MSFC-405-Abstract

NTREES Testing and Operations Status

Abstract.

Nuclear Thermal Rockets or NTR's have been suggested as a propulsion system option for vehicles traveling to the moon or Mars. These engines are capable of providing high thrust at specific impulses at least twice that of today's best chemical engines. The performance constraints on these engines are mainly the result of temperature limitations on the fuel coupled with a limited ability to withstand chemical attack by the hot hydrogen propellant. To operate at maximum efficiency, fuel forms are desired which can withstand the extremely hot, hostile environment characteristic of NTR operation for at least several hours. The simulation of such an environment would require an experimental device which could simultaneously approximate the power, flow, and temperature conditions which a nuclear fuel element (or partial element) would encounter during NTR operation. Such a simulation would allow detailed studies of the fuel behavior and hydrogen flow characteristics under reactor like conditions to be performed. Currently, the construction of such a simulator has been completed at the Marshall Space Flight Center, and will be used in the future to evaluate a wide variety of fuel element designs and the materials of which they are fabricated. This present work addresses the operational status of the Nuclear Thermal Rocket Element Environmental Simulator or NTREES and some of the design considerations which were considered prior to and during its construction.

MSFC-405-Presentation

Joint Propulsion Conference - 2007

NTREES Testing and Operations Status

Bill Emrich – NASA Marshall Space Flight Center

Nuclear Thermal Rocket Element Environmental Simulator (NTREES) Overview

A key technology element in Nuclear Thermal Propulsion is the development of fuel materials and components which can withstand extremely high temperatures while being exposed to flowing hydrogen. NTREES provides a cost effective method for rapidly screening of candidate fuel components with regard to their viability for use in NTR systems

- **The NTREES is designed to mimic the conditions (minus the radiation) to which nuclear rocket fuel elements and other components would be subjected to during reactor operation.**
- **The NTREES consists of a water cooled ASME code stamped pressure vessel and its associated instrumentation coupled with inductive heaters to simulate the heat provided by the fission process.**
- **The NTREES has been designed to allow hydrogen gas to be injected into internal flow passages of a test article mounted in the chamber.**

Numerous laboratory upgrades in 4205/110 have been required to support the operation of NTREES. These modifications include the installation of a cooling water system, a power distribution system consisting of switch panels and transformers, and a propellant gas feed/exhaust system.

Use of Depleted Uranium (DU) in NTREES

ER24/Nuclear Systems Branch

Propulsion Systems Department
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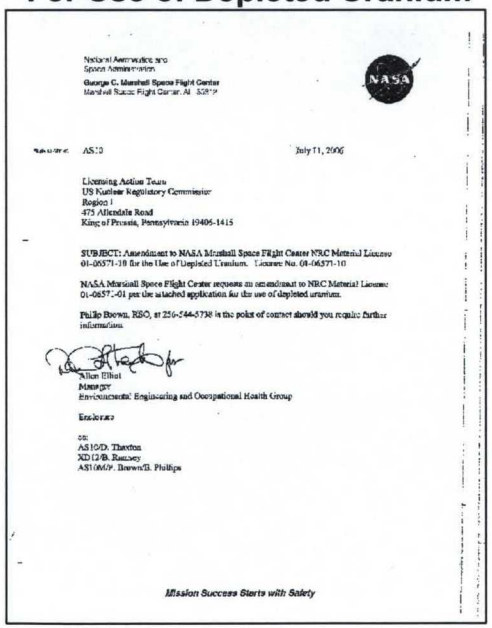
The NTREES system has been reviewed and approved by the MSFC Radiation Safety Officer (RSO) and has been licensed by the NRC to handle Depleted Uranium

- **The Operating Procedures have been approved by the RSO**
- **Filters have been installed on all vent lines (0.3 μm) to capture DU particles which escape the test element**
- **A mass spectrometer on the vent line monitors the exhaust for traces of U^{238} (DU)**

MSFC License Application For Use of Depleted Uranium



National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Marshall Space Flight Center, AL 35812

AS10 July 11, 2006

Licensing Action Team
US Nuclear Regulatory Commission
Region I
475 Allendale Road
King of Prussia, Pennsylvania 19406-1415

SUBJECT: Amendment to NASA Marshall Space Flight Center NRC Material License 01-06571-10 for the Use of Depleted Uranium. License No. 01-06571-10

NASA Marshall Space Flight Center requests an amendment to NRC Material License 01-06571-01 per the attached application for the use of depleted uranium.

Phillip Brown, RSO, at 256-544-5738 is the point of contact should you require further information.

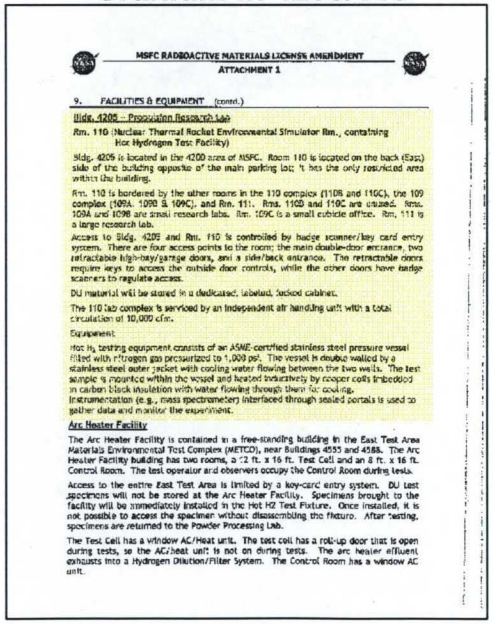
Allen Elliot
Manager
Environmental Engineering and Occupational Health Group

Enclosure

cc:
AS10/D. Thaxton
XD12/B. Ramsey
AS10M/P. Brown/B. Phillips

Mission Success Starts with Safety

MSFC License Application Authorizing use of Depleted Uranium in 4205/110



MSFC RADIOACTIVE MATERIALS LICENSE AMENDMENT
ATTACHMENT 1

9. FACILITIES & EQUIPMENT (contd.)

Bldg. 4205 – Propulsion Research Lab

Rm. 110 (Nuclear Thermal Rocket Environmental Simulator Rm., containing Hot Hydrogen Test Facility)

Bldg. 4205 is located in the 4200 area of MSFC. Room 110 is located on the back (East) side of the building opposite of the main parking lot. It has the only restricted area within the building.

