer of high-level radioactive waste packages.
2.	Maximum Design Grade:	±3%
3.	Maximum Speed:	8 km/hr (5 mph)
4.	Suspension:	Two 4-wheel trucks with roller bearings
5.	Radiation Shielding:	165 mm thickness carbon steel gamma shield and 300 mm air gap between waste package and shielding
6.	Coupler:	Standard with remote operation controlled from transport locomotive
7.	Brakes:	Air-operated brakes on all wheels with air reservoir

8. Approximately Dimensions and Weight:

a.	No. trucks:	Two (2)
b.	No. wheels/truck:	Four (4)
c.	Truck center to center:	3.7 m
d.	Truck wheel base:	1.8 m
e.	Overall length:	8.4 m
f.	Overall width:	2.7 m
g.	Overall height:	3.9 m above rail
h.	Coupler height:	0.79 m above rail
i.	Operating weight:	225 MT (250 tons)

Special Features:

1. The air brake system of the WP transporter to operate in both modes, manually and automatically.

2. The WP transporter doors to be remotely controlled and operated.

3. The WP transporter loading system, for transfer of the emplacement railcar, to be remotely controlled and operated.

4. The mechanical parking brake to be remotely actuated and controlled from locomotive.

Note: Above weights and dimensions are based on preliminary estimates and assumptions for approximate sizing of the mobile equipment for ACD. These weights and dimensions may change during subsequent design phases.

Suppliers:

1. Transfab, Inc.
   (304) 736-5256 Fax: (304) 736-8135
   Attn: John Cardia

2. Robbins Co.
   (206) 872-4539 Fax: (206) 872-0199
   Attn: Bob Moffat

3. National Engineering
   (303) 295-3385 Fax: (303) 295-6057
   Attn: Marty Martin

4. TWI Industries, Inc.
   (412) 835-9400 Fax: (412) 835-6693
   Attn: Charles Schultz

5. Muhlhauser Tunneling Equip.
   (206) 813-0669 Fax: (206) 850-8315
   Attn: Kent Smith

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PRELIMINARY LOCOMOTIVE SELECTION

SELECTION PROCEDURE

Tentative sizing of locomotives is based on selection procedure from:

Goodman Equipment Corp.
Mining Machine Sales Manual
Trolley Locomotive Calculations, Section 4068

where locomotive capacity is determined by the following equation:

where:

$$L = \frac{W \times R_t}{2000\ (K + .01) - (G \times 20 + R_2)}$$

- L = weight of locomotive (tons)
- W = weight of trailing load (tons)
- R_t = train resistance (lb/ton)
- = $R_r + (G)(20)$
- R_r = trailing load rolling resistance (lb/ton)
- R_2 = locomotive rolling resistance (20 lb/ton)
- G = grade (%)
- K = Adhesion factor for driving wheels (0.25 for steel wheel on dry rail)

Rolling resistance is 20 lb/ton for trailing loads with roller bearings and 30 lb/ton for sleeve bearings.

Transport Locomotive

Description: Class D combination electric mine service locomotive for primary trolley operation and secondary storage battery operation, and equipped for tandem operation with an identical unit.

Selection Criteria:

Trailing load (W):	250 tons
Rolling resistance (R_r):	20 lb/ton
Grade (G):	±2% Condition 1; ±3% Condition 2
Speed:	5 mph

Selection for Condition 1 (Single Locomotive):

$$L = \frac{W \times R_t}{2000\ (K + .01) - (G \times 20 + R_2)}$$

$$R_t = R_r + (G)(20)$$
$$= 20 + (2)(20) = 60\ lb/ton$$

$$L = \frac{(250)\ (60)}{2000\ (0.25 + .01) - (2 \times 20 + 20)}$$

$$L = 32.6\ tons$$

Select a 35-ton locomotive (32 MT).

Selection for Condition 2 (Tandem Locomotives):

$$L = \frac{W \times R_t}{2000\ (K + .01) - (G \times 20 + R_2)}$$

$$R_t = R_r + (G)(20)$$
$$= 20 + (3)(20) = 80\ lb/ton$$

$$L = \frac{(250)\ (80)}{2000\ (0.25 + .01) - (3 \times 20 + 20)}$$

$$L = 45.5\ tons$$

Using two 35-ton (32 MT) locomotives in tandem will meet the requirements of this condition.

Note: Above weights and dimensions are based on preliminary estimates and assumptions for approximate sizing of the mobile equipment for ACD. These weights and dimensions may change during subsequent design phases.

EMPLACEMENT LOCOMOTIVE

Description: A Class A electric mine service locomotive for storage battery operation.

Selection Criteria:

Trailing load (W):	87 tons
Rolling resistance (R_r):	30 lb/ton
Grade (G):	±0.75%

Selection:

$$L = \frac{W \times R_t}{2000\ (K + .01) - (G \times 20 + R_2)}$$

$$\begin{aligned} R_t &= R_r + (G)(20) \\ &= 30 + (0.75)(20) = 45 \text{ lb/ton} \end{aligned}$$

$$L = \frac{(87)\ (45)}{2000\ (.25 + .01) - (.75 \times 20 + 20)}$$

L = *8.1 tons.*

Select a 10-ton locomotive. The locomotive weight may be 10 MT or 10 tons, depending on availability; either will satisfy the load requirements.

<u>Note</u>: Above weights and dimensions are based on preliminary estimates and assumptions for approximate sizing of the mobile equipment for ACD. These weights and dimensions may change during subsequent design phases.

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TRANSFER LOCOMOTIVE

Description: A Class A electric mine service locomotive for storage battery operation.

Selection Criteria:

Trailing load (W):	33 tons
Rolling resistance (R_r):	20 lb/ton
Grade (G):	±3%

Selection:

$$L = \frac{W \times R_t}{2000\ (K + .01) - (G \times 20 + R_2)} \quad (tons)$$

$$R_t = R_r + (G)(20)$$
$$= 20 + (3)(20) = 80\ lb/ton$$

$$L = \frac{(33)\ (80)}{2000\ (.25 + .01) - (3 \times 20 + 20)}$$

$$L = 6.0\ tons$$

Based on this calculation, a six-ton locomotive will be adequate. However, for reasons of uniformity, a 10-ton locomotive is recommended. The locomotive weight may be 10 MT or 10 tons, depending on availability; either will satisfy the load requirements.

Note: Above weights and dimensions are based on preliminary estimates and assumptions for approximate sizing of the mobile equipment for ACD. These weights and dimensions may change during subsequent design phases.

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PRELIMINARY RAIL SIZE SELECTION

SELECTION PROCEDURE

Tentative rail sizing procedure is as follows:

1. Maximum wheel load is determined for the application.

2. Maximum wheel load is adjusted for the speed using a speed modification factor from Ref. 1.

3. Adjusted maximum wheel load and size is used with the appropriate table from Ref. 1 to determine minimum rail size and type required.

Ref. 1 Association of Iron and Steel Engineers (AISE) Technical Report No. 6. September 1991. *Specification for Electric Overhead Traveling Cranes for Steel Mill Service.*

EMPLACEMENT DRIFT RAIL

Service: Rail to provide for the placement of the WP/emplacement railcar by the emplacement locomotive in the emplacement drift and the support of the WP/emplacement railcar in the final placement position.

Selection Criteria:

The rail selection is based on the WP/emplacement railcar as the heaviest piece of equipment operating on the track with the criteria as follows:

Equipment:	
Emplacement railcar:	10 MT (22,000 lbs)
Waste Package Weight (max):	69 MT (151,800 lbs)
Total Weight:	79 MT (173,800 lbs)
Axles:	2
No. Wheels:	4
Diameter of Wheels:	0.46 m (18 in.)
Speed:	5 km/hr (3.1 mph) (275 fpm)
Safety Factor:	1.25
Rail Gauge:	1.44 m (56½ in.)
Rail Support:	Steel ties on compacted tuffaceous fill

Selection:

$$Design\ Wheel\ Load = \frac{173{,}800}{4}\ (1.25) = 54{,}312\ lbs$$

From Ref. 1 (Table 11) for a speed of 275 fpm and an 18-inch-diameter wheel:

$$Speed\ Modification\ Factor = 1.098$$

Adjusting maximum design wheel load for travel speed:

$$Maximum\ Design\ Wheel\ Load = (1.098)\ (54{,}312) = 59{,}635\ lbs.$$

From Ref. 1 (Table 9) for 18-inch wheel and 60-pound rail:

$$Allowable\ Wheel\ Load = 61{,}430\ lbs.$$

Select the next larger rail size: 90 lb/yd (44.64 kg/m)ASCE rail

Note: Table 10 is based on wheels heat treated to 58 Rc minimum and rails heat treated to 320 Bhn minimum.

MAIN DRIFT AND CROSS CUT RAIL

Service: Rail to provide for transport of the loaded WP transporter from Waste Handling Building at surface to subsurface emplacement drifts and other rail-mounted support equipment.

Selection Criteria:

The rail selection is based on the WP transporter as the heaviest piece of equipment operating on the track, with the criteria as follows:

Mobile Equipment:	WP transporter
Total Weight (with Load):	225 MT (250 tons)
No. Axles:	4
No. Wheels:	8
Wheel Diameter:	0.61 m (24 in.)
Speed:	8 km/hr (5 mph) (440 fpm)
Rail Gauge:	1.44 m (56½ in.)
Safety Factor:	1.25
Rail Support:	Steel ties on concrete inverts

Selection:

$$\textit{Design Wheel Load} = \frac{(250)(2000)}{8}(1.25) = 78{,}125\ \textit{lbs.}$$

From Ref. 1 (Table 11) for a speed of 440 fpm and 24-inch-diameter wheel:

$$\textit{Speed Modification Factor} = 1.122$$

$$\textit{Maximum Design Load} = (1.122)(78{,}125) = 87{,}656\ \textit{lbs.}$$

From Ref. 1 (Table 10) for a 24-inch wheel and a 104- to 105-pound rail:

$$\textit{Allowable Wheel Load} = 87{,}750\ \textit{lbs.}$$

Select the next larger rail size: 115 lb/yd (57.05 kg/m), AREA rail.

Note: Table 10 is based on wheels heat treated to 58 Rc minimum and rails heat treated to 320 Bhn minimum.

Above weights and dimensions for the selection of rails are based on preliminary estimates and assumptions of the rolling stock for ACD. These weights and dimensions may change during subsequent design phases.

APPENDIX F1

RAIL CORRIDOR DESCRIPTION

USGS Quadrangle	Cuml. Miles *	Sec Twp Rng	Location Description	Land-Use Constraints	Archeological & Historical Sites	Road Crossings & Proximity to Population	Topographic Considerations	Bridges & Hydrologic Considerations	Operating Considerations
	0.0	S3 T26S R59E	Borax Siding	Pipeline Right-of-Way N7100, (underground) 50 ft. Pipeline Right-of-Way NEV056213, (underground) 50 ft.					Connection with Union Pacific (to passing siding).
		S7,8,9,16,17,18 T26S R59E		Material Site NEV05336, S17 Material Site NEV04638, S17	Route passes through a very large unevaluated archeological site covering most of the area. If found to be a significant site, routing may still be possible if artifacts are diffused.				
Roach Lake 15' References: Q-39 *MTP-156* MTP-157 MTP-158 MTP-159 *Plate 17*: D1, D2	2.0	S16 T26S R59E	Interstate 15 (four lanes)	Highway Right-of-Way NEV046714, 400ft. *Powerline Right-of-Way* N2078, 20 ft. Telephone Right-of-Way N43923, (underground) 10 ft.		Grade Separation			
	5.0	S30 T26S R59E	Foot of Spring Mtns.						
							Extensive earthwork for 3 miles around southern tip of Spring Mtns. Cuts and fills range up to 80'.		2.2 % upgrade. Some sharp curves.
	6.5	S6 T27S R59E	*Vicinity of State Line* (casinos)			*Probable* track location within 2.0 miles of casinos.			
	8.0	S35 T26S R58E	Enter California						
	10.5	S28 T18N R14E	State Line Pass	*Route parallels perimeter of* Stateline Wilderness Area for approx. 4.0 mile. California Desert Conservation Act of 1994.			Deep cut through alluvial fan at summit.	Cut through alluvial fan will require considerable flood protection measures.	Top of grade.
							Extensive earthwork for 3 miles along face of Spring and Clark Mtns. *Cuts and fills range up* to 100' in hardrock; some tunneling may be necessary.	High run-off rates due to hard ground surface. Some canyon outflows will require major culvert installations.	2.2 % downgrade. Some sharp curves.
	14.0	S17 T26S R58E	Exit California						

* Cumulative Mileage figures are approximate and refer to this route section only; mileage between adjoining route sections is not contiguous.

USGS Quadrangle	Cuml. Miles *	Sec Twp Rng	Location Description	Land-Use Constraints	Archeological & Historical Sites	Road Crossings & Proximity to Population	Topographic Considerations	Bridges & Hydrologic Considerations	Operating Considerations
Clark Mtn. 15' References: Q-40 MTP-160 *Plate 16*: D5		S36 T25S R57E		Corral Community Pit N48722			Route crosses a series of alluvial fans at base of Spring Mtns.	Some major culvert installations per above.	
	21.5	S10,14,15,22,23, 24,25,26,27 T25S R57E	Enter vicinity of Sandy Valley	Community Pit N48722		Route is adjacent to southeast limit of populated area.			
Shenandoah Peak 15' References: Q-41 MTP-161 MTP-162 MTP-163 MTP-164 MTP-165 MTP-166						Probable track location parallels Cherokee St. and is less than 1.0 mile from homes.	Route crosses series of alluvial fans.		
	24.0	S3 T25S R57E	Sandy Valley Rd.	Community Pit N48722	Probable track location passes within 0.5 mile of Shenandoah Mill, an unevaluated historical site.	Grade Separation			
	25.5	S33 T24S R57E	Wilson Pass Rd.			Signaled Grade Crossing			
	27.0	S29 T24S R57E	Exit vicinity of Sandy Valley			Route is adjacent to northern limit of populated area. Within 1.0 mile of school.			
	33.0	S34 T23S R56E	Road from Sandy Valley to Hwy. 160			Signaled Grade Crossing			
Plate 16: B4, B5, C4, C5	39.5	S6 T23S R56E			Crossing of Old Spanish Trail, a significant historic site.				
Pahrump 15'		S18,19,20,28,27, 34,35 T22S R55E		Powerline Right-of-Way NEV066209, 20 ft. Powerline Right-of-Way NEV53100, 80 ft.					
References: Q-74		S14,15,16,17,18 T21S R55E		Powerline Right-of-Way N17151, 20 ft.					
MTP-167 MTP-168		S3,4,5 T21S R55E		Pipeline Right-of-Way					
MTP-169 MTP-170 MTP-171		S6,8,17,21,26,27, 35,36 T20S R54E		Powerline Right-of-Way NEV065524, 200 ft.					
MTP-172		S27,34 T20S R54E		Water System N46682					
Plate 16: A2, A3	45.5	30 T22S R55E	Old Spanish Trail Hwy. *Match point for either North Pahrump Alternate or Stewart Valley Alternate.*			Grade Separation	If Stewart Valley Alternate adjoins, location is in S21 T22S R55E.		

* Cumulative Mileage figures are approximate and refer to this route section only; mileage between adjoining route sections is not contiguous.

USGS Quadrangle	Cuml. Miles *	Sec Twp Rng	Location Description	Land-Use Constraints	Archeological & Historical Sites	Road Crossings & Proximity to Population	Topographic Considerations	Bridges & Hydrologic Considerations	Operating Considerations
Goodsprings 15' References: Q-75 MTP-173 MTP-174 MTP-175 MTP-176 MTP-177 MTP-178 *Plate 17:* B1, C1, C2	0.0	S12 T25S R59E	Jean	Pipeline Right-of-Way N7100 (underground), 50 ft. Pipeline Right-of-Way NEV056213 (underground), 50 ft.		Connection trackage within 0.5 mile of casinos and industrial buildings, unless connection site moved to the north.			Connection with Union Pacific (to passing siding). Other potential connecting sites within 3 miles to the north of Jean. 2.2 % upgrade begins within 0.5 mile of connection.
	0.7	S12 T25S R59E	Hwy. 604	*Highway Right-of-Way* CC0200954, 400 ft.		Grade Separation	As the slope of the valley floor is over 1.5 %, long fills will be required in advance of and between grade separations over Hwy. 604 and Interstate 15.		
	1.0	S12 T25S R59E	Interstate 15 (four lanes)	*Highway Right-of-Way* NEV046714, 400 ft.		Grade Separation			
		S32 T24S R59E		Powerline Right-of-Way NEV015022, 100 ft.	One small unevaluated archeological site within corridor.				
	7.5	S24 T24S R58E	Goodsprings	Powerline Right-of-Way N37856, 20 ft. Enter proposed BLM utility corridor		Probable track location is within 1.0 mile of recently constructed homes on north side of Goodsprings.			2.2 % upgrade, continuous for approx. 15 miles.
		S2 T24S R58E	Goodsprings Valley	Fence			Route loops around north end of valley, adding sufficient distance to maintain proper grade.		
	15.3	S17 T24S R58E	Wilson Pass Rd.			Signaled Grade Crossing			
	15.5	S17 T24S R58E	East Portal, Wilson Pass Tunnel			Above crossing of Wilson Pass Rd. may possibly be avoided by locating tunnel portal north of road.			*Top of 2.2 % grade.*
Goodsprings 15' Shenandoah Peak 15'			Wilson Pass Tunnel				Approx. 2.0 mile long tunnel through crest of Spring Mtns. at about 4600' elevation. Design may establish length as much as 0.4 mile shorter or longer.		Tunnel ventilation system may be required due to combined effects of tunnel length and 2.2 % approach grade.
	17.5	S7 T24S R58E	West Portal, Wilson Pass Tunnel						
Shenandoah Peak 15' *Plate 16:* B4, B5, C4, C5		S12 T24S R57E			Two small unevaluated archeological sites within corridor.				
		S6 T24S R58E	Wilson Pass Rd.			Signaled Grade Crossing. May be avoided depending upon site of tunnel portal (1500' road relocation would be necessary).			

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USGS Quadrangle	Cuml. Miles *	Sec Twp Rng	Location Description	Land-Use Constraints	Archeological & Historical Sites	Road Crossings & Proximity to Population	Topographic Considerations	Bridges & Hydrologic Considerations	Operating Considerations
							Extensive earthwork for approx. 3 miles between tunnels; cuts and fills range up to 60'. Earthwork may be reduced by lengthening both tunnels.		
Shenandoah Peak 15' *Plate 16:* B4, B5, C4, C5	20.5	S35 T23S R57E	Potosi Tunnel	Powerline Right-of-Way NEV066148, 20 ft.			Approx 0.5 mile long tunnel through branch of Spring Mtns. Design may lengthen as much as 0.4 mile.		Tunnel ventilation system probably not required. 2.2 % downgrade begins at west portal.
							Route crosses series of alluvial fans.	Many culverts required.	2.2 % downgrade, approx. 6 miles long
	26.5	S6 T23S R57E	Road from Sandy Valley to Hwy. 160			Signaled Grade Crossing			Approx. foot of 2.2 % grade.
	28.5	S35 T22S R56E			Crossing of Old Spanish Trail, a significant historic site.				
	28.6	S35 T22S R56E	Lovell Wash					Bridge up to 300' long	
Mountain Springs 15' References: Q-76 MTP-179 MTP-180 *Plate 16:* A4, A5									
Pahrump 15' *Plate 16:* A2, A3	37.5	S10 T22S R55E	Old Spanish Trail Hwy. *Match point for either North Pahrump Alternate or Stewart Valley Alternate*			Grade Separation			

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USGS Quadrangle	Cuml. Miles *	Sec Twp Rng	Location Description	Land-Use Constraints	Archeological & Historical Sites	Road Crossings & Proximity to Population	Topographic Considerations	Bridges & Hydrologic Considerations	Operating Considerations
Pahrump 15' *Plate 16:* A2, A3	0.0	S10 T22S R55E	*Old Spanish Trail Hwy. Match point for either Wilson Pass Alternate or State Line Pass Alternate.*			Grade Separation	Route crosses series of alluvial fans at base of Spring Mtns.	Numerous culverts required.	
	7.0	S13 T21S R54E	Hwy. 160			Grade Separation			
	8.0	S11 T21S R54E	Enter vicinity of built-up portion of Pahrump			Route is adjacent to eastern limit of populated area.			2.0 % downgrade.
	9.5	S2 T21S R54E	Carpenter Canyon Road			Signaled Grade Crossing			
	11.5	S27 T20S R54E					Route along southern tip of branch of Spring Mtns., using grades to avoid tunnel.		
	12.0	S27 T20S R54E	Clark / Nye County Line						2.0 % upgrade.
	13.0	S21 T20S R54E	County road			Signaled Grade Crossing			
	14.5	S17 T20S R54E	Wheeler Wash					Bridge up to 100' long.	
	15.5	S8 T20S R54E	Wheeler Pass Rd.			Signaled Grade Crossing. Route is adjacent to central portion of Pahrump; nearest housing is approx. 1.5 miles from probable track location.		Numerous culverts required. Several of the larger washes will require major culvert installations.	
Mt. Stirling 15' References: Q-77 MTP-181 MTP-182 MTP-183 *Plate 14:* C1, D1		S31 T19S R54E		Powerline Right-of-Way NEV065524, ft.			Route crosses series of alluvial fans at base of Spring Mtns. Optional routing to avoid private lands would be approx. 1.5 miles further east and to an elevation 600' higher on the slope of the Spring Mtns. The additional elevation gain would require approx. 3 miles additional construction involving heavy earthwork.		
	22.0	S12 T19S R53E	Exit vicinity of built-up portion of Pahrump			Route is adjacent to northern limit of populated area, although private lands continue northward.			
	23.0	S1 T19S R53E		Enter private lands.					
	25.5	S26 T18S R53E		Exit private lands.					
Mt. Schader 7.5' References: Q-78 MTP-184 MTP-185 MTP-186 *Plate 13:* C5	27.5	S15 T18S R53E		Enter private lands.					
	30.0	S8 T18S R53E		Northern limit of private lands in Pahrump area.					
	32.5	S36 T17S R52E	Johnnie Pass		One unevaluated site within corridor.				2.2 % downgrade, approx. 6.5 miles long.
		S25 T17S R52E			One unevaluated site within corridor.		Route through hills at base of Mt. Schader. Approx. 1800' tunneling required in addition to very heavy earthwork.		
	36.0	S14 T17S R52E	Foot of Mt. Schader						

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USGS Quadrangle	Cuml. Miles *	Sec Twp Rng	Location Description	Land-Use Constraints	Archeological & Historical Sites	Road Crossings & Proximity to Population	Topographic Considerations	Bridges & Hydrologic Considerations	Operating Considerations
Specter Range 15' References: Q-84 MTP-194 MTP-195 MTP-196 MTP-197 MTP-198 *Plate 13:* A4, A5, B4, B5	42.0	S22 T16S R52E	Hwy. 160	Highway Right-of-Way NEV065993 Telephone Right-of-Way N47397 (underground), 20 ft. Within proposed BLM utility corridor		Grade Separation			
	42.5	S21 T16S R52E	Wash					Bridge up to 200' long.	
	45.0	S19 T8S R52E	County Road			Signaled Grade Crossing			
	47.5	S22 T16S R51E	*Match point for Amargosa Desert Section.*						

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Pahrump 15' *Plate 16:* A2, A3	0.0	S10 T22S R55E	Old Spanish Trail Hwy. *Match point for either Wheeler Pass Alternate or State Line Pass Alternate.*			Grade Separation	If State Line Pass Alternate adjoins, location is in S21 T22S R55E.		
	3.0	S7 T22S R55E		Enter BLM proposed 2640' Utility/Trans. Corridor					
	6.5	S3 T22S R54E	Clark / Nye County Line	Powerline Right-of-Way NEV066289, 20 ft. Telephone Right-of-Way NEV065104, 20 ft.					
	10.0	S25 T21S R53E	Homestead Road			Grade Separation. At least 5 homes are within 0.2 mile of probable track location, numerous other homes are within 1.0 mile.			
Nopah Peak 7.5' References: Q-79 *Plate 16:* A1									
Sixmile Spring 7.5' References: Q-80 MTP-187 *Plate 13:* E5	*19.5*	S22 T24N R8E	*Hwy. 372*			*Grade Separation*			
						Probable track location is within 0.5 mile of California state line, and within 0.6 mile of at least 10 homes (some new) and homes under construction in both Nevada and California.	Extensive earthwork required through hills at southern tip of Last Chance Range.		2.0 % grades.
Stewart Valley 7.5' References: Q-81 MTP-188 MTP-189 MTP-190 MTP-191 *Plate 13:* E4	23.5	S5 T24N R8E		Exit BLM proposed 2640' Utility/Trans. Corridor					
Stewart Valley 7.5' High Peak 7.5' *Plate 13:* D4, E4			Stewart Valley			Probable track location within 0.1 mile of Ash Meadows Road for about 6 miles, and within 0.4 mile of 5 homes.	Route along base of High Peak, parallel to Ash Meadow Road.		

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High Peak 7.5'	30.0	S13 T19S R51E	Amargosa Rd.			Grade Separation	Route through western hills of Last Chance Range.		
References: Q-82	34.5	S32 T18S R52E	Wash					*Bridge up to 200' long.*	2.0 % upgrade, approx. 7 miles long.
MTP-192	35.5	S29 T18S R52E	Wash					Major culvert installation.	
Plate 13: D4	37.0	S19 T18S R52E	Summit						Top of grade.
							Some heavy earthwork required		2.0 % downgrade, approx. 6 miles long. Some sharp curves.
Amargosa Flat 7.5'	39.0	S8 T18S R52E	Foot of Mt. Montgomery						
References:							Route crosses alluvial fans.	Many culverts required.	
Q-83 MTP-193 *Plate 13:* C4	45.5	S9 T17S R52E	*County road (to Crystal)*	Powerline Right-of-Way NEV059100, 80 ft. Telephone Right-of-Way NEV064817, 10 ft. Powerline Right-of-Way NEV065524, 200ft.		*Grade Separation*			
	49.5	S30 T18S R52E	County road			Signaled Grade Crossing			
Spector Range 15' *Plate 13:* A4, A5, B4, B5	52.0	S22 T16S R51E	*Match point for Amargosa Desert Section.*						

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Specter Range 15' *Plate 13:* A4, A5, B4, B5	0.0	S22 T16S R51E	*Match point for either North Pahrump Alternate or Stewart Valley Alternate.*						
	7.0	S3 T16S R50E	Rock Valley Wash					Bridge up to 200' long	
							Route around south side of Skeleton Hills		
Lathrop Wells 15' *Plate 13:* A2, A3, B2, B3	11.5	S20 T15S R50E	Hwy. 95	Highway Right-of-Way CC018078, 400 ft. Powerline Right-of-Way NEV059100, 80 ft. Telephone Right-of-Way NEV065524, 100 ft. Powerline Right-of-way NEV058116, 100 ft.		Grade Separation			1.5 % upgrade.
	15.0	S4 T15S R50E	Enter Nevada Test Site	Nevada Test Site			Probable route parallels power line.		
					One significant archeological site within corridor.				
Topopah Spring 15' *Plate 12:* E3, E4	21.0		Topopah Wash					Bridge up to 200' long	
	21.3		NTS Road			Grade Separation	Probable route is straight across Jackass Flats, west of powerline. Lack of significant topography permits flexibility in routing to accommodate NTS requirements in this area.		
	21.5		NTS Road			Signaled Grade Crossing			
	24.0		NTS Road			Signaled Grade Crossing			
	25.0		NTS Road			Signaled Grade Crossing			
	27.0		Fortymile Wash		Numerous significant archeological sites, primarily on terraces along wash.			Bridge up to 600' long. Probable location at narrow point near BM 3403.	
							Route through gap in hills 1.0 mile east of North Portal.		2.0 % upgrade. Some sharp curves.
	29.0		Repository Site (North Portal)						

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Dry Lake 15' References: Q-85 MTP-199 MTP-200 *Plate 15:* D4	0.0	S8 T19S R63E	Approx. midway between Dike and Apex near U.P. Milepost 349.	Clark County Development of Apex Heavy Industrial area Park - Public Law 101-67 would affect corridor from Dike to Apex. Connection at Dike would shorten line by approx. 2 miles, but would move probable track location approx. 0.5 mile closer to 7500 acre proposed land exchange area. Enter BLM utility corridor N52787 Powerline Right-of-Way NEV061985, 100ft. Powerline Right-of-Way NEV067348, 100ft. Powerline Right-of-Way N39815			Connection at Apex would require 2 miles additional track construction with heavy earthwork and grade separation over Hwy. 604.		Connection with U.P., directly to mainline. One mile long 1.5 % upgrade begins within 0.5 mile of connection.
	1.0	S1 T19S R62E	Enter Nellis Small Arms Range	Nellis Wilderness Study Area A, B, C Nellis Small Arms Range, to be transferred to BLM.					
Gass Peak 15' References: Q-86 MTP-201 MTP-202 MTP-203 MTP-204 MTP-205 *Plate 15:* D2, D3		*S11 T19S R62E*			One small significant archeological site within corridor.				
		S3 T19S R62E			One small significant archeological site within corridor.				Approx. 3 miles of 1.5 % upgrade.
	4.0	S3 T19S R62E					Area of very large alluvial fan (4.5 miles across).	Primary route is above North Las Vegas flood control facilities. Many large culverts required	
		S4 T19S R62E			One small significant archeological site within corridor				

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Gass Peak 15' References: Q-86 MTP-201 MTP-202 MTP-203 MTP-204 MTP-205 *Plate 15:* D2, D3	6.0	S5 T19S R62E		Closest point to 7500 proposed land exchange area. Probable track location is approx. 1.5 miles from northeast corner; elsewhere is 2.0 miles or more from northern property line.					
	6.5	S5 T19S R62E	Exit Nellis Small Arms Range						
	7.5	S1 T19S R61E	Enter Desert National Wildlife Range						
	8.5	S36 T18S R61E		Desert National Wildlife Range					
Gass Peak 15' *Plate 15:* D2, D3							Route crosses a series of alluvial fans at base of Las Vegas Range.	Some major culvert installations required.	
	14.5	S31 T18S R61E	Exit Desert National Wildlife Range				Route passes approx. 1.5 miles north of retention basin on Las Vegas Wash.		
	16.5	S26 T18S R60E	Re-enter Desert National Wildlife Range	Desert National Wildlife Range			Route crosses a series of alluvial fans at base of Las Vegas Range.	Some major culvert installations required.	
Corn Creek Springs 15' References: Q-87 MTP-206 MTP-207 MTP-208 MTP-209 *Plate 15:* C1, D1	18.0	S21 T18S R60E	Exit Desert National Wildlife Range						
	21.0	S34 T18S R59E		Quail Springs Wilderness Study Area Telephone Right-of-Way NEV065905, 20 ft.		Closest point to Las Vegas Paiute Indian Reservation. Probable track location is approx. 1.0 mile from northeast corner of Reservation.	Route crosses alluvial fans.	Many culverts required.	
	22.0	S13 T18S R59E	Las Vegas Wash		Two small unevaluated archeological sites, one on each side of Las Vegas Wash, near probable bridge site.			Bridge from north to south side of wash.	
	26.0	S9 T18S R59E				Closest point to private lands and homes in NW 1/4 S4 T18S R59E. Probable track location is approx. 0.5 mile from southwest corner of private land.			Approx. 4.5 miles of 1.5 % upgrade.

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USGS Quadrangle	Cuml. Miles *	Sec Twp Rng	Location Description	Land-Use Constraints	Archaeological & Historical Sites	Road Crossings & Proximity to Population	Topographic Considerations	Bridges & Hydrologic Considerations	Operating Considerations
Corn Creek Springs 15' *Plate 15:* C1, D1	27.5	S32 T17S R59E	Corn Creek Springs Rd.	Telephone Right-of-Way N50113 (underground), 100 ft.		Signaled Grade Crossing			
	31.0	S14 T17S R58E	First entry onto Nellis Air Force Range			Probable track location is parallel to and 0.3 to 0.8 miles north of Hwy. 95.			
				Series of firing range facilities (including many small buildings) along approx. centerline of corridor for about 2.5 miles. Relocation of some of these facilities (further north) may be necessary to keep rail line an acceptable distance from Hwy. 95.					
Black Hills SW 7.5' References: Q-88 *Plate 14:* B5				Probable track location is close to irregular boundary of Nellis Air Force Range, crossing boundary multiple times in this area. Road Right-of-Way N1197, 100 ft., in S21.					
Indian Springs SE 7.5' References: Q-89 MTP-210 MTP-211 *Plate 14: B4*	34.5	T16S R57E	*Match point for either Indian Hills Alternate or Cactus Springs Alternate.*						

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	0.0	T16S R57E	*Match point for Las Vegas Wash Section.*						
Indian Springs SE 7.5' *Plate 14:* B4	0.5	T16S R57E	Hwy. 95 (four lanes)	Highway Right-of-Way CC018191, 400 ft. Telephone Right-of-Way CC021488, 40 ft. Powerline Right-of-Way NEV043546, 100 ft.		Grade Separation			
		S28,29 T16S R57E		Withdrawal, Power Project N50954	One small significant archeological site in northern portion of corridor, south of Hwy. 95.		Route crosses series of alluvial fans along base of Spring Mtns.	Many culverts required.	Approx. 8.0 miles of 1.5 % upgrade.
	5.5	S22 T16S R56E	Eastern foot of hills	Within proposed BLM utility corridor		Probable track location is approx. 1.5 miles south of (and is not visible from) populated area at Indian Springs.			
Indian Springs 7.5' References: Q-90 MTP-212 MTP-213							Extensive earthwork needed for good alignment through eastern portion of hills. Some cuts up to 80' deep, but all are relatively short.		
Plate 14: B3	8.0	S20 T16S R56E	Summit						Top of grade.
							Route crosses alluvial fans.	Many culverts required.	Approx. 3.0 miles of 1.5 % downgrade.
	11.5	S24 T16S R55E	Willow Creek					Bridge up to 200' long.	
Mercury 15' References: Q-91		T16S R55E		Route corridor closely follows 2640' wide utility corridor. Telephone Right-of-Way CC021488, 40 ft.					
MTP-214 MTP-215 MTP-216 MTP-217 MTP-218	25.0	S36 T15S R53E	Hwy. 95 (four lanes)	Highway Right-of-Way CC018191, 400 ft.		Grade Separation			
Plate 14: A1, B1, B2	26.0	T15S R53E	Enter Nevada Test Site. *Match point for Mercury Section.*						

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Indian Springs SE 7.5' *Plate 14:* B4	0.0	T16S R57E	*Match point for Las Vegas Wash Section.*						
	1.0	T16S R57E	Road into Air Force Range			Grade Separation			
	3.5	S13 T16S R56E	Exit Nellis Air Force Range			Probable track location is parallel to and 0.3 to 0.8 miles north of Hwy. 95.			
Indian Springs 7.5' *Plate 14:* B3	5.5-6.5	S10 T16S R56E	Re-enter Nellis Air Force Range						
			Indian Springs	Indian Springs Air Force Auxiliary Field and adjacent military and civilian support facilities.		Routing north of the airfield may require a grade separation over the road into Nellis Air Force Range. Routing south of the airfield may require two signaled grade crossings in addition to the grade separation; housing on the opposite side of Hwy. 95 would be within 0.2 mile of track location.	Rail line could pass either in the open area north of the airfield (approx. 0.3 mile from end of runway) or in the narrow area between the airfield and Hwy. 95. The latter would require relocation of some Air Force and civilian facilities.		
	9.5-10.5	S1 T16S R55½E	Exit Nellis Air Force Range						
Mercury 15' *Plate 14:* A1, B1, B2	12.5	S12 T16S R55E	Indian Springs Wash					Due to width of wash (approx. 1000'), crossing may involve several dispersed spans.	
			Indian Springs Valley				Routing in the lower hills on the north side of Indian Springs Valley would require some heavy earthwork over a 3 mile distance, while routing closer to the valley bottom would require heavy earthwork only in section 12.	Routing in the valley bottom north of the wash may require channel relocation in section 12.	Up to 3 miles of 1.5 % upgrade required for routing in the lower hills.
	19.0	S2 T16S R54E	Enter Nellis Air Force Range						
	20.5	S3 T16S R54E	Clark / Nye County Line						
	23.5	S31 T15S R54E	Summit between Indian Springs Valley and Mercury Valley			Probable track location is approx. 0.2 mile from Hwy. 95 due to summit			
	25.5	T15S R53E	Enter Nevada Test Site. *Match point for Mercury Section.*						

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Mercury 15' *Plate 14:* A1, B1, B2	0.0	T15S R53E	Enter Nevada Test Site. *Match point for either Indian Hills Alternate or Cactus Springs Alternate.*	Nevada Test Site			Routing along upper slopes of Mercury Valley, between the site of Camp Desert Rock and Mercury, limits elevation changes and thereby permits moderate grades.		Short 1.5 % grades, mostly downgrades.
	1.0		Road to Tower Hill			Signaled Grade Crossing			
	2.0		Mercury Highway			Grade Separation. Closest point to town of Mercury, approx. 1.0 mile from probable track location.			
	3.0		Jackass Flats Road			Grade Separation			
							Probable route would generally parallel power line. Some short stretches of heavy earthwork.		Short 1.5 % upgrades.
Specter Range 15' *Plate 13:* A4, A5, B4, B5	10.5		Summit between Mercury Valley and Rock Valley		One small significant archeological site near summit.	Close proximity to Jackass Flats Road is likely in vicinity of summit.	Extensive earthwork in vicinity of summit.		
	11.5		Cane Spring Road		Very significant archeological site, approx. 0.5 mile in diameter, in upper portion of Rock Valley.	Signaled Grade Crossing	Probable route is along base of Skull Mtn., north of Jackass Flats Road.		Short 1.5 % downgrades.
					One small unevaluated archeological site within route corridor.				
	16.5		Jackass Flats Road		One small significant archeological site in vicinity of probable track location.	Grade Separation			
					One significant archeological site within corridor.		Some heavy earthwork along southwest side of Little Skull Mountain.		
Topopah Spring 15' *Plate 12:* E3, E4	25.5		Topopah Wash					Bridge up to 200' long.	
	25.8		NTS Road			Grade Separation	Probable route is straight across Jackass Flats, west of powerline. Lack of significant topography permits flexibility in routing to accommodate NTS requirements in this area.		1.5 % upgrade.
	26.0		NTS Road			Signaled Grade Crossing			
	28.5		NTS Road			Signaled Grade Crossing			
	29.5		NTS Road			Signaled Grade Crossing			
	31.5		Fortymile Wash		Numerous significant archeological sites, primarily on terraces along wash.			Bridge up to 600' long. Probable location at narrow point near BM 3403.	
							Route through gap in hills 1.0 mile east of North Portal.		2.0 % upgrade. Some sharp curves.
	33.5		Repository Site (North Portal)						

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Beowawe 15'** Reference: Q-42 MTP-43 MTP-44 *Plate 1*: B5	0.0	S9 T31N R49E	Vicinity Beowawe			Connection is about 1.5 miles east of Beowawe and within 1.0 miles of a school.			Connection with Southern Pacific (directly to mainline). Connection with Union Pacific is via crossover(s) between S.P. and U.P.
Dunphy 15'** Reference: Q-43 MTP-45 MTP-46 *Plate 1*: B4	6.0	S1,2 T30N R48E			One significant archeological site within corridor.				
Crescent Valley 15'** Reference: Q-44 MTP-47 MTP-48 MTP-49 MTP-50 ** Every other section is private land in a checkerboard fashion. See Table 4.1 *Plate 1*: C4, D3, D4	12.8	S3 T29N R48E		Recreation and Public Purposes Lease N38444		Grade Separation			
	13.5	S4 T29N R48E		Material Pit N39953 Road Right-of-Way N35119		Corridor is about 1.0 mile east of the town of Crescent Valley			
	17.6	S29,30 T29N R48E	Eureka/Lander county line.	Airport Lease N56882					
	17.7	S29 T29N R48E		Road Right-of-Way N35118 Telephone Right-of-Way N2616 (underground), 10 ft.		Signalized Grade Crossing			
	20.0	S6 T28N R48E		Road Right-of-Way N52826, 60 ft.		Grade Separation			
	21.2	S12 T28N R47E		Telephone Right-of-Way N55672 (underground), 10 ft.		Signalized Grade Crossing			
	21.8	S12 T28N R47E		Powerline		Signalized Grade Crossing			

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Cortez 15' Reference: Q-45 MTP-51 MTP-52 MTP-53 MTP-54 MTP-55 *Plate 2:* A4	27.0	T27N R47E	Corridor passes between Cortez and Gold Acres mining operations.						
	28.5	S8 T27N R47E		Telephone Right-of-Way N7808, 30 ft. Road Right-of-Way N43670, 50 ft.		Signalized Grade Crossing			
	28.8	S8 T27N R47E		Telephone Right-of-Way N30650, 10 ft.		Signalized Grade Crossing			
	31.0	S13 T27N R47E			One small unevaluated archeological site within corridor.				
Carico Lake 15' Reference: Q-46 MTP-56 *Plate 2:* A3	33.5	S26 T27N R46E	Vicinity Rocky Pass	Telephone Right-of-Way N30650, 10 ft.					
				Mining Patent					
	35.8	S3 T26N R46E				Signalized Grade Crossing			2% Upgrade
	46.0	S20 T25N R46E	Dry Canyon Summit						Top of Grade
									2% Downgrade
	49.0	S33 T25N R46E	Dry Canyon Spring						
Hall Creek 15' Reference: Q-47 *Plate 2:* B3, C3	56.0	S3 T23N R46E		Fence	Several Unevaluated archeological sites at various springs within corridor.				
Walti Hot Springs 15' Reference: Q-48 *Plate 2:* B4, C4	64.0	T22N R46E		Withdrawal, N378, Desert Land Entry. Beginning of split corridor.	One large unevaluated archeological site at quarry within corridor.		Route crosses a series of alluvial fans.		

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USGS Quadrangle	Cuml. Miles *	Sec Twp Rng	Location Description	Land-Use Constraints	Archeological & Historical Sites	Road Crossings & Proximity to Population	Topographic Considerations	Bridges & Hydrologic Considerations	Operating Considerations
Ackerman Canyon 15' Reference: Q-49 *Plate 2:* D4	66.0	T22N R46E		Mining Patent, State Selection					
	69.0	S11 T21N R46E			Very significant Burial ground near ranch within corridor.				
Mount Callaghan 15' Reference: Q-50 MTP-57 MTP-58 MTP-59 MTP-60 MTP-61 MTP-62 *Plate 2:* D2, D3, E3, E4	70.0	S3 T21N R46E		Corridor is split for approximately 15 miles due to private lands.	Large unevaluated archeological site, 2.0 miles long, along creek extending into corridor.				
	72.0	S9,10,16 T21N R46E	Grass Valley Ranch			Corridor passes within 1.0 mile of ranch.			
	75.5	S29 T21N R46E				Signalized Grade Crossing			
	79.0	S7 T20N R46E		End of split corridor					2% Upgrade
	81.0	S18 T20N R45E	Rye Patch Canyon Summit						Top of Grade
	83.0	S25 T20N R45E		Powerline Right-of-Way N5253, 125 ft.	One significant archeological site within corridor 0.5 mile east of high point in section 25.				
Spencer Hot Springs 15' *Plate 3:* A2, A3, B2	88.0	S24 T19N R45E	*Match point for either Big Smoky Valley Alternate or Monitor Valley Alternate.*	Powerline Right-of-Way N25341, 140 ft. Telephone Row N51021, 15 ft. Comm Site N51021					

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USGS Quadrangle	Cuml. Miles *	Sec Twp Rng	Location Description	Land-Use Constraints	Archeological & Historical Sites	Road Crossings & Proximity to Population	Topographic Considerations	Bridges & Hydrologic Considerations	Operating Considerations
Spencer Hot Springs 15' References: Q-51 MTP-63 MTP-64 MTP-65 MTP-66 MTP-67 *Plate 3:* A2, A3, B2	0.0	S24 T19N R45E	*Match point for Crescent Valley Section.*	Road Row NEV042796, 200 ft.					
	0.5	S24 T19N R45E	Pony Express Trail		Pony Express Trail is a historical crossing.				
	4.0	S1,2 T18N R45E		Road Row N7219, 66 ft. Well N39525	One significant archeological site within corridor.				
	7.4	S27 T18N R45E				Signalized Grade Crossing			
	10.4	S10 T17N R45E				Signalized Grade Crossing			
Wildcat Peak 15' Reference: Q-52 *Plate 3:* C2, D2	24.3	S17 T15N R45E	Lander/Nye county line	Fence			Route crosses a long series of alluvial fans.		
Millett Ranch 15' References: Q-53 MTP-68 *Plate 3:* D1				Road Right-of-Way N6971, 70 ft.					
Carvers, NE 7.5' Reference: Q-54 *Plate 3:* E1	45.0	S18 T12N R44E		Withdrawal N37187, Desert Land Entry Withdrawal N37189, Desert Land Entry		Signalized Grade Crossing			

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Carvers SE 7.5' References: Q-55 MTP-69 MTP-70 MTP-71 MTP-72 *Plate 4:* A5	53.0	S24 T11N R43E		Withdrawal N37188, Desert Land Entry Powerline Right-of-Way N25341, 140 ft. Withdrawal R-0345					
Carvers 7.5' References: Q-56 MTP-73 MTP-74 *Plate 4:* A4	56.5	S3 T10N R43E		Road Right-of-Way N39967, 80 ft. Flume Right-of-Way N39891, 10 ft.		Grade Separation, Highway 376			

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USGS Quadrangle	Cuml. Miles *	Sec Twp Rng	Location Description	Land-Use Constraints	Archeological & Historical Sites	Road Crossings & Proximity to Population	Topographic Considerations	Bridges & Hydrologic Considerations	Operating Considerations
Pablo Canyon Ranch 7.5' Reference: Q-57 *Plate 4:* B4	59.0	S20 T10N R43E		Corridor is split for approximately 10 miles due to the town of Hadley, the Hadley Airport and private lands. West Leg: Powerline Right-of-Way NEV064717, 30 ft. Pipeline Right-of-Way CC09123, 100 ft. Powerline Right-of-Way N55147, 250 ft. Powerline Right-of-Way N11777, 25 ft. Pipeline Right-of-Way N46536, 50 ft. Road Right-of-Way N46508, 100 ft.		Grade Separation			
	61.0	S28 T10N R43E		Withdrawal N39765, Desert Land Entry Withdrawal N53593, Desert Land Entry East Leg: Right-of-Way N54310, 12 ft. Powerline Right-of-Way N55147, 250 ft Pipeline Right-of-Way N45089 (underground), 50 ft. Powerline Right-of-Way N11777, 25 ft. Telephone Right-of-Way N46314 (underground), 100 ft. Road Right-of-Way N46508, 100 ft.		Corridor is within 1.0 mile of city of Hadley.			

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USGS Quadrangle	Cuml. Miles *	Sec Twp Rng	Location Description	Land-Use Constraints	Archeological & Historical Sites	Road Crossings & Proximity to Population	Topographic Considerations	Bridges & Hydrologic Considerations	Operating Considerations
Round Mountain 7.5' References: Q-58 MTP-75 *Plate 4:* B5	61.5	S29 T10N R43E		Powerline Right-of-Way N25341, 40 ft. Recreation and Public Purposes Lease, N34726 Road Right-of-Way N53177, 60 ft. Highway Right-of-Way CC020778 Telephone Right-of Way N33405, 20 ft. Road Right-of Way N54310, 12 ft. Flume Right-of-Way N54310, 15 ft. Pipeline Right-of-Way N45089 (underground), 30 ft. Powerline Right-of-Way N55247, 250 ft.	Jett Canyon Pipeline is a significant historical site across corridor.	Signalized Grade Crossing			
	63.0	S5 T9N R43E							
Seyler Peak 7.5' References: Q-59 MTP-76 MTP-77 MTP-78 *Plate 4:* C4	72.5	S24 T8N R42E				Signalized Grade Crossing			
San Antonio Ranch 15' References: Q-60 MTP-79 MTP-80 MTP-81 *Plate 4:* D3, E3	*85.0*	*S11 T6N R41E*	*Match point for Klondike Alternate.*						

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USGS Quadrangle	Cuml. Miles *	Sec Twp Rng	Location Description	Land-Use Constraints	Archeological & Historical Sites	Road Crossings & Proximity to Population	Topographic Considerations	Bridges & Hydrologic Considerations	Operating Considerations
San Antonio Ranch 15' *Plate 4:* D3, E3	0.0	S11 T6n R41E	*Match point for either Big Smoky Valley Alternate or Baxter Springs Alternate.*						
Baxter Spring 15' References: Q-61 MTP-82 MTP-88 *Plate 4:* D4, D5, E4, E5	2.0	S23 T6N R41E			One significant archeological site within corridor				
	16.5	S35 T4N R41E				Grade Separation			
	16.7	S35T4N R41E	Nye/Esmeralda county line						
Lone Mountain 15' References: Q-62 MTP-89 MTP-90 MTP-91 MTP-92 MTP-93 *Plate 6:* A2, B2	18.3	S11 T3N R41E		Highway Right-of-Way CC018394, 400 ft. Telephone Right-of-Way CC021488, 40 ft. Powerline Right-of-Way NEV043264, 60 ft. Powerline Right-of-Way N33242, 75 ft.	One unevaluated archeological site within corridor.		Route crosses a long series of alluvial fans.		
	20.6	S24 T3N R41E				Grade Separation			
	23.2	S1 T2N R41E			Old railroad grade is a significant historical site crossing corridor.				
Klondike 7.5' References: Q-63 MTP-94 MTP-95 *Plate 6:* C2	31.1	S10 T1N R42E		Powerline Right-of-Way NEV043264, 50 ft. Highway Right-of-Way N10914		Grade Separation			
	33.5	S24 T1N R42E	Vicinity Klondike						

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Mud Lake 15' References: Q-64 MTP-96 MTP-97 MTP-123 MTP-124 MTP-125 MTP-126 MTP-127 *Plate 6:* C3, C4, D3, D4	35.0	S25 T1N R42E		Telephone Right-of-Way CC021489, 40 ft. Powerline Right-of-Way CC020795, 400 ft.	Significant archeological site within corridor in mining area.		Route passes through rugged area with high cuts and fills.		
	38.5	S4 T1S R42E	Esmeralda/Nye county line						
	39.5	S9 T1S R42E	*Match point for Goldfield Section.*						

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Spencer Hot Springs 15' *Plate 3:* A2, A3, B2	0.0	S26 T19N *R45E*	*Match point for Crescent Valley Section*						
	6.0	S35 T19N R45E, S1,12,13,24 T18N R45E	Adjacent to Overland Express Route		One significant site in Rye Patch Canyon.				
	8.0	T18N R46E	South end of Cape Horn (Simpson Park Mountains)	Material Site NEV044851	Overland Stage Station near Cape Horn is eligible for *National Register of Historic* Places.				
	13.5	T18N R46E	Cross Highway 50	Highway Right-of Way NEV042796, 200 ft.		Route parallels Highway 50 from Cape Horn to grade separation at east edge of Spencer Hot Springs Quad.	Extensive earthwork and rock excavation required for 5.5 miles.	130 linear foot bridge.	
Hickison Summit 15' References: Q-65 MTP-98 MTP-99 MTP-100 MTP-101 MTP-102 MTP-103 *Plate 3:* A4, B4	18.0	T18N R46E	Summit of Toquima Range	Road Right-of-Way NEV042778, 400 ft.	Significant petroglyph site north of the highway near Hickison Summit must be avoided.		Extensive earthwork and rock excavation required for 8.5 miles over Toquima Range.		
	22.0	T17 N R47E	East foot of Toquima Range						
Dianas Punch Bowl 15' References: Q-66 MTP-104 MTP-105 MTP-106 *Plate 3:* C4, D4	39.5	S35 T15N R47E	Potts Ranch Vicinity		Monitor Ranch is eligible for National Register of Historic Places.	Signalled crossing of Highway 82.		Two major drainage structures	
	43.7	S21 T14N R47E	Dianas Punch Bowl Vicinity		Significant site at Dianas Punch Bowl hot springs.				
Box Spring 7.5' References: Q-67 MTP-107 MTP-108 MTP-109 MTP-110 *Plate 3:* B4	49.5	T13N R47E	West of Dry Lake		Two large "no-record" sites and several small "no-record" sites.	Two signalled crossings of Highway 82.		Two major drainage structures.	

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USGS Quadrangle	Cuml. Miles *	Sec Twp Rng	Location Description	Land-Use Constraints	Archeological & Historical Sites	Road Crossings & Proximity to Population	Topographic Considerations	Bridges & Hydrologic Considerations	Operating Considerations
Mosquito Creek 7.5' References: Q-68 *Plate 5:* A3	60.0	S1 T11N R47E	Mosquito Creek secondary road crossing		Two unevaluated sites in Mosquito Creek area.				
Pine Creek Ranch 7.5' References: Q-69 *Plate 5:* A2	65.0	S26,35 T11N R46E	Pine Creek Ranch secondary road crossings						
Corcoran Canyon 7.5' References: Q-70 MTP-111 MTP-112 *Plate 5:* B2	70.0	T10N R46E	Stone House Ranch secondary road crossing	Application N27690, Desert Land Entry Road Right-of-Way N6926, 60 ft.					
Belmont East 7.5' References: Q-71 MTP-113 MTP-114 MTP-115 MTP-116 *Plate 5:* C2	74.0	S18 T9N R46E	East of Black Butte			Signalled crossing		Three major drainage structures.	
	80.0	S24 T8N R45E	*Match point for either Baxter Spring Alternate or Ralston Valley Alternate*				Extensive earthwork required for 2.5 miles in the Horse Heaven Summit area.		

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Belmont East 7.5' *Plate 5:* C2	0.0	S24 T8N R45E	*Match point for Monitor Valley Alternate.*	Application N36381, Desert Land Entry Application N34295, Desert Land Entry Application N34294, Desert Land Entry Application N36210, Desert Land Entry Application N36211, Desert Land Entry					
	2.5	S14 T8N R45E	Monarch site vicinity		Town site of Monarch is an unevaluated site. Section 17 is an unevaluated site.				
Big Ten Peak West 7.5' Reference: Q-72 MTP-117 MTP-118 *Plate 5:* D1	13.0	T7N R45E	North of Big Ten Well	Application N30010, Desert Land Entry Application N30009, Desert Land Entry		Cross Highway 82- Signalled Grade Crossing		130 lineal foot bridge and five major drainage structures.	
	14.0	T7N R45E	West of Big Ten Well Vicinity						
Baxter Spring 15' *Plate 4:* D4, D5, E4, E5	25.0	S16 T6N R43E	Highway 8A			Cross Highway 8A- Signalled Grade Crossing	Route crosses a series of alluvial fans at south end of Toquima Range	Cut through alluvial fan will require culverts and erosion protection measures 130 lineal foot bridge and one major drainage structure.	
San Antonio Ranch 15' *Plate 4:* D3, E3	37.0	S27 T5N R41E	*Match point for Klondike Alternate.*	Powerline Right-of-Way N25341, 140 ft. Powerline Right-of-Way NEV043264, 100ft. Powerline Right-of-Way N33242, 75 ft.			Route crosses a series of alluvial fans at north end of San Antonio Mountains	Cut through alluvial fan will require culverts and erosion protection measures	

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Belmont East 7.5' *Plate 5:* C2	0.0	S24 T8N R45E	*Match point for Monitor Valley Alternate*						
	2.5	S14 T8N R45E	Monarch site vicinity		Town site of Monarch is an unevaluated site. Section 17 is an unevaluated site.	One signalled road crossing			
Big Ten Peak West 7.5' *Plate 5:* D1	8.5	T7N R45E	Hunts Canyon					200 lineal foot bridge and one major drainage structure.	
	13.0	T7N R45E	East of Big Ten Well						
Baxter Spring 15' *Plate 4:* D4, D5, E4, E5	26.0	S28, T4N R44E	West of Thunder Mountain	Telephone Right-of-Way N4213, 20 ft. Pipeline Right-of-Way R-0240, 10 ft. Highway Right-of-Way CC020465, 400 ft.					
Tonopah 15' References: Q-73 MTP-119 MTP-120 MTP-121 MTP-122 *Plate 6:* A4, B4	38.0	S34, T3N R44E	Cross US 6	Powerline Right-of-Way NEV061459, 30 ft. Powerline Right-of-Way N32741 (underground), 10 ft. Powerline Right-of-Way NEV048554, 25 ft.		Grade separation at US 6		130 lineal foot bridge drainage structure.	
Mud Lake 15' *Plate 6:* C3, C4, D3, D4	55.0	S9, T1S R42E	*Match point for Goldfield Section.*		Significant sites north of Mud Lake, see discussion in Caliente description.				

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Caliente 7.5' References: Q-1 *Plate 10:* E4	0.0		Caliente			Route is within 0.1 mile of Nevada Girls Training Center.			Connection with Union Pacific (to passing siding).
	0.5		Road to Nevada Girls Training Center			Signalled Grade Crossing. Route is within 0.1 mile of housing areas and within 0.2 mile of hospital.		Bridge up to 150' long. (Clover Creek)	
	0.8		1st crossing. Meadow Valley Wash				Use roadbed of abandoned U.P. Pioche Branch along bottom of canyon formed by Meadow Valley Wash.	Bridge up to 170' long.	
Chief Mountain 7.5' References: Q-2 *Plate 10:* D4	1.3	S5 T4S R67E	2nd crossing. Meadow Valley Wash		Abandoned U.P. roadbed is an unevaluated site.	Route is parallel to and approx. 100' from Hwy. 93.		Bridge up to 200' long.	
Indian Cove 7.5' References: Q-3 MTP-1 MTP-2 *Plate 10:* D5	3.2	S28 T3S R67E	3rd crossing. Meadow Valley Wash	Fence				Bridge up to 150' long.	Bridge on sharp curve.
	3.3	S28 T3S R67E	4th crossing. Meadow Valley Wash					Bridge up to 150' long.	
	3.6	S28 T3S R67E	5th crossing. Meadow Valley Wash					Bridge up to 150' long.	
	7.0	S11 T3S R67E	Small wash	Fence				Bridge up to 75' long.	
	8.2	S2 T3S R67E	Branch of Meadow Valley Wash		Significant site near west corridor boundary.	Route is roughly parallel to Hwy. 93, distance varies from 100' to 1500'.	Use roadbed of abandoned U.P. Pioche Branch across Meadow Valley.	Bridge up to 150' long.	
					Abandoned U.P. roadbed is an unevaluated site.				
	10.5	S25 T2S R67E	Branch of Meadow Valley Wash					Bridge up to 600' long.	
Panaca 7.5' References: Q-4 MTP-1 *Plate 10:* C5	10.9	S25 T2S R67E	Hwy. 93	Telephone Right-of-Way N43923 (underground), 10 ft.		Grade Separation			
Bennett Pass 7.5' References: Q-5 MTP-3 *Plate 10:* C4		S7 T2S R67E			Unevaluated site near Bennett Springs.		Route ascends Chief Range generally along south side of Bennett Springs Wash, using a loop in upper hills to gain elevation.		2.2 % upgrade. Some sharp curves.
		S36 T1S R66E			Unevaluated site near west corridor boundary.				
	22.2		Bennett Pass	Telephone Right-of-Way N43923 (underground), 10 ft. Powerline Right-of-Way CC020073, 100 ft.			Route passes between Chief and Highland Ranges.		

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Bennett Pass 7.5'									2.0 % downgrade.
	27.4	S11 T2S R65E	Black Canyon					Bridge up to 200' long.	
The Bluffs 7.5' References: Q-7 MTP-3 MTP-5 MTP-12 *Plate 10:* C3									
Deadman Spring SE 7.5' References: Q-6 MTP-4 MTP-5 *Plate 10:* C2	35.1	S34 T1S R64E	Coyote Wash	Fence			Route is nearly straight across Dry Lake Valley.	Bridge up to 500' long.	
	35.6	S23 T1S R64E	Branch of Coyote Wash					Bridge up to 500' long.	
	37.3	S22 T1S R64E	Small wash					Bridge up to 300' long.	
Deadman Spring NE 7.5' References: Q-8 MTP-6 *Plate 10:* B2				Fence Fence Pipeline Right-of-Way 4070					2.3 % upgrade.
	47.1		Summit	Pipeline Right-of-Way 4070	Significant site near Black Rock Spring.		Pass through North Pahroc Range.		
Deadman Spring 7.5' References: Q-9 MTP-7 MTP-8 MTP-9 MTP-10 *Plate 10:* B1					Two large significant sites on the west side of the White River, approx. 3 to 6 miles south of probable bridge site.		Extensive earthwork; cuts and fills range up to 60'.		1.6 % downgrade. Shifting the proposed site of the White River bridge further south would increase grade to as much as 2.0 %.
Silver King Mtn. SW 7.5' References: Q-10 MTP-11 *Plate 10:* A1	54.0	S19 T2N R63E	Hwy. 318	Highway Right-of-Way N43923, 400 ft.		Grade Separation			
	54.4	S19 T2N R63E	White River	Road Right-of-Way N14148, 60 ft Material Site.				Bridge up to 400' long. Location up to 1.5 miles further south may offer better bridge site and improved route profile to west.	

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Timber Mtn. Pass East 7.5'	58.7	S34 T3N R62E	Lincoln / Nye County Line						
Reference: Q-11 MTP-13 MTP-14		S32 T3N R62E		Fence					2.3 % upgrade. Grade could be reduced to 2.0 % by shifting proposed site of the White River bridge further south.
Plate 9: D5		T3N R61E		Road Right-of-Way N53636, 40 ft.					
Timber Mtn. Pass West 7.5'	66.2		Timber Mtn. Pass	Road Right-of-Way N53636, 40 ft.			Pass through Seaman Range.		
Reference: Q-12 MTP-15 *Plate 9:* D4				Fence					2.4 % downgrade. Grade could be reduced to 2.0 % by adding distance through larger loops.
Water Gap East 7.5'	77.0		Small wash	Fence			Coal Valley	Bridge up to 300' long.	
Reference: Q-13 MTP-16 MTP-17 MTP-18				Road Right-of-Way N53636, 40 ft.					2.2 % upgrade.
Plate 9: D3	81.9		Summit	Road Right-of-Way N57490, 60 ft. Fence			Pass through Golden Gate Range. Alternate route approx. 4 miles to the south through Water Gap would reduce grades.		

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Water Gap West 7.5'							Route nearly straight across Garden Valley.		2.2 % downgrade.
References: Q-14 MTP-19	84.0		Small wash					Bridge up to 500' long.	
	87.6		Cherry Creek					Bridge up to 200' long.	
	88.9		Sand Creek					Bridge up to 200' long.	
Plate 9: D2	89.3		Nye / Lincoln County Line	Pipeline Right-of-Way 4137					
Wadsworth Ranch 7.5' References: Q-15 MTP-20	90.4		Pine Creek	Pipeline Right-of-Way/Reservoir 4137				Bridge up to 400' long.	
Plate 9: D1	93.4		Cottonwood Creek	Pipeline Right-of-Way 4026				Bridge up to 300' long.	
Worthington Peak 7.5' References: Q-16 MTP-16 MTP-17	94.8	S32 T2N R57E	Barton Creek	Pipeline Right-of-Way 4026			Route nearly straight across Garden Valley.	Bridge up to 300' long.	
Plate 9: E1		S1, 12 T1N R56E		Oil/Gas Lease					1.5 % upgrade.
McCutchen Spring 7.5' References: Q-17 MTP-16 MTP-21 MTP-22	100.5	S11 T1N R56E	Summit	Oil/Gas Lease N52646 Oil/Gas Lease N52649 Oil/Gas Lease N52648 Oil/Gas Lease N52650 Oil/Gas Lease N52651			Route passes between Quinn Canyon Range and Worthington Mountains.		
Plate 8: B5									2.2 % downgrade.
	105.2	S19 T1N R56E	Davis Creek					Bridge up to 300' long.	
Quinn Canyon Springs 7.5' References: Q-18 MTP-22 *Plate 8:* B4	109.0	S28 T1N R55E	Quinn Canyon Creek				Route nearly straight along northwest side of Sand Spring Valley.	Bridge up to 500' long.	

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Honest John Well 7.5' References: Q-19 MTP-23 *Plate 8:* C4									
Black Top 7.5'	116.7		Lincoln /Nye County Line						
Q-20 MTP-24	119.0		Summit		Unevaluated site near southern corridor boundary.		Pass through Quinn Canyon Range.		
				Fence			Railroad Valley		1.4 % downgrade.
Plate 8: C3	124.3	S10 T2S R53E	Hwy. 375	Material Site	Two unevaluated sites near probable grade separation.	Grade Separation			
Reveille Peak 15' References: Q-21 MTP-25 MTP-26 MTP-27				Probable track location is within 2.5 miles of Nellis Air Force Range boundary. Pipeline Right-of-Way 0641 Pipeline Right-of-Way 04976 Pipeline Right-of-Way 4717		Probable track location is parallel to and within 0.1 mile of secondary roads for a total of approx. 32 miles.			
MTP-28 MTP-29 MTP-30 MTP-31	135.2	T2S R50E	Small wash					Bridge up to 400' long.	
Plate 8: B1, C1, C2		T1S R52E			Unevaluated site near BM 5926.				
Kawich Peak 15' References: Q-22 MTP-32 MTP-33 MTP-34 MTP-35 MTP-36 *Plate 7:* C4, C5, D4				Pipeline Right-of-Way 4976 Pipeline Right-of-Way 4717 Pipeline Right-of-Way 0659			Route is largely straight through Reveille Valley.		

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USGS Quadrangle	Cuml. Miles *	Sec Twp Rng	Location Description	Land-Use Constraints	Archeological & Historical Sites	Road Crossings & Proximity to Population	Topographic Considerations	Bridges & Hydrologic Considerations	Operating Considerations
Warm Springs 15' References: Q-23 MTP-37 MTP-38 MTP-39 MTP-40 MTP-41 MTP-42 *Plate 7:* A4, A5, B4, B5		S22 T2N R50E			Reveille Mill is an unevaluated site.				
	163.2	T3N R50E	Cow Canyon					Bridge up to 500' long.	
				Pipeline Right-of-Way 0668 Pipeline Right-of-Way 0139					2.3 % upgrade.
	169.2	T4N R49E	Summit			Probable track location is parallel to and within 0.1 mile of Hwy 6 for approx. 1.0 mile.	Route passes between Kawich and Hot Creek Ranges.		
					Clifford mine is an unevaluated site.				2.0 % downgrade.
Stone Cabin Ranch SE 7.5' References: Q-24 *Plate 7:* B3	178.0	S26 T3N R48E	Branch of Bellehelen Canyon Creek	Pipeline Right-of-Way R3523				Bridge up to 400' long.	
Stone Cabin Ranch SW 7.5' References: Q-25 *Plate 7:* B2	182.9	S8 T2N R48E	Haws Canyon Creek			Probable track location is parallel to and within 0.1 mile of secondary road for approx. 9.0 miles.	Route nearly straight across Stone Cabin Valley.	Bridge up to 600' long.	
Stinking Spring 15' References: Q-26 MTP-123 MTP-124 MTP-125 MTP-126 *Plate 7:* C2, C3				Flightline Right-of-Way NEV052668, 400 ft.					
		S30 T1N R47E		Communications Site/Access Road Right-of-Way N26253 Pipeline Right-of-Way N26253 Powerline Right-of-Way N4436, 40 ft.	Unevaluated site within corridor.		Cactus Flat		

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USGS Quadrangle	Cuml. Miles *	Sec Twp Rng	Location Description	Land-Use Constraints	Archeological & Historical Sites	Road Crossings & Proximity to Population	Topographic Considerations	Bridges & Hydrologic Considerations	Operating Considerations
Cactus Peak 15' Reference: Q-27 *Plate 6:* C5		S19 T1N R46E			Reeds Ranch is a significant site.				
	199.1		Large unnamed wash from northern Cactus Flat					Bridge up to 1000' long.	
	199.8		Small wash					Bridge up to 400' long.	
				Probable track location is within 0.5 mile of Nellis Air Force Range boundary. Flightline Right-of-Way NEV052668, 400 ft. Powerline Right-of-Way N33242, 75 ft.			Route traverses Ralston Valley using flat curves and long tangents, passing north and west of Mud Lake.		
Mud Lake 15' *Plate 6:* C3, C4, D3, D4	208.6		Large unnamed wash from northeastern Ralston Valley					Bridge up to 700' long.	
		T1N R44E T1N R43E			Several very significant sites within 2.0 miles of north end of Mud Lake.				
	219.6	S9 T1S R43E	*Match point for Goldfield Section.*						

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USGS Quadrangle	Cuml. Miles *	Sec Twp Rng	Location Description	Land-Use Constraints	Archeological & Historical Sites	Road Crossings & Proximity to Population	Topographic Considerations	Bridges & Hydrologic Considerations	Operating Considerations
	0.0	S9 T1S R43E	*Match print for either Reveille Section (Caliente Route) or Klondike / Ralston Valley Sections (Beowawe Route).*	Mining Patent (Irregular Shape), east edge of main route.			Alternate corridor 4 to 7 miles to the east would avoid high summit near Espina Hill, reducing grades to less than 1.5 %, but would penetrate Nellis Air Force Range up to 3.5 miles over a distance of approx. 14 miles.		2.3 % upgrade.
Mud Lake 15'		S28 T2S R43E			Significant site at Tognoni Springs.				
	9.9	S34 T2S R43E	Summit near Espina Hill			Probable track location is within *4.0 miles of Goldfield.*			
Plate 6: C4, C5, D3, D4		S2 T3S R43E		Five Mining Patents (Irregular Shape)	Significant site at Willow Springs.				
		S5,8 T3S R44E			Six unevaluated sites within alternate corridor.				2.4 % downgrade. Some sharp curves.
	21.3	S22 T4S R43E	Small unnamed wash from Cuprite Hills				Stonewall Flat	Bridge up to 200' lng.	
Gold Field 15' References: Q-28 MTP-127 MTP-128 MTP-129 MTP-130 MTP-131 *Plate 11:* A2, A3									
Stonewall Pass 7.5' References: Q-29 MTP-132 *Plate 11:* B2					Old railroad grades are unevaluated sites. Significant site along lakebed near highway.		Lida Valley		
Scottys Junction NE References:	33.0	T6S R43E	Large unnamed wash from Lida Valley		Old railroad grades are unevaluated sites.			Bridge up to 1200' lng.	
Plate 11: B3	34.7	T6S R43E	Summit						

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USGS Quadrangle	Cuml. Miles *	Sec Twp Rng	Location Description	Land-Use Constraints	Archeological & Historical Sites	Road Crossings & Proximity to Population	Topographic Considerations	Bridges & Hydrologic Considerations	Operating Considerations
Scottys Junction 7.5' Reference: Q-31 MTP-133 MTP-134 MTP-135 *Plate 11:* C4		T7S R43E		Material Sites Telephone Right-of-Way CC021488, 40 ft. Powerline Right-of-Way NEV066136, 20 ft. Powerline Right-of-Way N1614, 20 ft.					2.0 % downgrade.
	40.9	S17 T7S R44E	Large unnamed wash from upper Sarcobatus Flat	Powerline Right-of-Way NEV0665524, 200 ft.		If routed west of Hwy. 95, probable track location is within 1.5 miles of both Hwy. 95 and occupied housing. *If routed* through Nellis Air Force Range, track location is within 1.0 mile of housing and 2.0 miles of Hwy. 95.	Route is nearly straight across Sarcobatus Flat. Two route corridors are possible, one on either side of *Hwy. 95*. These corridors avoid private lands and housing throughout the 4 milestretch south of Scottys Junction. The corridor west of the Hwy. 95 requires an *(continued on next page)*	Bridge up to 1300' long.	
		S32 T7S R44E			Small unevaluated site.				
Bonnie Claire 7.5' References: Q-32 *Plate 11:* D3		S34 T8S R44E			Small unevaluated site.				
Tolicha Peak 15' References: Q-32 MTP-136 MTP-137 *Plate 11:* C4									

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USGS Quadrangle	Cuml. Miles *	Sec Twp Rng	Location Description	Land-Use Constraints	Archeological & Historical Sites	Road Crossings & Proximity to Population	Topographic Considerations	Bridges & Hydrologic Considerations	Operating Considerations
Springdale 15' References: Q-33 MTP-138 MTP-139 MTP-140 MTP-141 MTP-142 *Plate 11:* D4, D5, E5	49.1	T8S R44E	Hwy. 95	Telephone Right-of-Way CC02148, 40 ft. Powerline Right-of-Way NEV 066116, 20 ft. *Material Site* Powerline Right-of-Way NEV065524, 200 ft.		Grade Separation	*(cont. from previous page)* additional grade separation (at mileage 43.1), over Hwy. 72. The corridor east of Hwy. 95 penetrates the Nellis Air Force Range a maximum of 3.0 miles over a distance of approx. 17 miles, and would potentially avoid the two grade separations over Hwy. 95 as well as over Hwy. 72.		
	50.6	T8S R45E	Tolicha Wash	Fence Numerous Material Sites				Bridge up to 500' long.	
	55.4	T9S R45E	Hwy. 95	Road Right-of-Way N47795, 60 ft. Telephone Right-of-Way N24739, 20 ft. Road Right-of-Way N47795, 30 ft. Powerline Right-of-Way NEV065524, 200 ft.	Small unevaluated site near probable grade separation.	Grade Separation			
Thirsty Canyon 15' References: Q-34 MTP-143 MTP-144 MTP-145 *Plate 12:* C1	70.2	S22 T10S R47E	Thirsty Canyon Wash	Powerline Right-of-Way NEV065524, 200 ft.				Bridge up to 1200' long.	
				Powerline Right-of-Way N57777, 20 ft. Road Right-of-Way N52809, 30 ft.		Probable track location is within 2.0 miles of housing along upper Amargosa River.			

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USGS Quadrangle	Cuml. Miles *	Sec Twp Rng	Location Description	Land-Use Constraints	Archeological & Historical Sites	Road Crossings & Proximity to Population	Topographic Considerations	Bridges & Hydrologic Considerations	Operating Considerations
Bare Mtn. 15' References: Q-35 MTP-146 MTP-147 MTP-148 MTP-149 MTP-150 MTP-151 MTP-152 *Plate I2:* D1, D2, E2	78.9	T11S R48E	Beatty Wash		Small unevaluated site along bottom of wash near west edge of corridor.			Bridge up to 300' long.	
							Route is very circuitous in ascent to summit, involving large loop to increase distance and reduce grade.		2.0 % upgrade. Many sharp curves.
	81.9	T11S R48E	Summit			Probable track location is within 7.0 miles of Beatty.			
							Route is very circuitous in northern portion of Crater Flat. Descent from summit involves several large loops to increase distance and reduce grade. Alternate corridor area, which clips corner of Nellis Air Force Range for approx 4 miles, would facilitate an alignment approx. 8.5 miles shorter.		1.8 % downgrade. Many sharp curves.
Big Dome 15' References: Q-36 MTP-153 MTP-154 *Plate I3:* A1	105.3	T14S R49E	Southern tip of Yucca Mtn.			Probable route is approx. 4.5 miles from Hwy. 95.	Route around southern tip of Yucca Mtn.		
Lathrop Wells 15' References: Q-37 MTP-219 MTP-220 MTP-221 MTP-222 *Plate I3:* A2, A3, B2, B3	109.2	T14S R49E	Enter Nevada Test Site.	Nevada Test Site.					Undulating profile with grades up to 2.2 %. Some sharp curves.

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USGS Quadrangle	Cuml. Miles *	Sec Twp Rng	Location Description	Land-Use Constraints	Archeological & Historical Sites	Road Crossings & Proximity to Population	Topographic Considerations	Bridges & Hydrologic Considerations	Operating Considerations
Tonopah Spring 15' References: Q-38 MTP-155 MTP-223 *Plate 12:* E3, E4					Numerous significant sites, primarily on terraces along Fortymile Wash.		Route along west side of Fortymile Wash, close to base of hills to avoid archaeological sites.		2.2 % maximum upgrade. Some sharp curves.
	117.4		Road to Repository Site from Hwy. 95.			Signalled Grade Crossing	Route through gap in hills 1.0 mile east of North Portal.		
	118.5		Repository Site (North Portal)						

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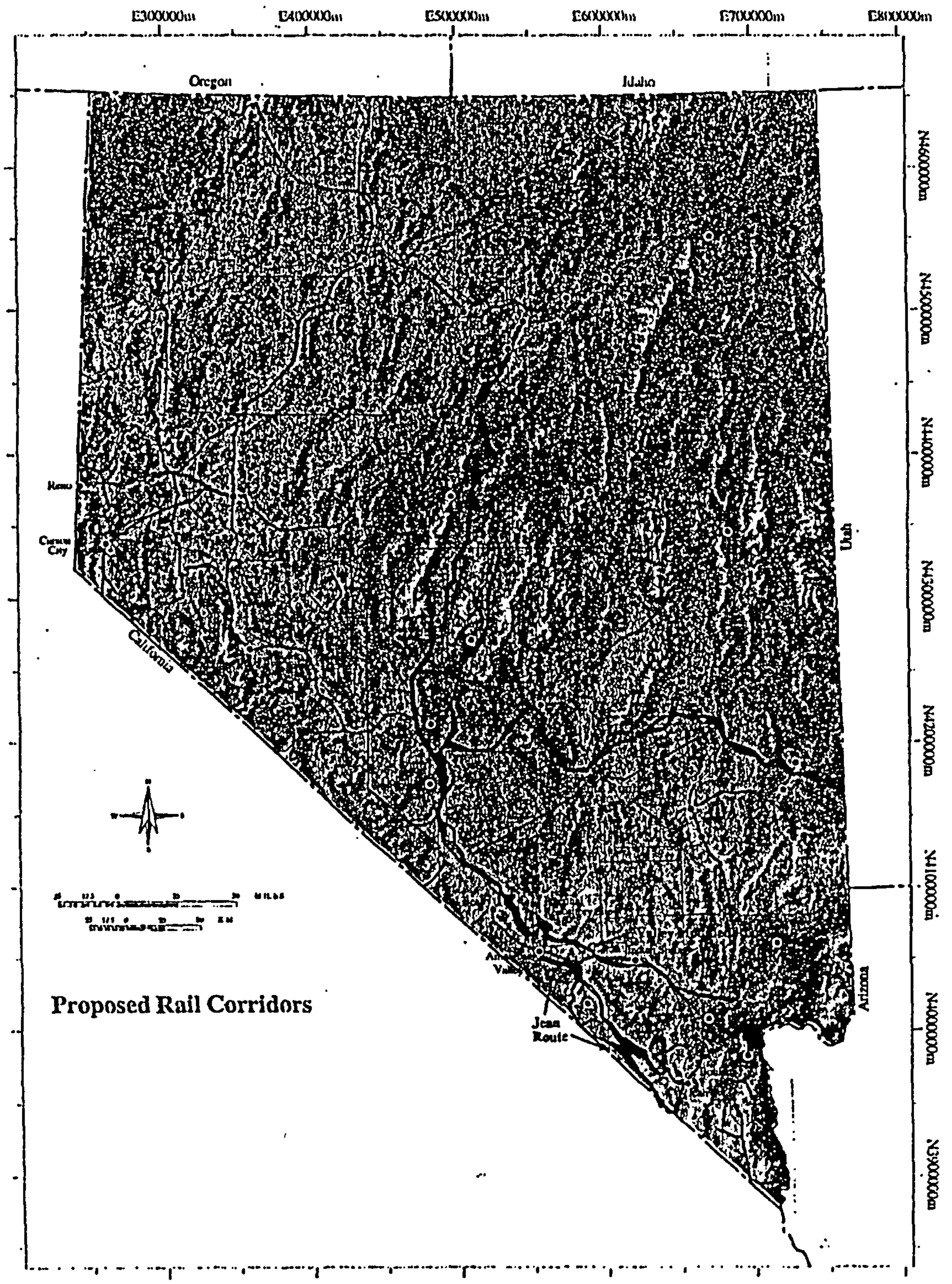
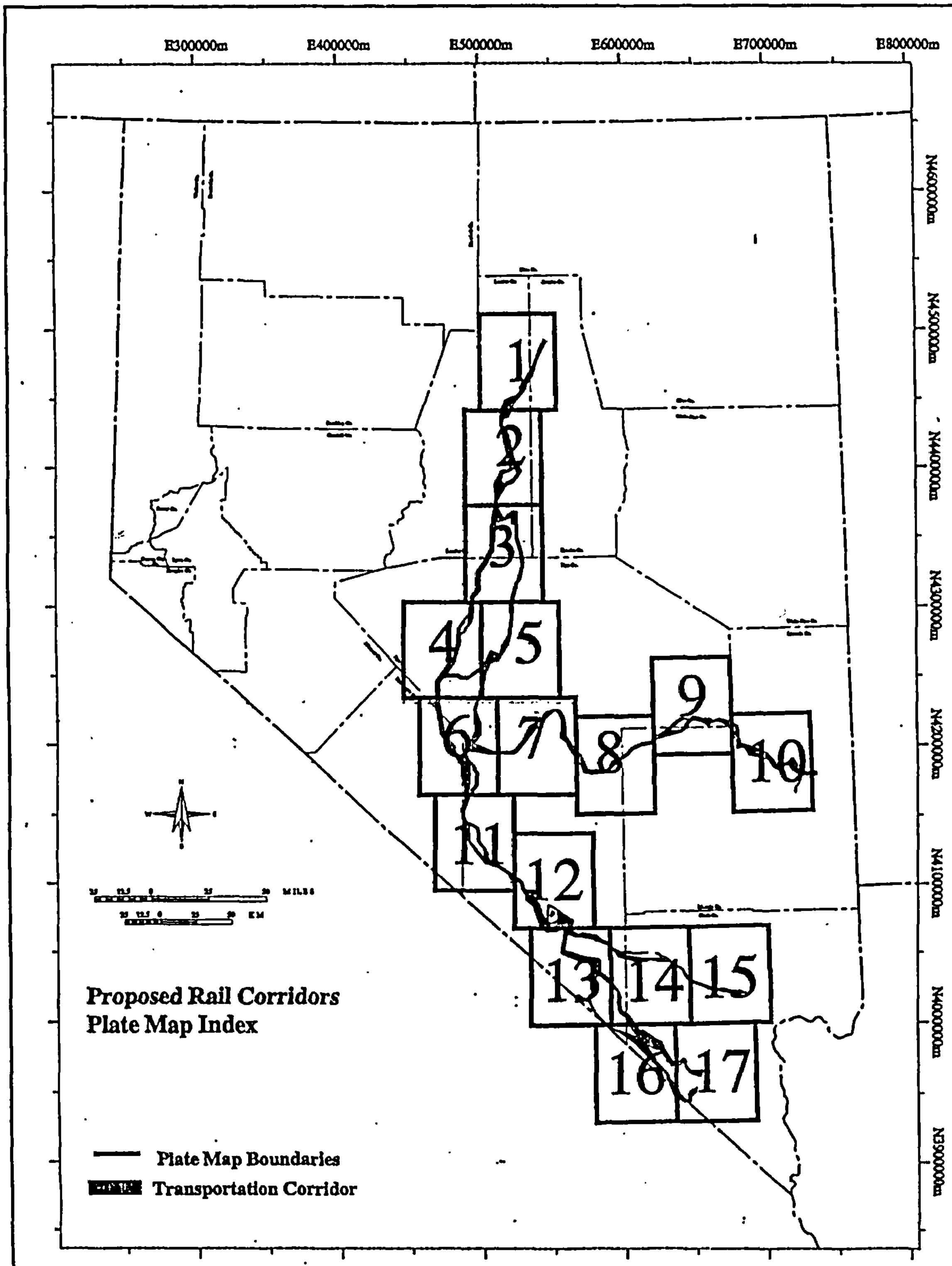
APPENDIX F2

RAIL CORRIDOR MAPS



Proposed Rail Corridors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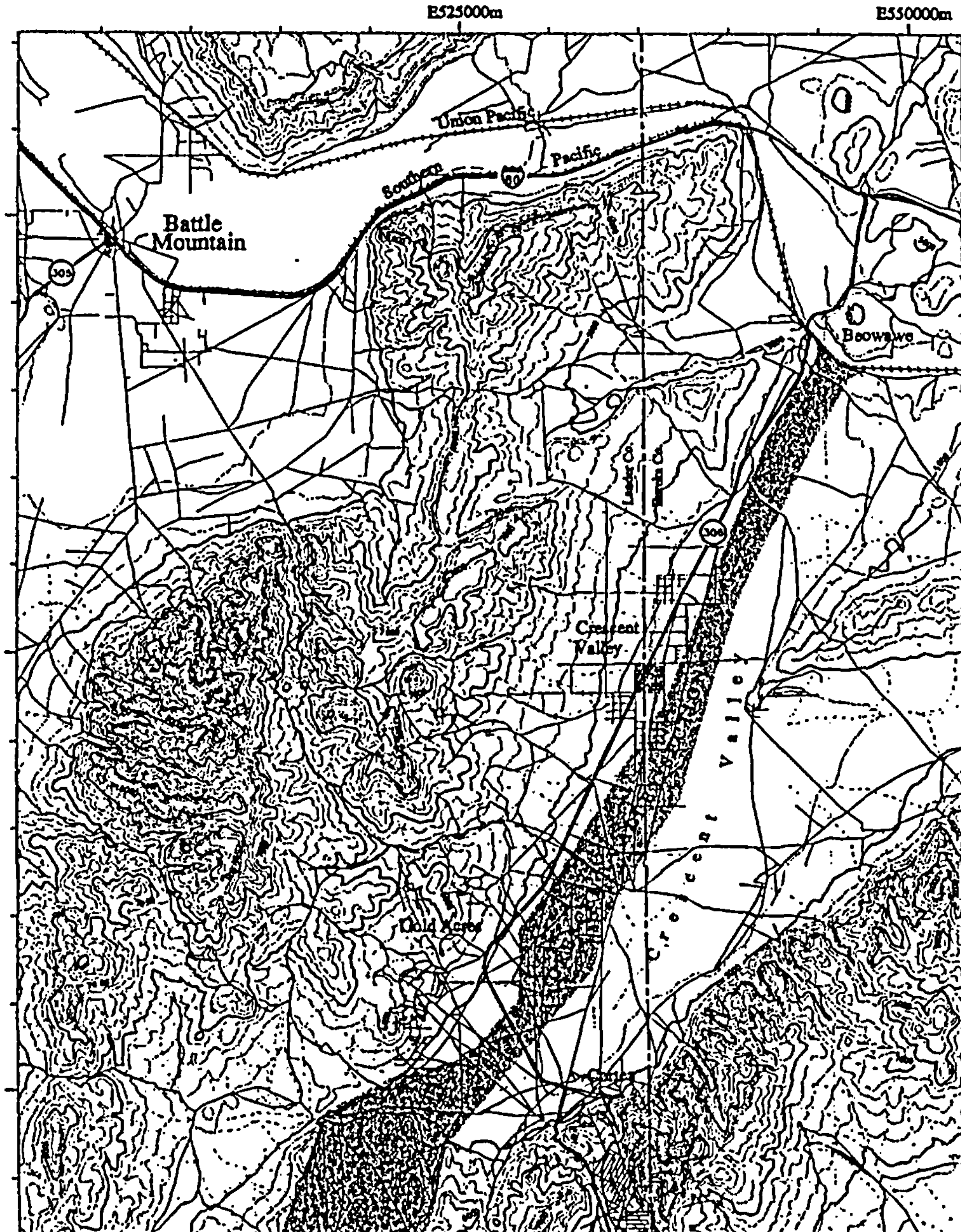
Proposed Rail Corridors
Plate Map Index
Plate Map Boundaries
Transportation Corridor



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MILES

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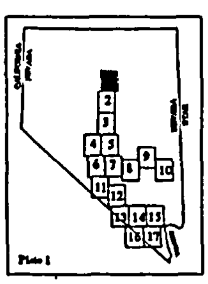
PROPOSED RAIL CORRIDORS
Carlin Route



TRANSPORTATION CORRIDOR

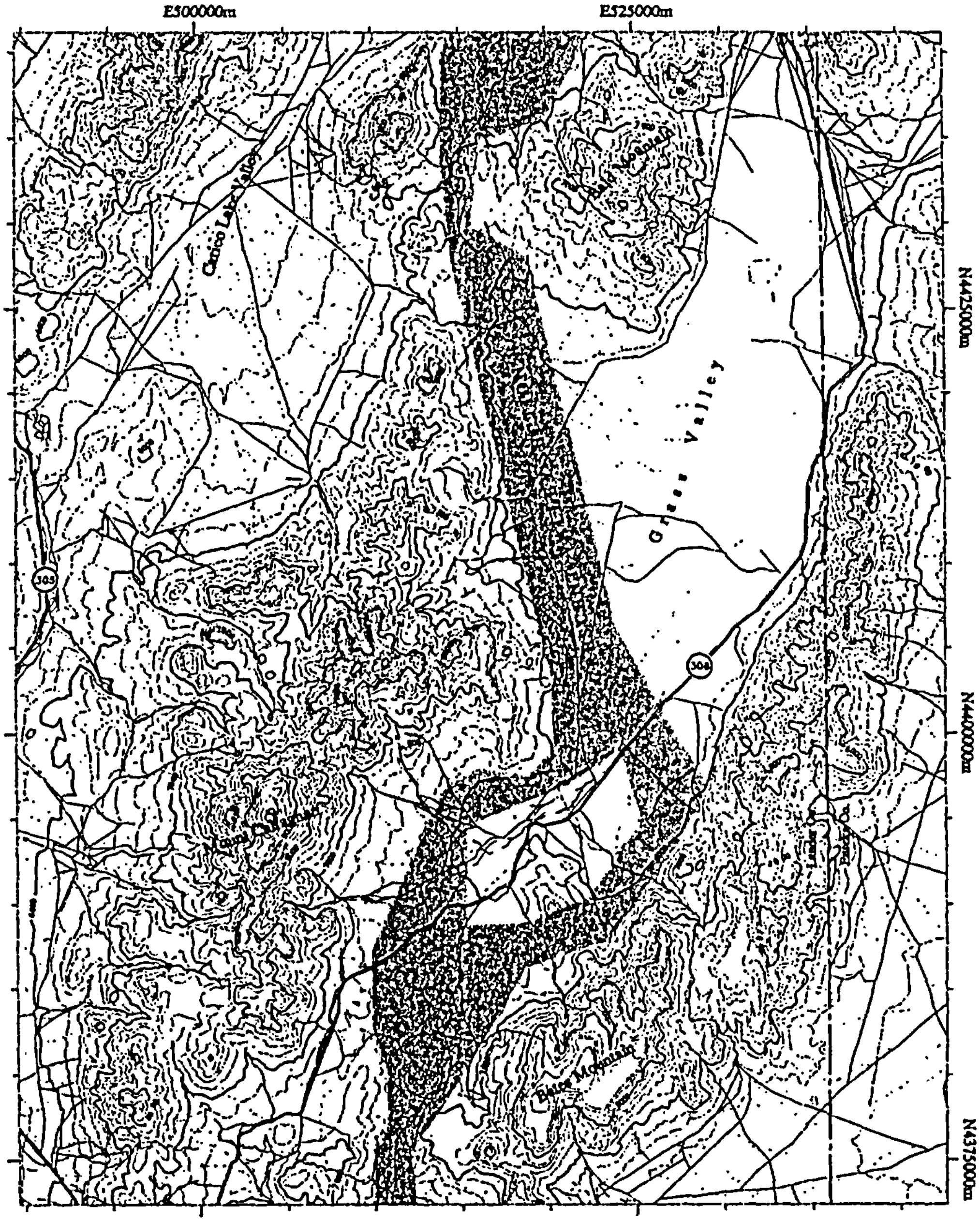
- Primary and Alternate Routes
- DOD/DOE Lands

PHYSIOGRAPHY

- Perennial Streams
- Intermittent Streams
- Intermediate Contour (200 ft. Interval)
- Index Contour (1000 ft. Interval)

INFRASTRUCTURE

- Primary Route, Class 1
- Secondary Route, Class 2
- Road or Street, Class 3 and 4
- Railroad
- Conceptual Controlled Area Boundary
- Proposed Repository Outline



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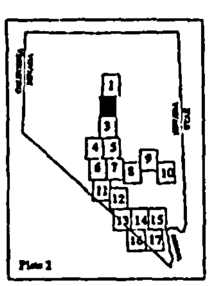
PROPOSED RAIL CORRIDORS
Carlin Route



TRANSPORTATION CORRIDOR
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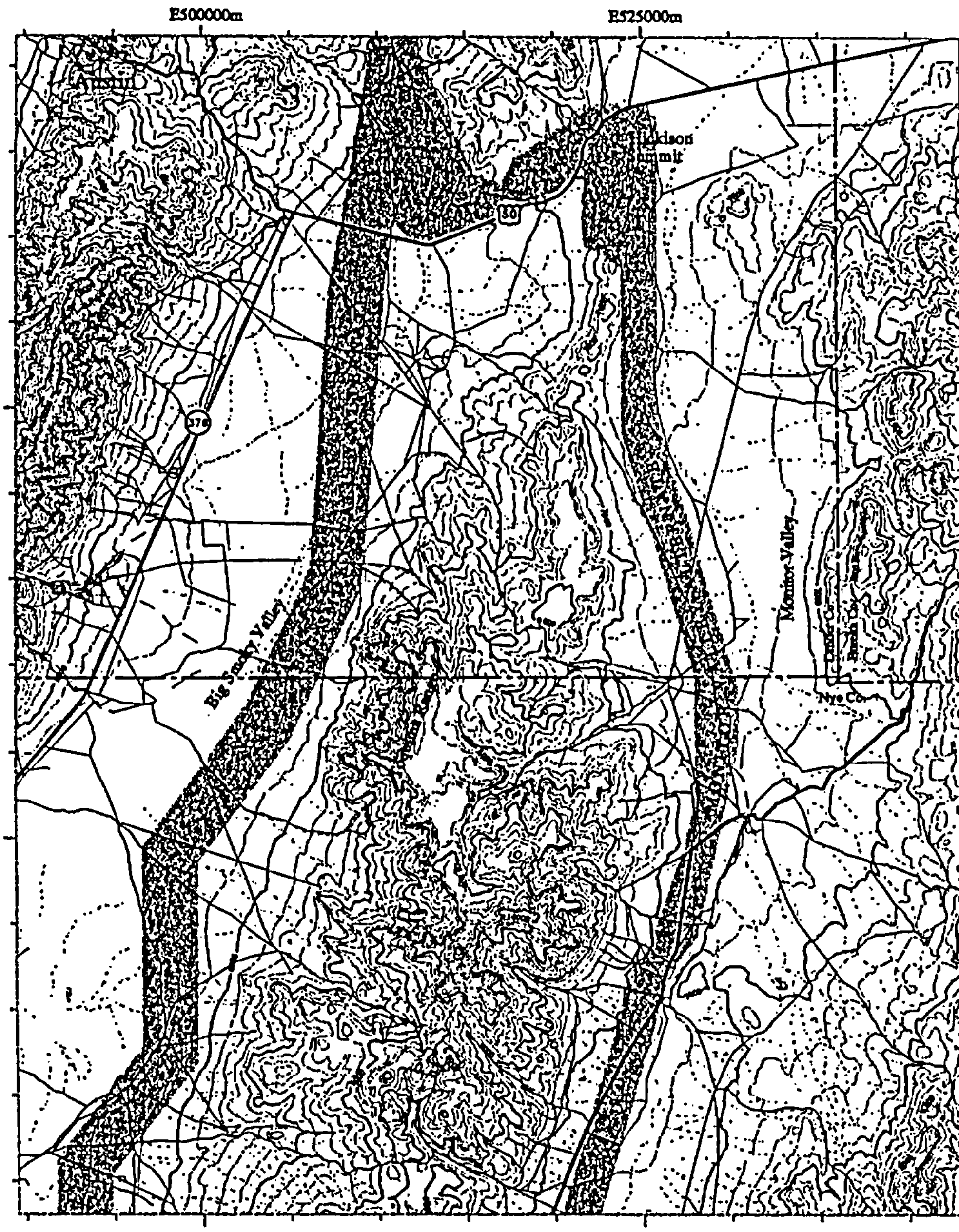

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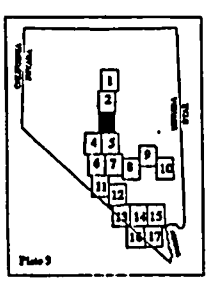
PROPOSED RAIL CORRIDORS
Carlin Route



TRANSPORTATION CORRIDOR

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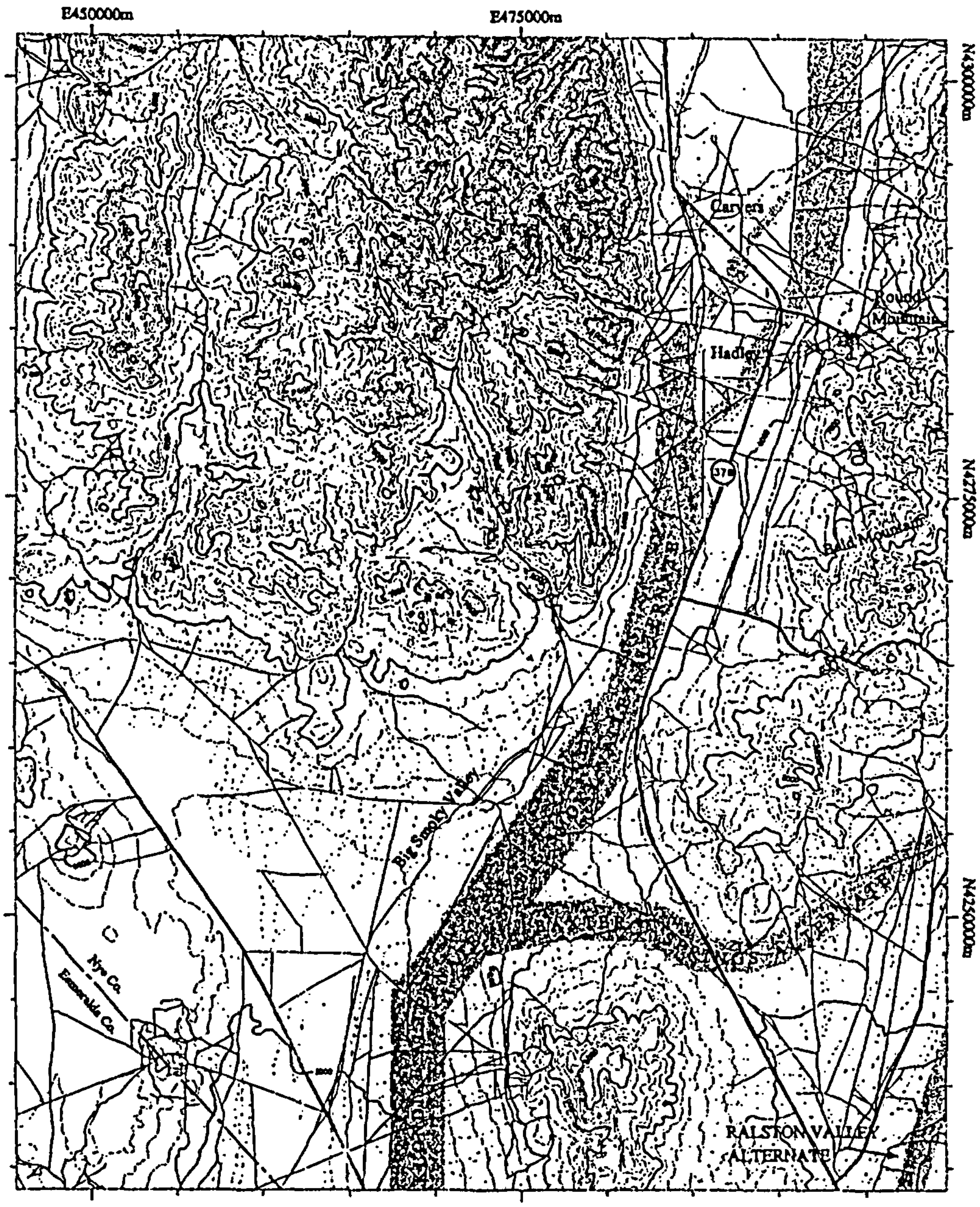

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MILES

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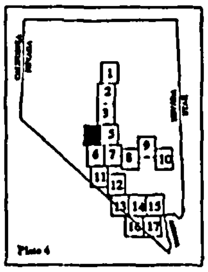
PROPOSED RAIL CORRIDORS

Carlin Route



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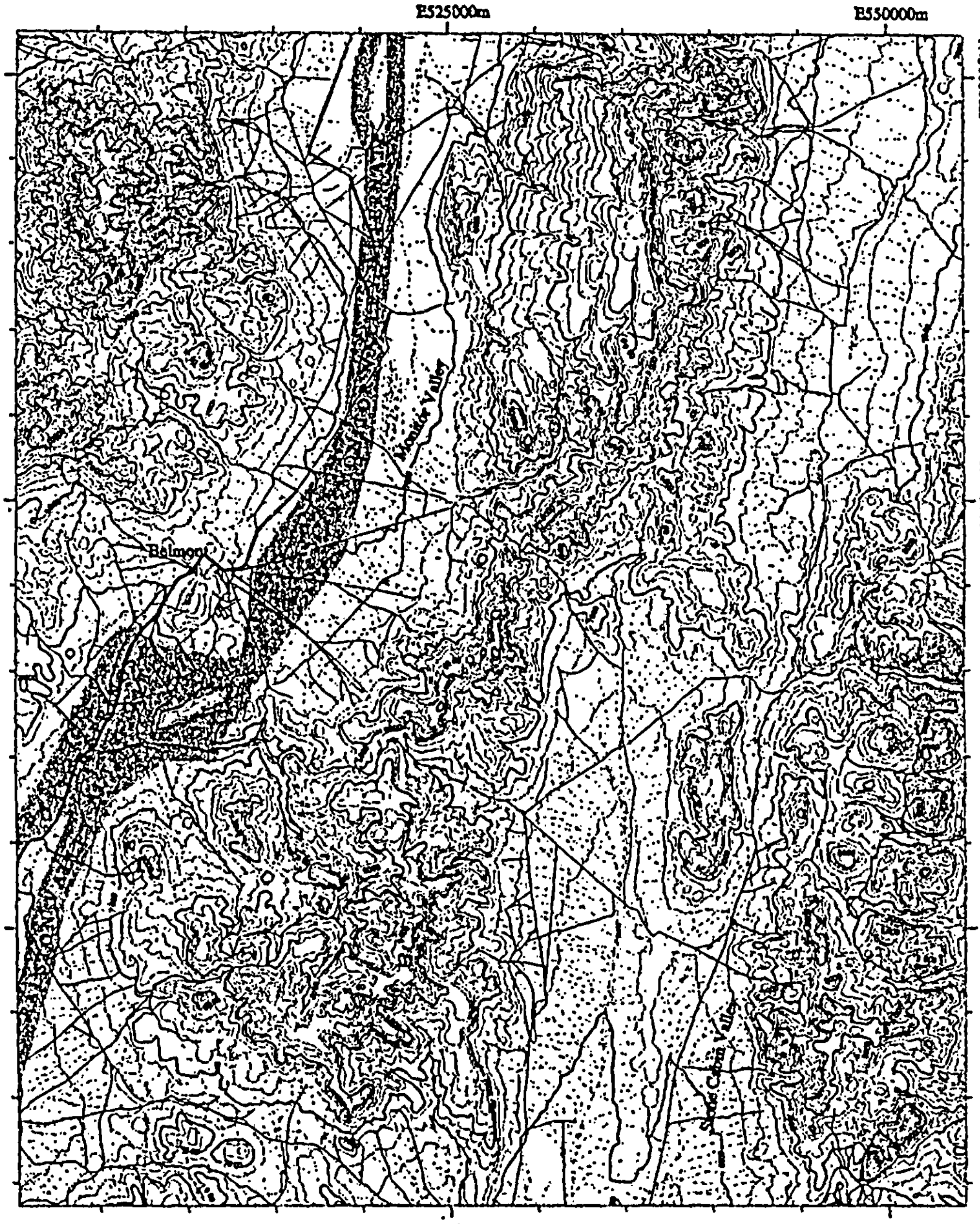

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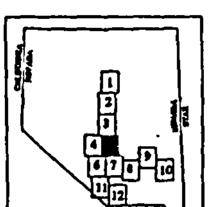
PROPOSED RAIL CORRIDORS
Carlin Route



TRANSPORTATION CORRIDOR
- Primary and Alternate Routes
- DOD/DOE Lands

PHYSIOGRAPHY
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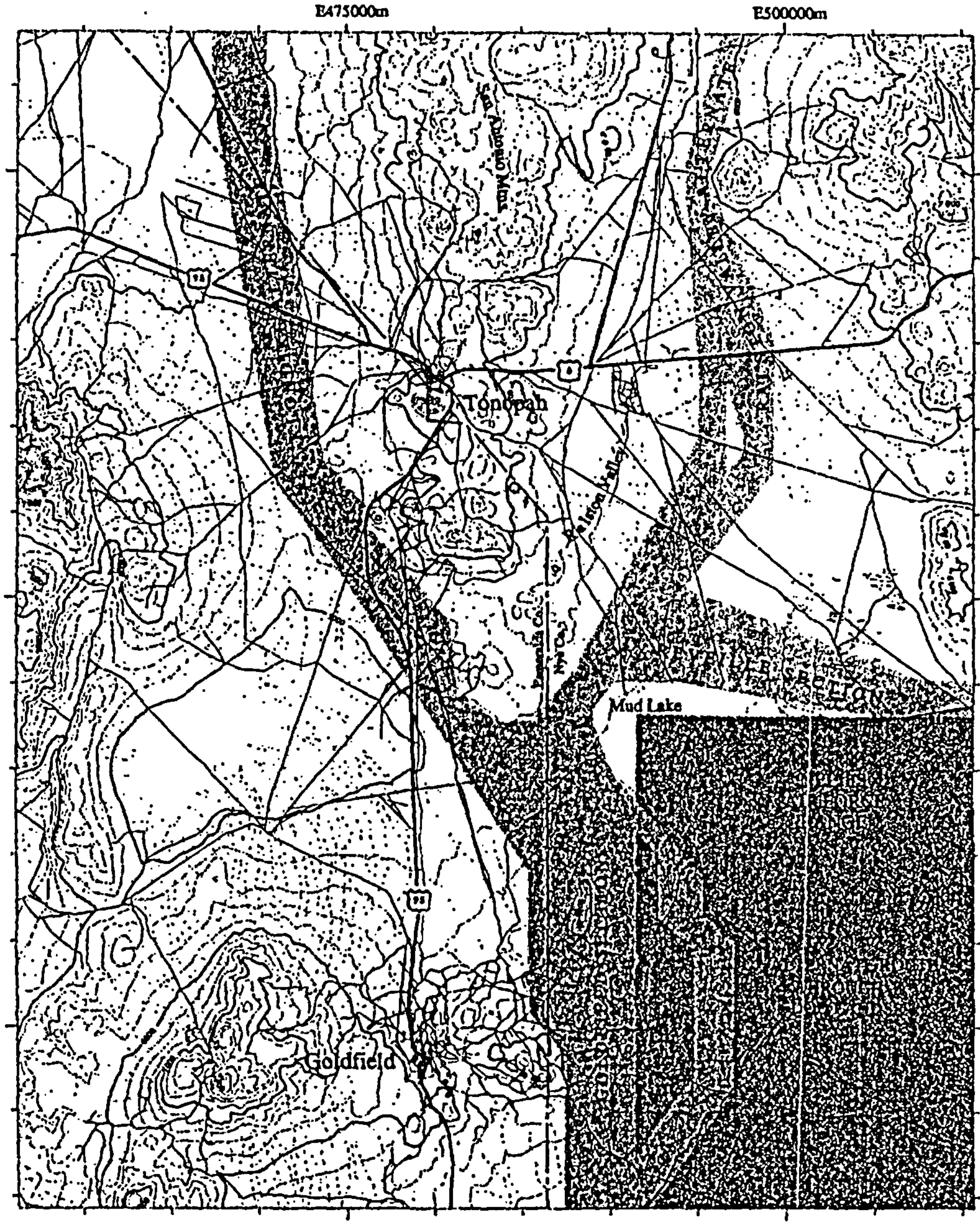

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MILE

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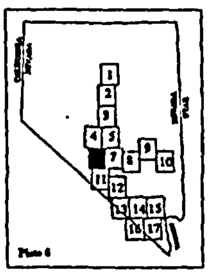
PROPOSED RAIL CORRIDORS

Carlin & Caliente Routes



TRANSPORTATION CORRIDOR

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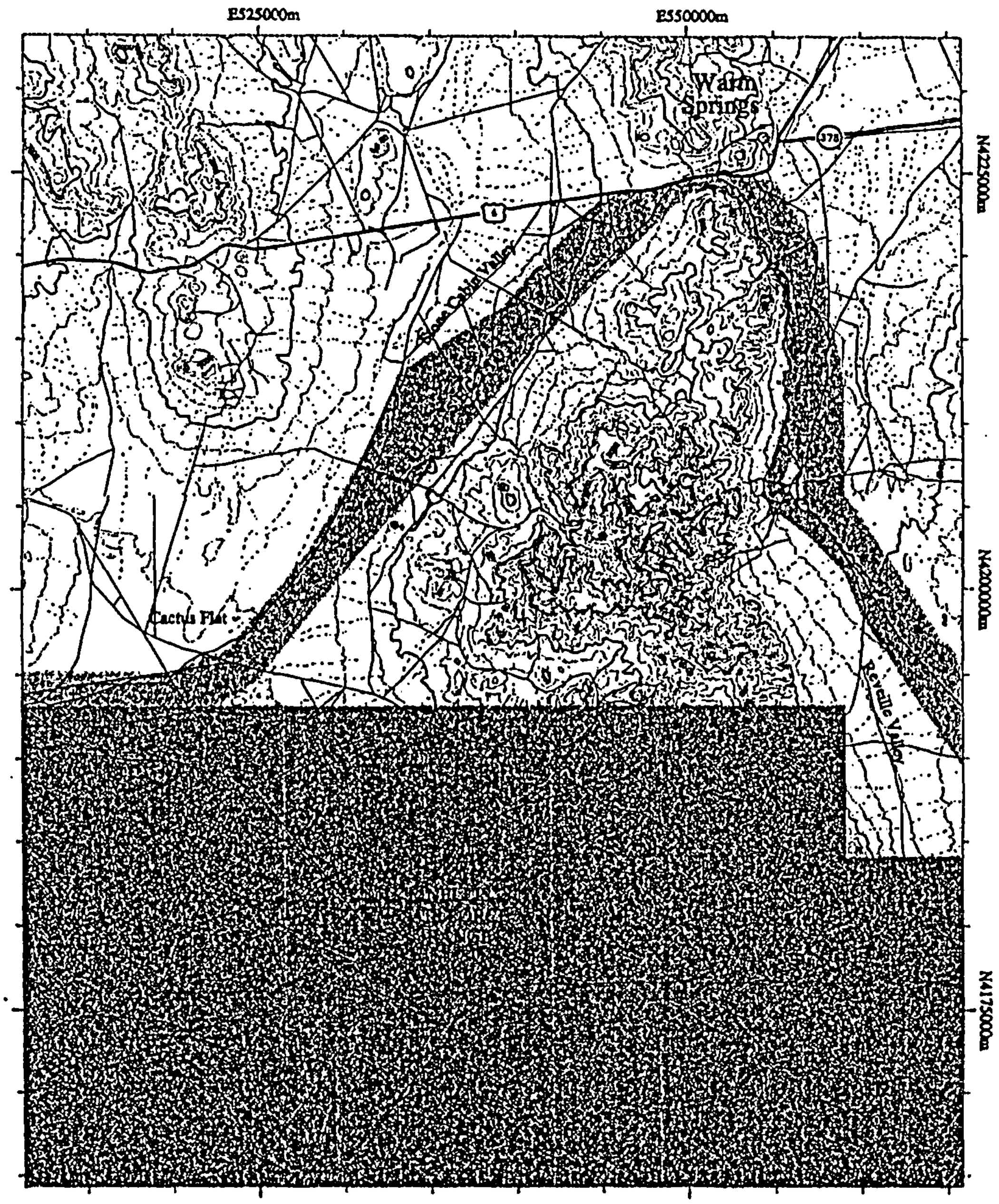

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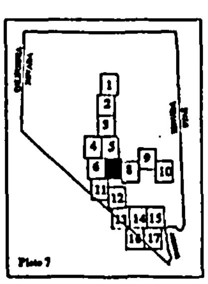
PROPOSED RAIL CORRIDORS
Caliente Route



TRANSPORTATION CORRIDOR

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PHYSIOGRAPHY

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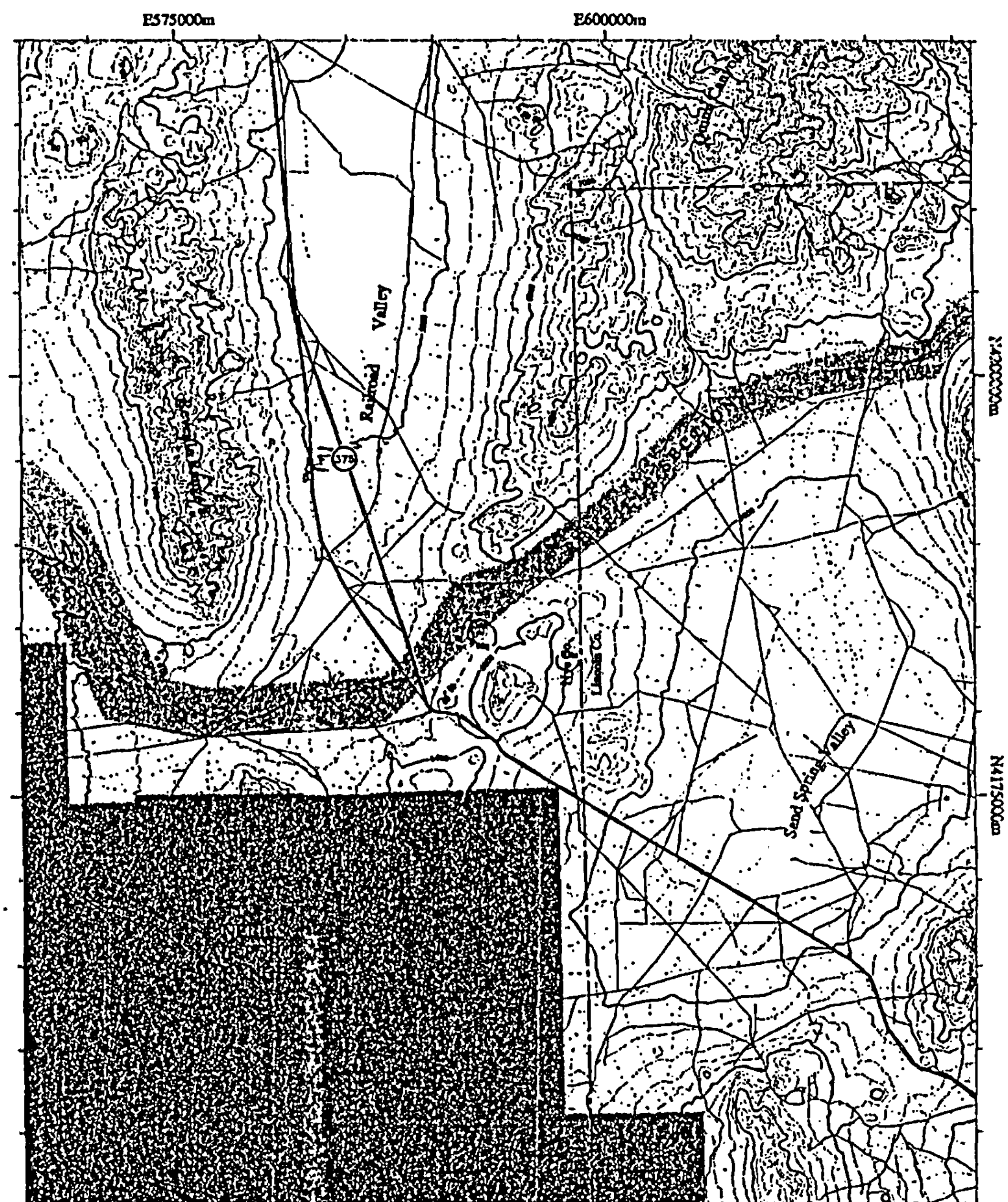

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MILES

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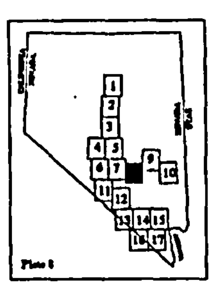
PROPOSED RAIL CORRIDORS
Caliente Route



TRANSPORTATION CORRIDOR

Primary and Alternate Routes

DOD/DOE Lands

PHYSIOGRAPHY

Perennial Streams

Intermittent Streams

Intermediate Contour (200 ft. Interval)

Index Contour (1000 ft. Interval)

INFRASTRUCTURE

Primary Route, Class 1

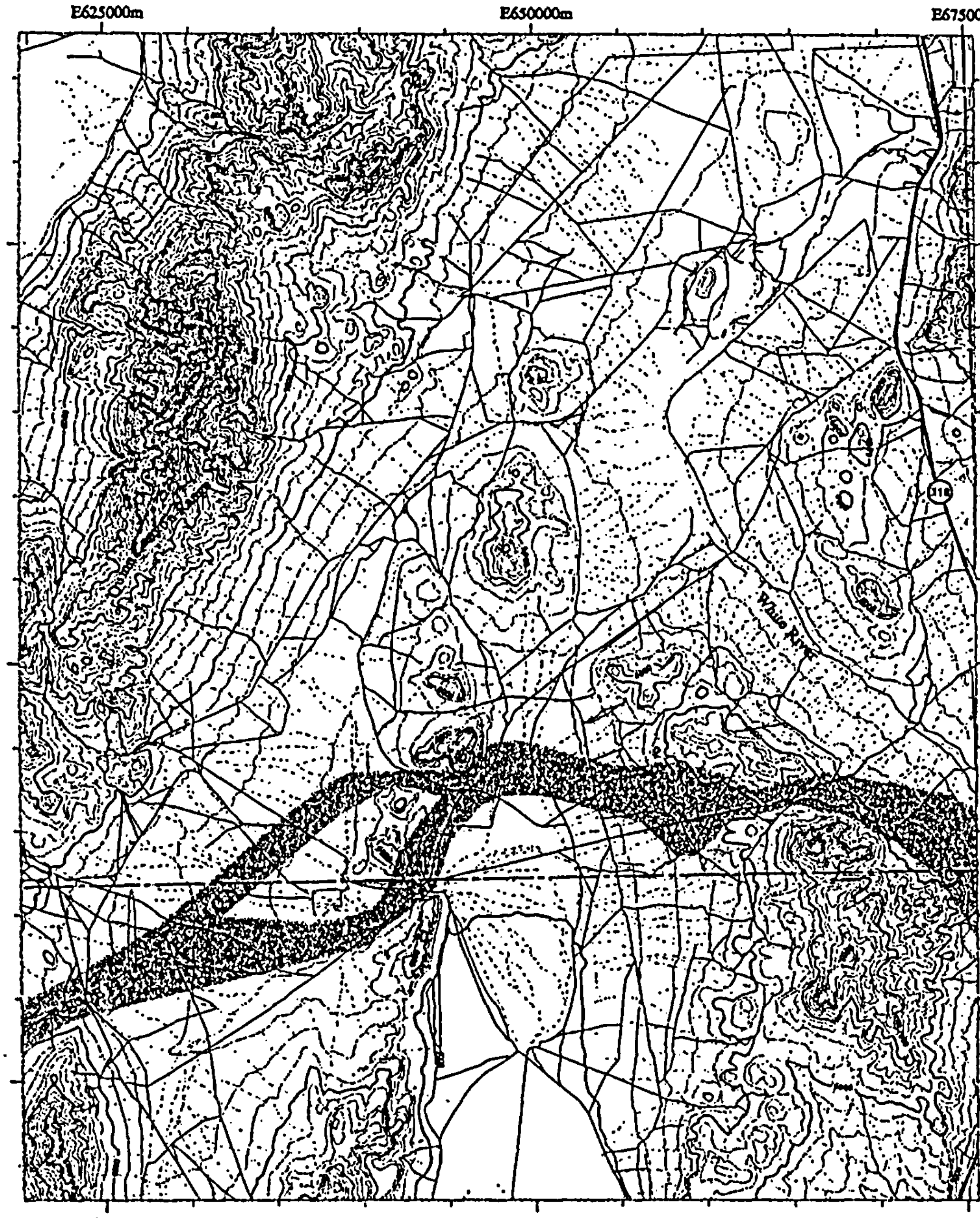
Secondary Route, Class 2

Road or Street, Class 3 and 4

Railroad

Conceptual Controlled Area Boundary

Proposed Repository Outline



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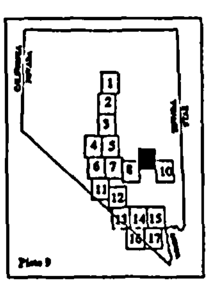
PROPOSED RAIL CORRIDORS
Caliente Route



TRANSPORTATION CORRIDOR
- Primary and Alternate Routes
- DOD/DOE Lands

PHYSIOGRAPHY
- Perennial Streams
- Intermittent Streams
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INFRASTRUCTURE
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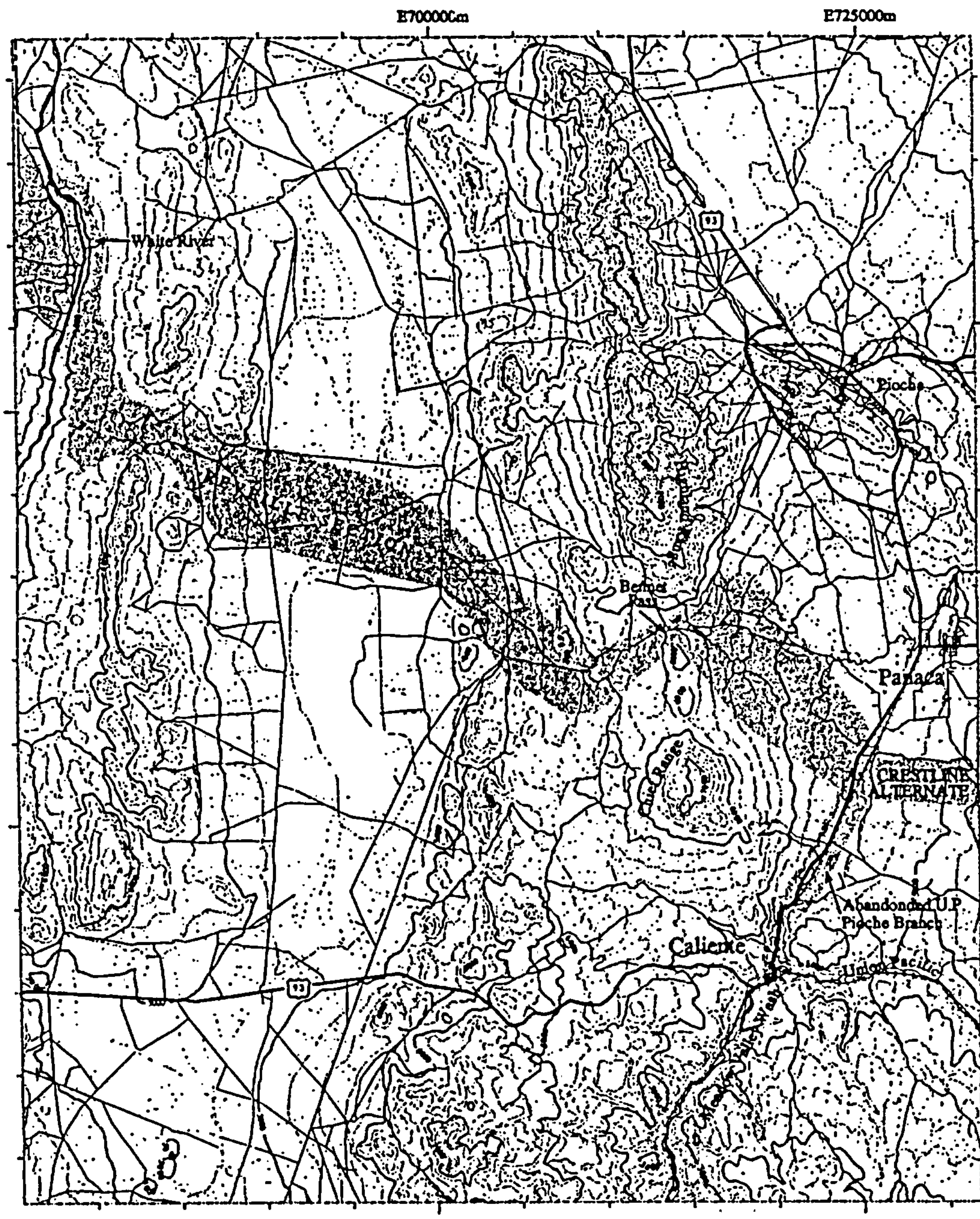

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MILES

KM

PROPOSED RAIL CORRIDORS
Caliente Route

TRANSPORTATION CORRIDOR
- Primary and Alternate Routes
- DOD/DOE Lands

PHYSIOGRAPHY
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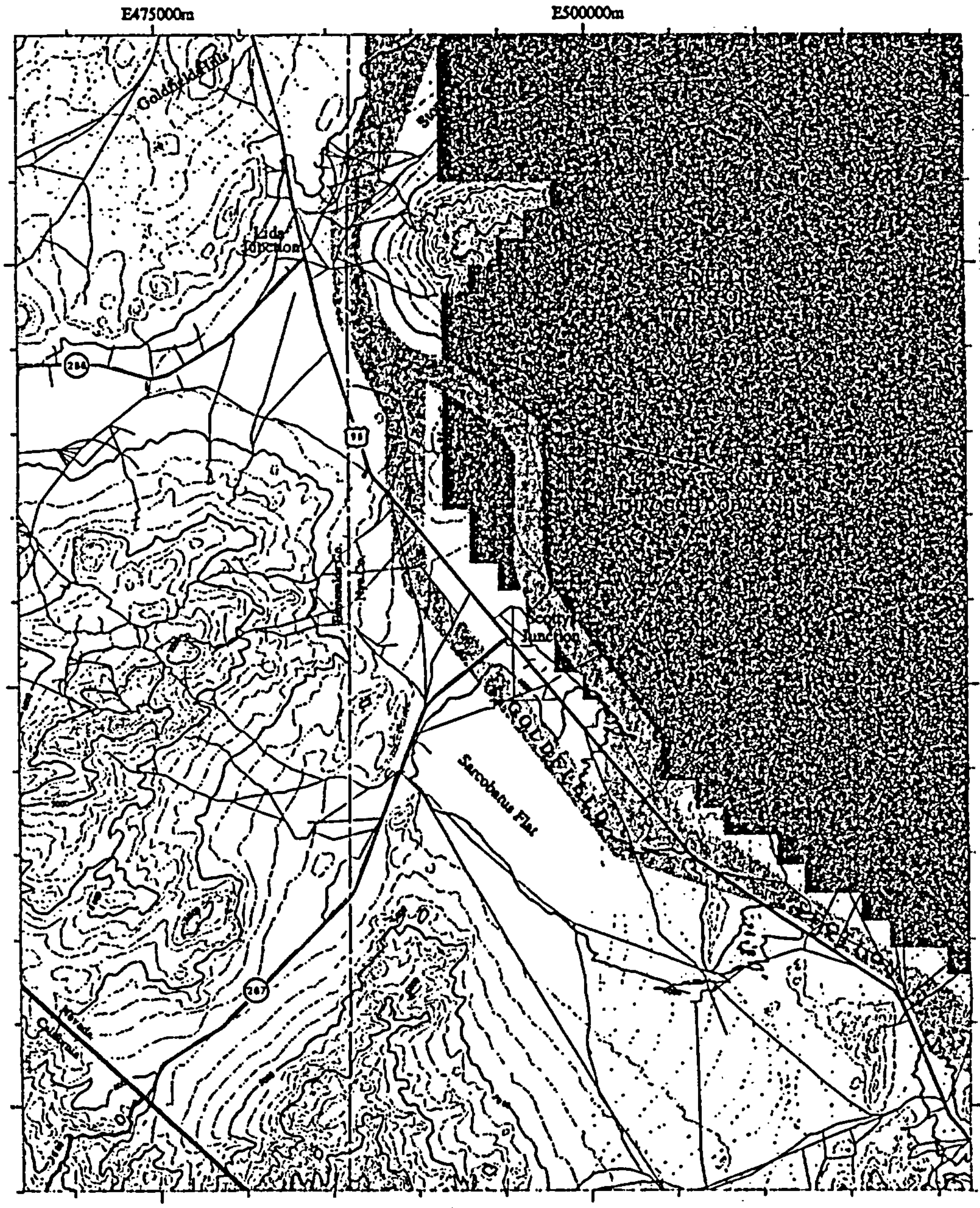

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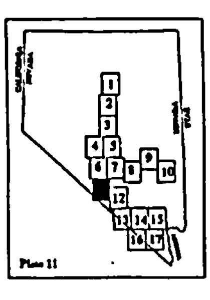
PROPOSED RAIL CORRIDORS
Carlin & Caliente Routes



TRANSPORTATION CORRIDOR
- Primary and Alternate Routes
- DOD/DOE Lands

PHYSIOGRAPHY
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- Intermittent Streams
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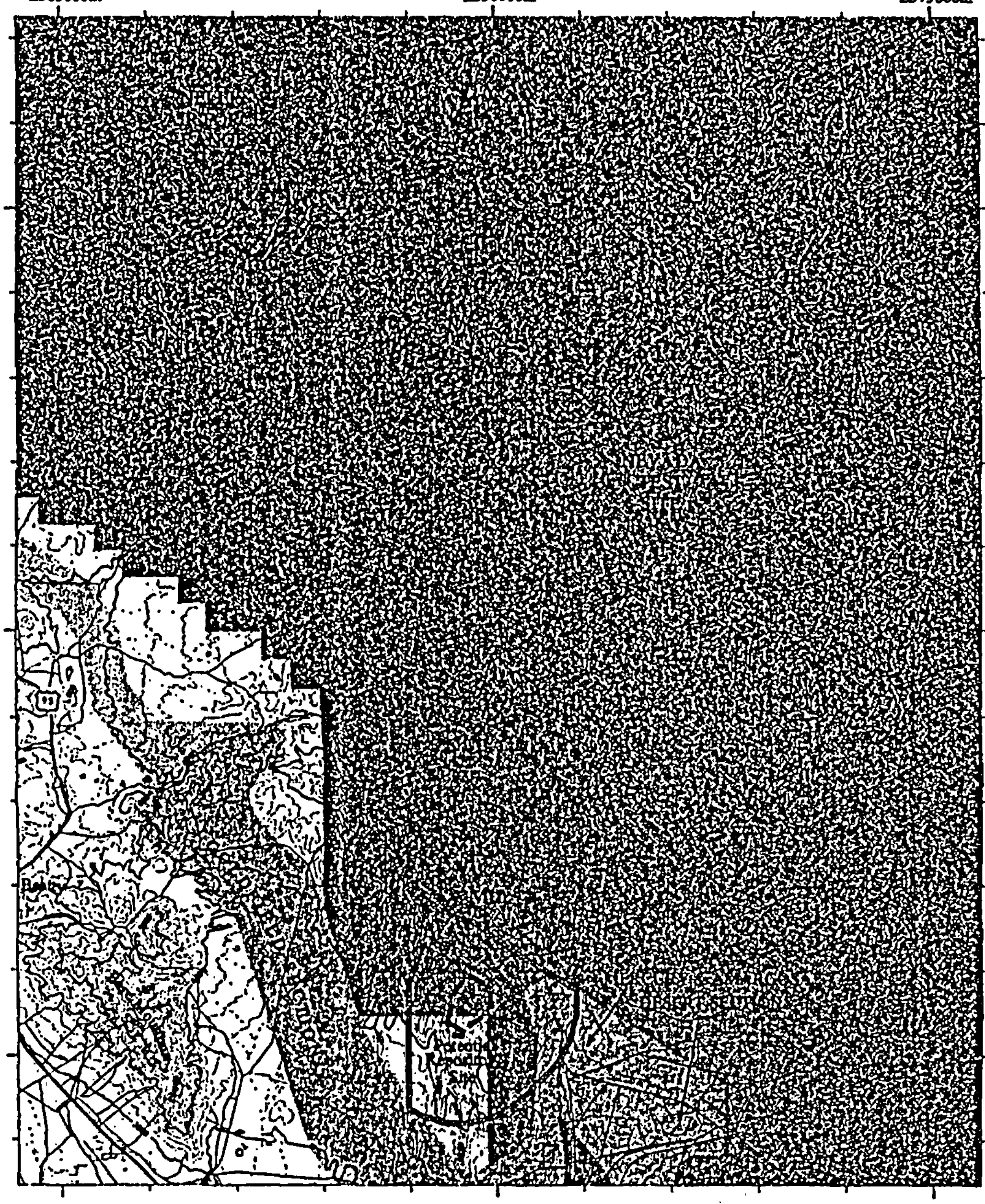
- Conceptual Controlled Area Boundary
- Proposed Repository Outline



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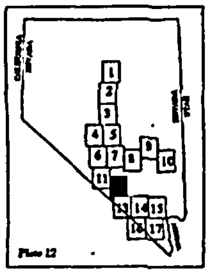
MILES

KM

PROPOSED RAIL CORRIDORS

Carlin, Caliente, Valley Modified & Jean Routes



TRANSPORTATION CORRIDOR

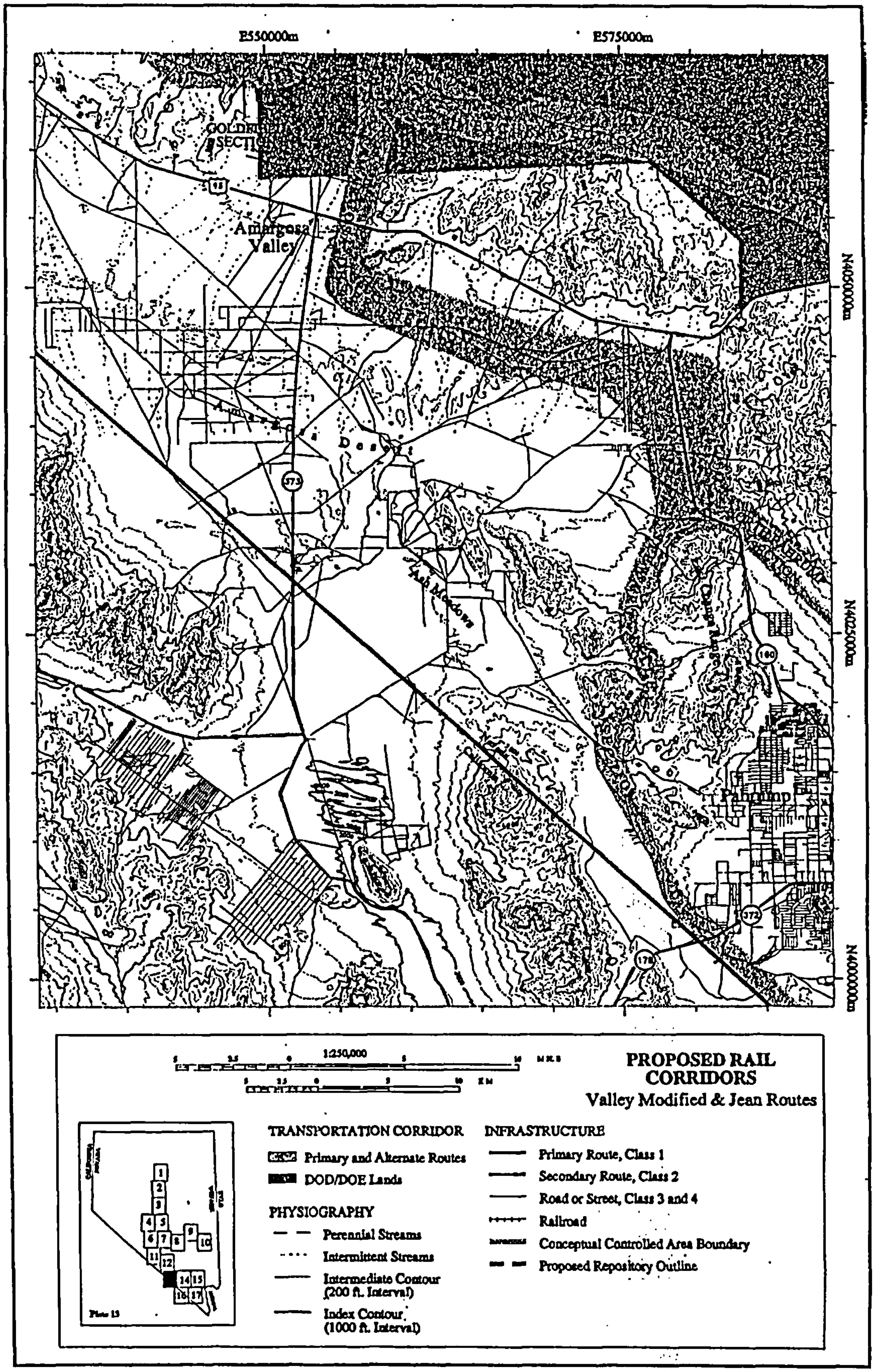
- Primary and Alternate Routes
- DOD/DOE Lands

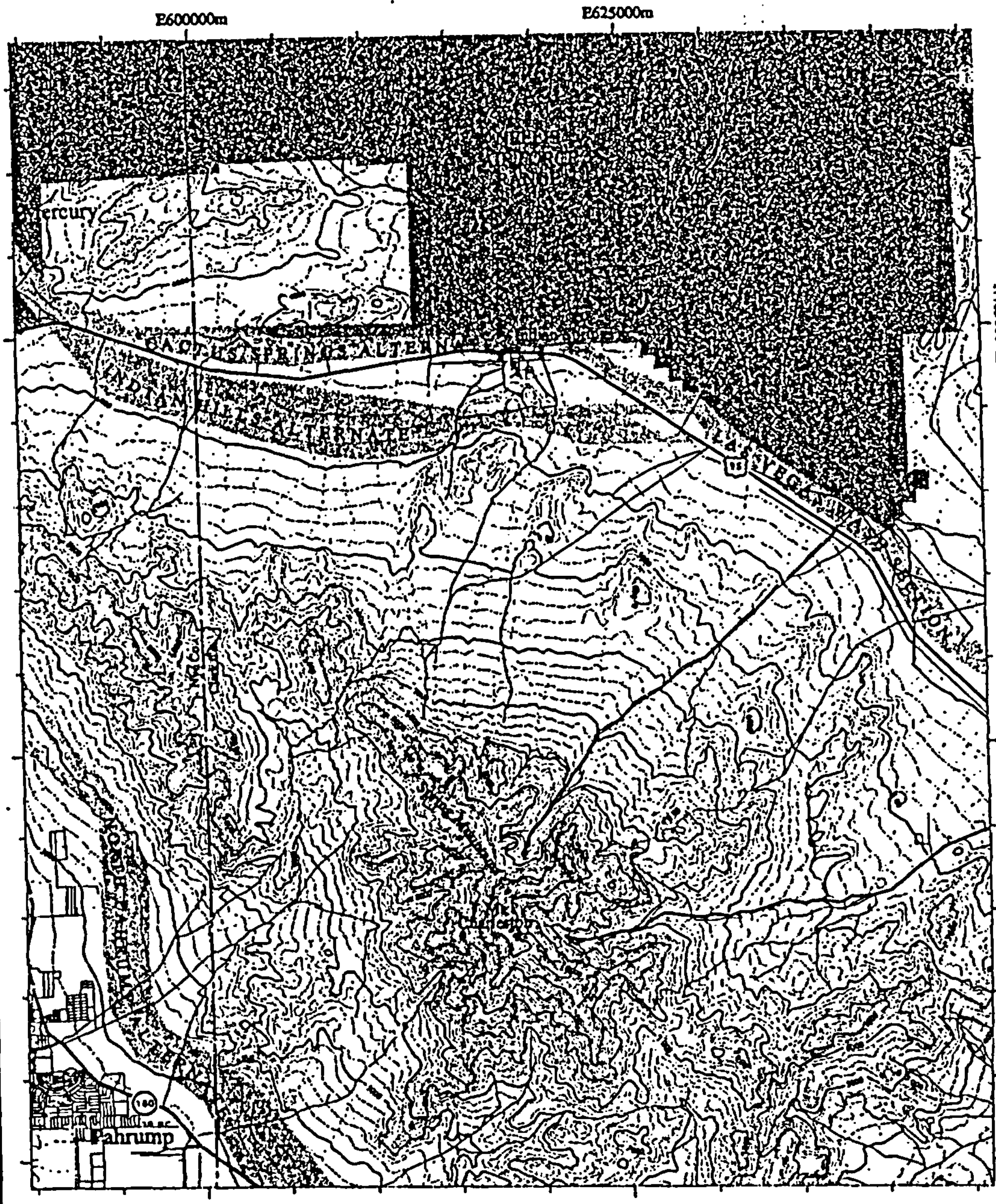
PHYSIOGRAPHY

- Perennial Streams
- Intermittent Streams
- Intermediate Contour (200 ft. Interval)
- Index Contour (1000 ft. Interval)

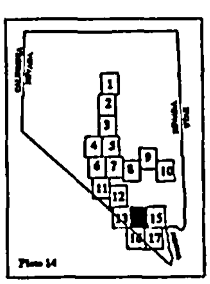
INFRASTRUCTURE

- Primary Route, Class 1
- Secondary Route, Class 2
- Road or Street, Class 3 and 4
- Railroad
- Conceptual Controlled Area Boundary
- Proposed Repository Outline


E550000m
E575000m
N4050000m
N4025000m
N4000000m
Amargosa Valley
Ash Meadows
Pahrump
95
373
160
372
178
1:250,000
PROPOSED RAIL CORRIDORS
Valley Modified & Jean Routes
TRANSPORTATION CORRIDOR
Primary and Alternate Routes
DOD/DOE Lands
PHYSIOGRAPHY
Perennial Streams
Intermittent Streams
Intermediate Contour (200 ft. Interval)
Index Contour (1000 ft. Interval)
INFRASTRUCTURE
Primary Route, Class 1
Secondary Route, Class 2
Road or Street, Class 3 and 4
Railroad
Conceptual Controlled Area Boundary
Proposed Repository Outline
Plate 13



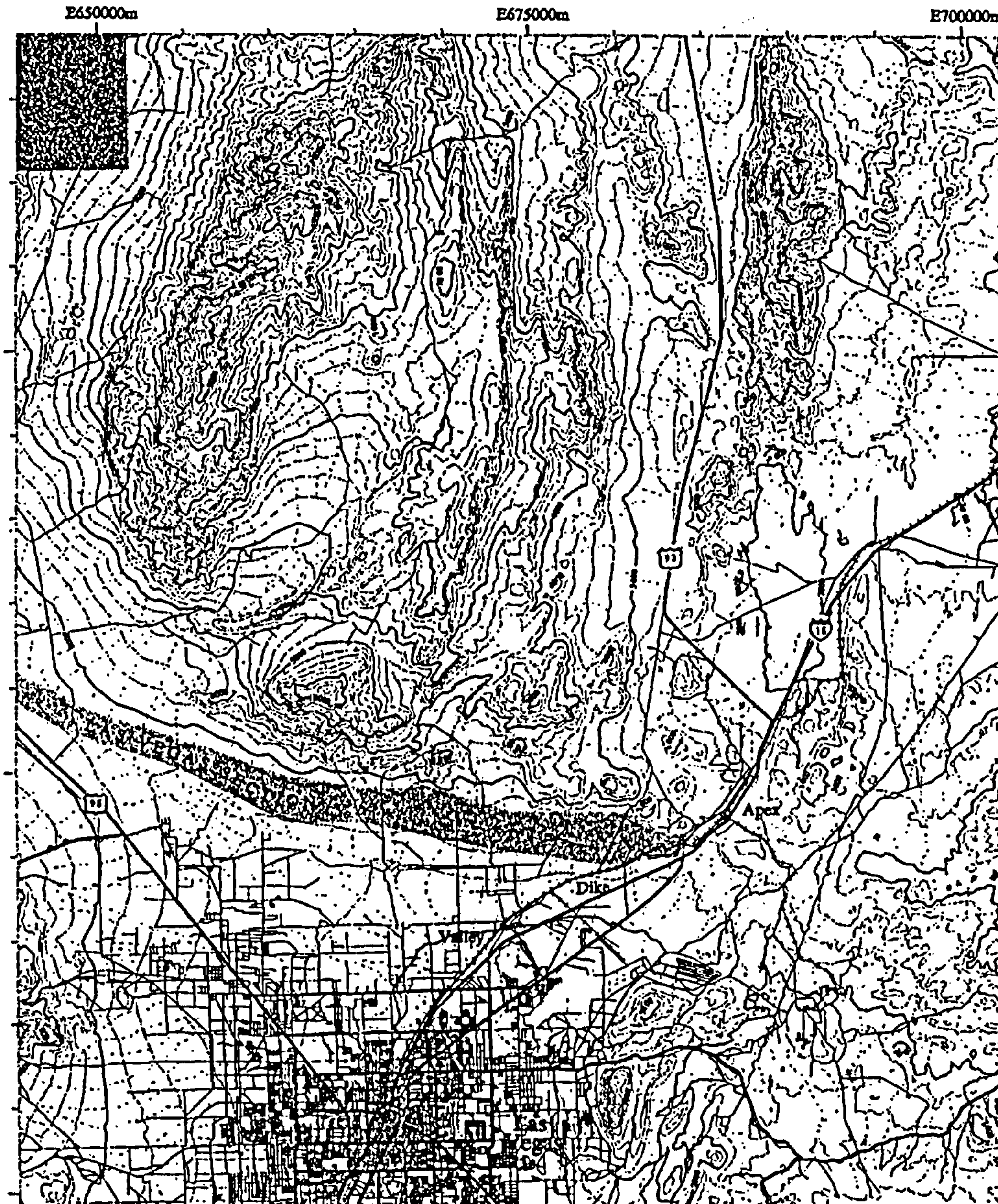
PROPOSED RAIL CORRIDORS
Valley Modified & Jean Routes



TRANSPORTATION CORRIDOR
- Primary and Alternate Routes
- DOD/DOE Lands

PHYSIOGRAPHY
- Perennial Streams
- Intermittent Streams
- Intermediate Contour (200 ft. Interval)
- Index Contour (1000 ft. Interval)

INFRASTRUCTURE
- Primary Route, Class 1
- Secondary Route, Class 2
- Road or Street, Class 3 and 4
- Railroad
- Conceptual Controlled Area Boundary
- Proposed Repository Outline



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MILES

KM

PROPOSED RAIL CORRIDORS

Valley Modified Route

TRANSPORTATION CORRIDOR

- Primary and Alternate Routes
- DOD/DOE Lands

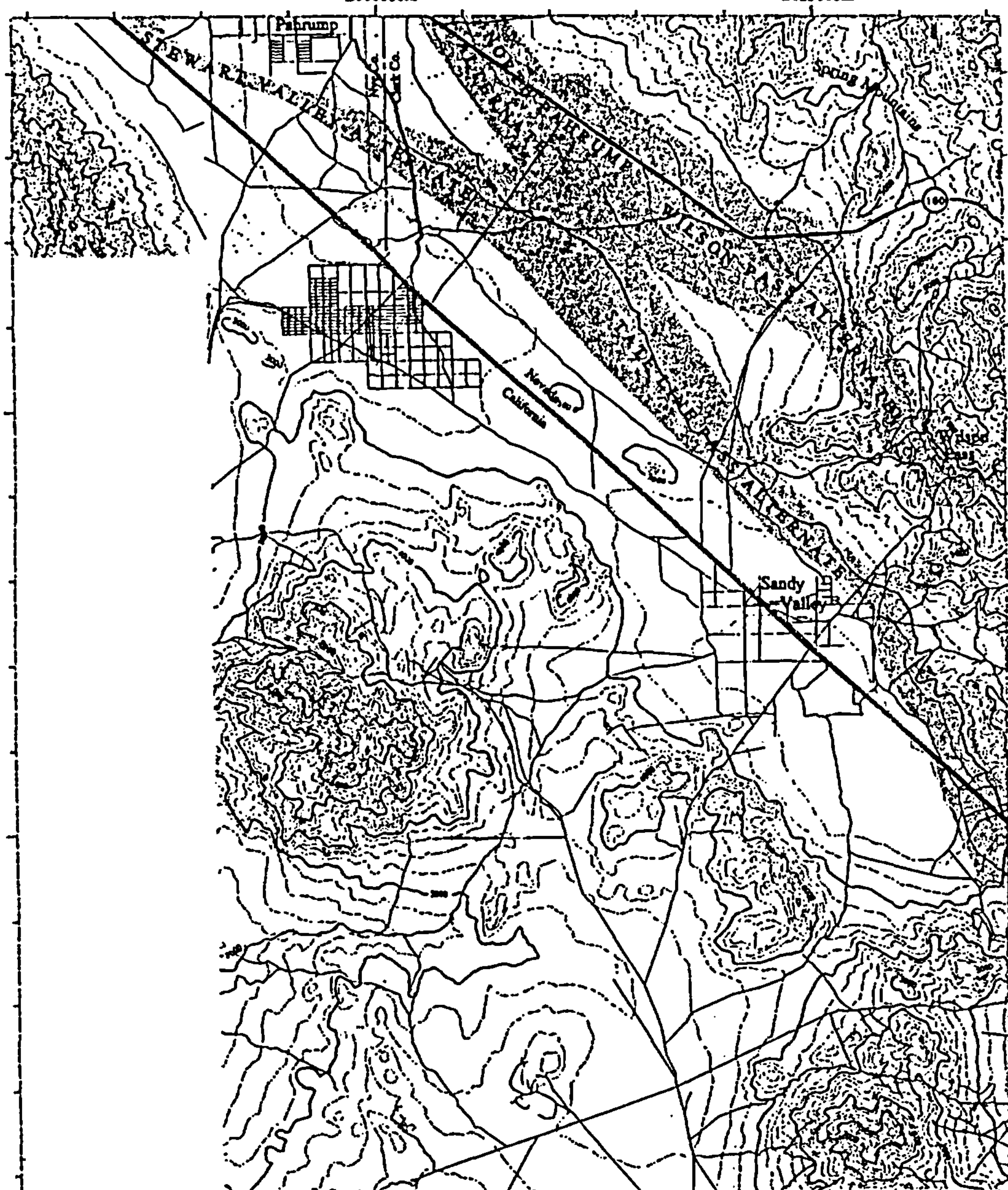
PHYSIOGRAPHY

- Perennial Streams
- Intermittent Streams
- Intermediate Contour (200 ft. Interval)
- Index Contour (1000 ft. Interval)

INFRASTRUCTURE

- Primary Route, Class 1
- Secondary Route, Class 2
- Road or Street, Class 3 and 4
- Railroad
- Conceptual Controlled Area Boundary
- Proposed Repository Outline

Plate 15



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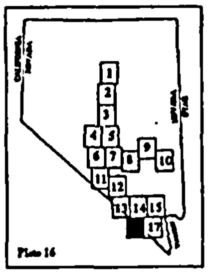
MILES

KM

PROPOSED RAIL CORRIDORS

Jean Route



TRANSPORTATION CORRIDOR

- Primary and Alternate Routes
- DOD/DOE Lands

PHYSIOGRAPHY

- Perennial Streams
- Intermittent Streams
- Intermediate Contour (200 ft. Interval)
- Index Contour (1000 ft. Interval)

INFRASTRUCTURE

- Primary Route, Class 1
- Secondary Route, Class 2
- Road or Street, Class 3 and 4
- Railroad
- Conceptual Controlled Area Boundary
- Proposed Repository Outline

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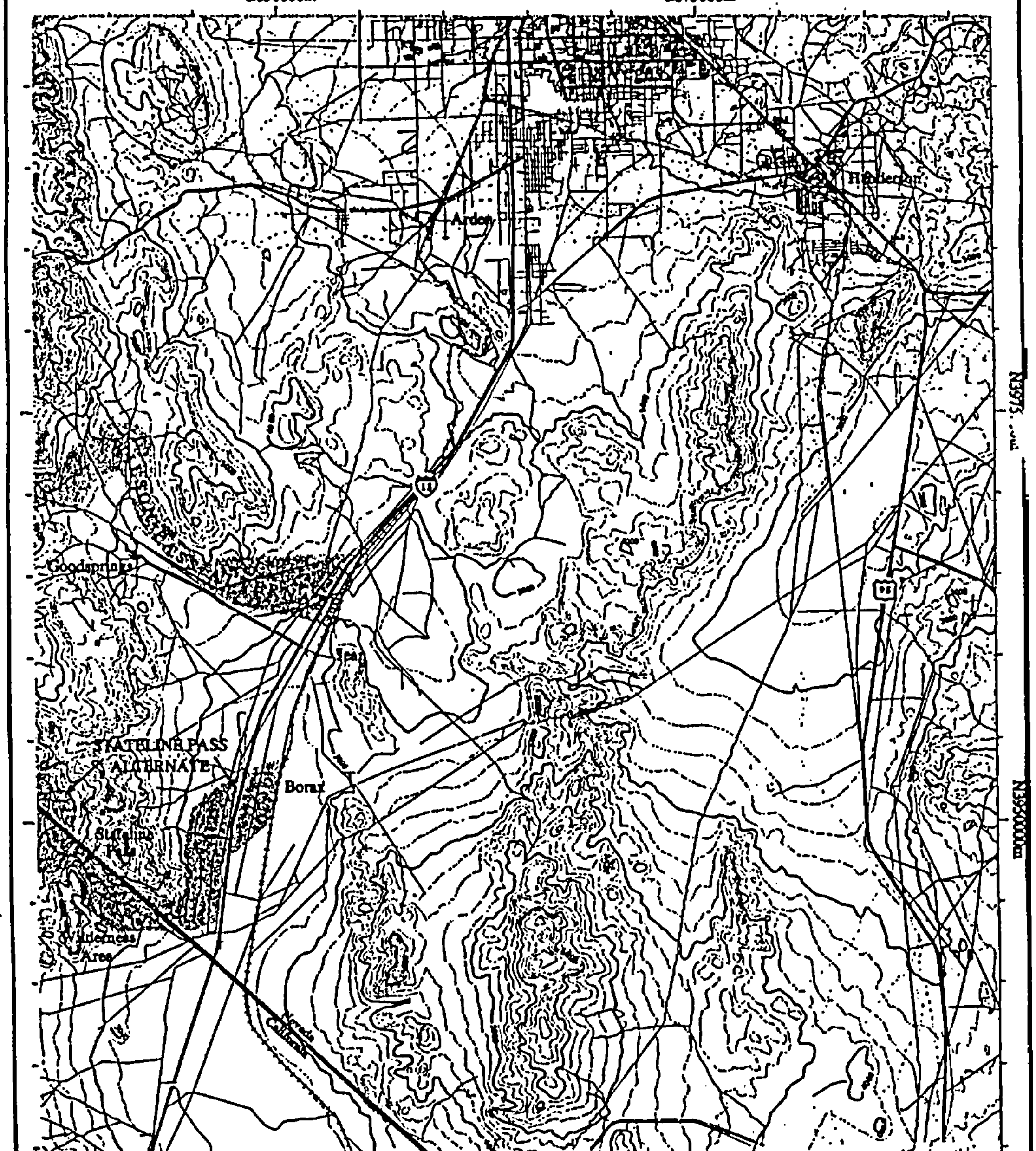

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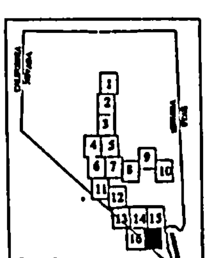
MILE

KM

PROPOSED RAIL CORRIDORS

Jean Route



TRANSPORTATION CORRIDOR

- Primary and Alternate Routes
- DOD/DOE Lands

PHYSIOGRAPHY

- Perennial Streams
- Intermittent Streams
- Intermediate Contour (200 ft. Interval)
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- Primary Route, Class 1
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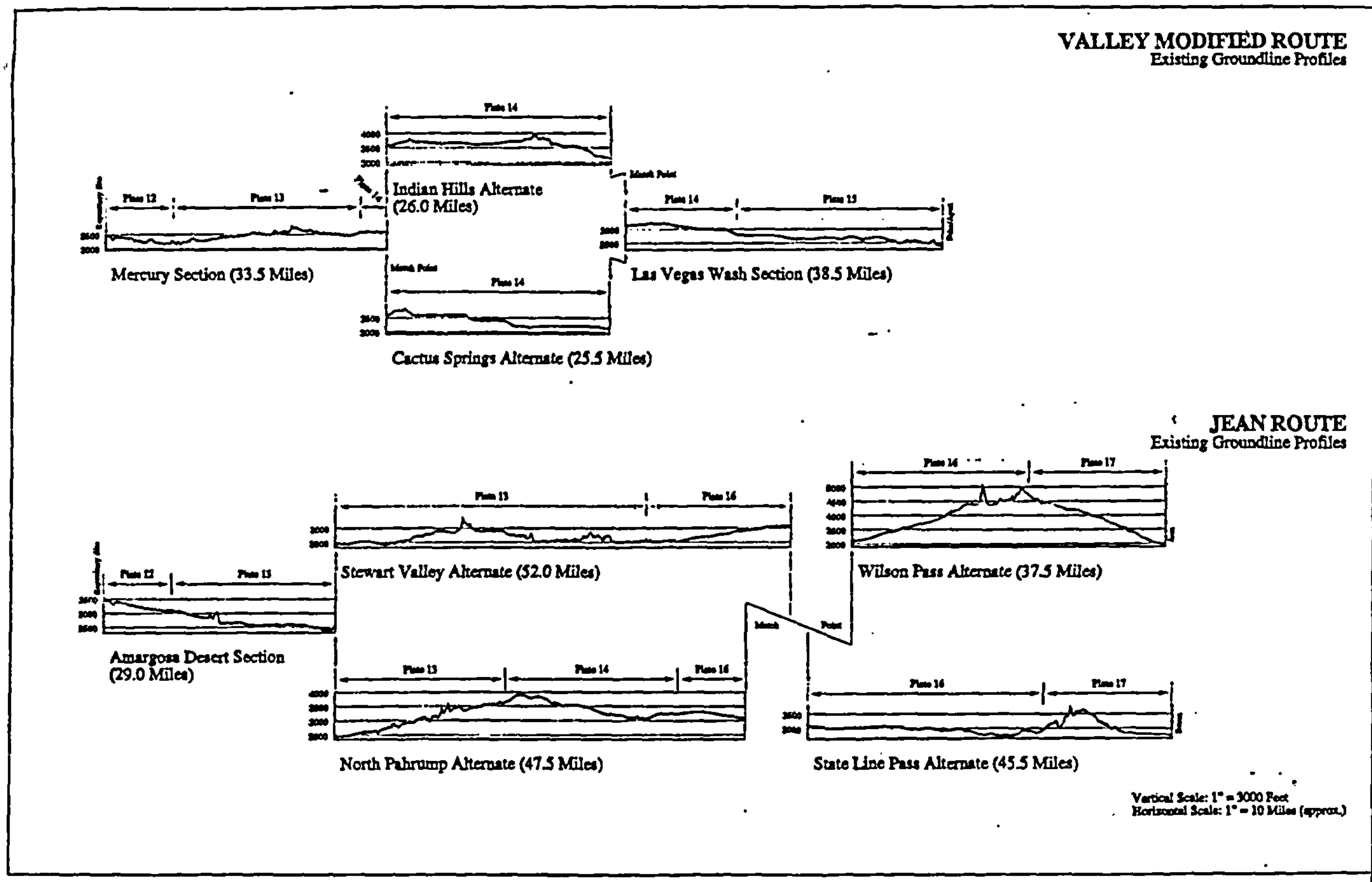
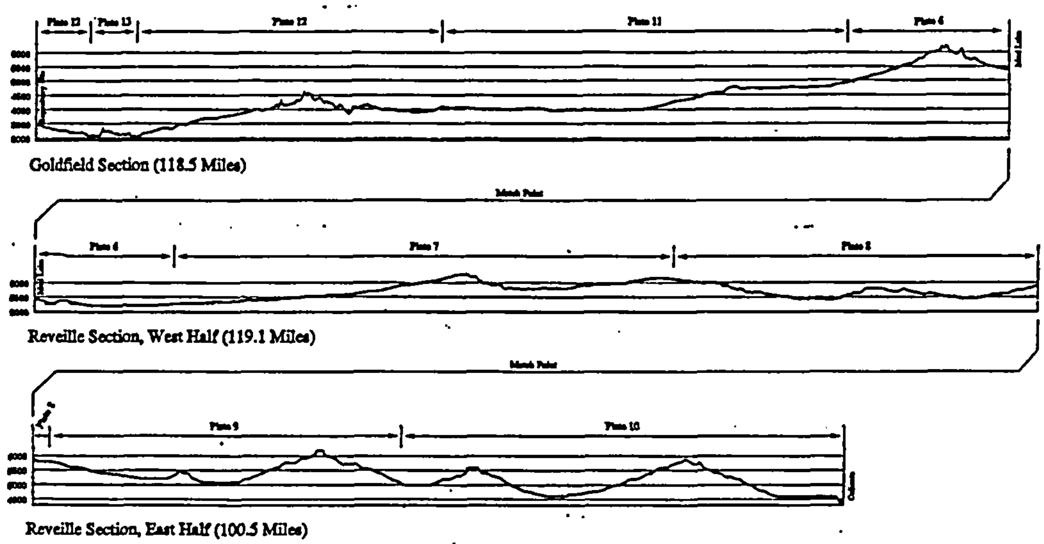

VALLEY MODIFIED ROUTE
Existing Groundline Profiles
Indian Hills Alternate (26.0 Miles)
Mercury Section (33.5 Miles)
Las Vegas Wash Section (38.5 Miles)
Cactus Springs Alternate (25.5 Miles)
JEAN ROUTE
Existing Groundline Profiles
Stewart Valley Alternate (52.0 Miles)
Wilson Pass Alternate (37.5 Miles)
Amargosa Desert Section (29.0 Miles)
North Pahrump Alternate (47.5 Miles)
State Line Pass Alternate (45.5 Miles)
Vertical Scale: 1" = 3000 Feet
Horizontal Scale: 1" = 10 Miles (approx.)

CALIENTE ROUTE
Existing Groundline Profiles



Vertical Scale: 1" = 3000 Feet
Horizontal Scale: 1" = 10 Miles (approx.)

CARLIN ROUTE
Existing Groundline Profiles