Rm. 110 is bordered by the other rooms in the 110 complex (110B and 110C), the 109 complex (109A, 109B & 109C), and Rm. 111. Rms. 110B and 110C are unused. Rms. 109A and 109B are small research labs. Rm. 109C is a small cubicle office. Rm. 111 is a large research lab.

Access to Bldg. 4205 and Rm. 110 is controlled by badge scanner/key card entry system. There are four access points to the room; the main double-door entrance, two retractable high-bay/garage doors, and a side/back entrance. The retractable doors require keys to access the outside door controls, while the other doors have badge scanners to regulate access.

DU material will be stored in a dedicated, labeled, locked cabinet.

The 110 lab complex is serviced by an independent air handling unit with a total circulation of 10,000 cfm.

Equipment

Hot H2 testing equipment consists of an ASME-certified stainless steel pressure vessel filled with nitrogen gas pressurized to 1,000 psi. The vessel is double walled by a stainless steel outer jacket with cooling water flowing between the two walls. The test sample is mounted within the vessel and heated inductively by copper coils imbedded in carbon block insulation with water flowing through them for cooling. Instrumentation (e.g., mass spectrometer) interfaced through sealed portals is used to gather data and monitor the experiment.

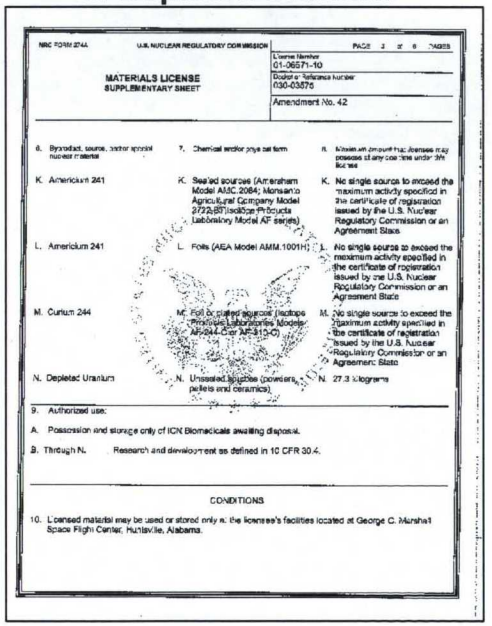
Arc Heater Facility

The Arc Heater Facility is contained in a free-standing building in the East Test Area Materials Environmental Test Complex (METCD), near Buildings 4535 and 4588. The Arc Heater Facility building has two rooms, a 12 ft. x 16 ft. Test Cell and an 8 ft. x 16 ft. Control Room. The test operator and observers occupy the Control Room during tests.

Access to the entire East Test Area is limited by a key-card entry system. DU test specimens will not be stored at the Arc Heater Facility. Specimens brought to the facility will be immediately installed in the Hot H2 Test Fixture. Once installed, it is not possible to access the specimen without disassembling the fixture. After testing, specimens are returned to the Powder Processing Lab.

The Test Cell has a window AC/Heat unit. The test cell has a roll-up door that is open during tests, so the AC/heat unit is not on during tests. The arc heater effluent exhausts into a Hydrogen Dilution/Filter System. The Control Room has a window AC unit.

NRC License allowing MSFC To Possess Up to 27.3 kg of Depleted Uranium



NRC FORM 374A — U.S. NUCLEAR REGULATORY COMMISSION — PAGE 2 OF 6 PAGES

MATERIALS LICENSE
SUPPLEMENTARY SHEET

License Number: 01-06571-10
Docket or Reference Number: 030-03876
Amendment No. 42

6. Byproduct, source, and/or special nuclear material	7. Chemical and/or physical form	8. Maximum amount that licensee may possess at any one time under this license
K. Americium 241	K. Sealed sources (Amersham Model AMC.2084; Monsanto Agricultural Company Model 272A/B; Nuclear Products Laboratory Model AF series)	K. No single source to exceed the maximum activity specified in the certificate of registration issued by the U.S. Nuclear Regulatory Commission or an Agreement State.
L. Americium 241	L. Foils (AEA Model AMM.1001H)	L. No single source to exceed the maximum activity specified in the certificate of registration issued by the U.S. Nuclear Regulatory Commission or an Agreement State.
M. Curium 244	M. Foil or plated sources (Isotope Products Laboratories Models AF-244-C or AF-315-C)	M. No single source to exceed the maximum activity specified in the certificate of registration issued by the U.S. Nuclear Regulatory Commission or an Agreement State.
N. Depleted Uranium	N. Unsealed sources (powders, pellets and ceramics)	N. 27.3 kilograms

9. Authorized use:

A. Possession and storage only of ICN Biomedicals awaiting disposal.

B. Through N. Research and development as defined in 10 CFR 30.4.

CONDITIONS

10. Licensed material may be used or stored only at the licensee's facilities located at George C. Marshall Space Flight Center, Huntsville, Alabama.

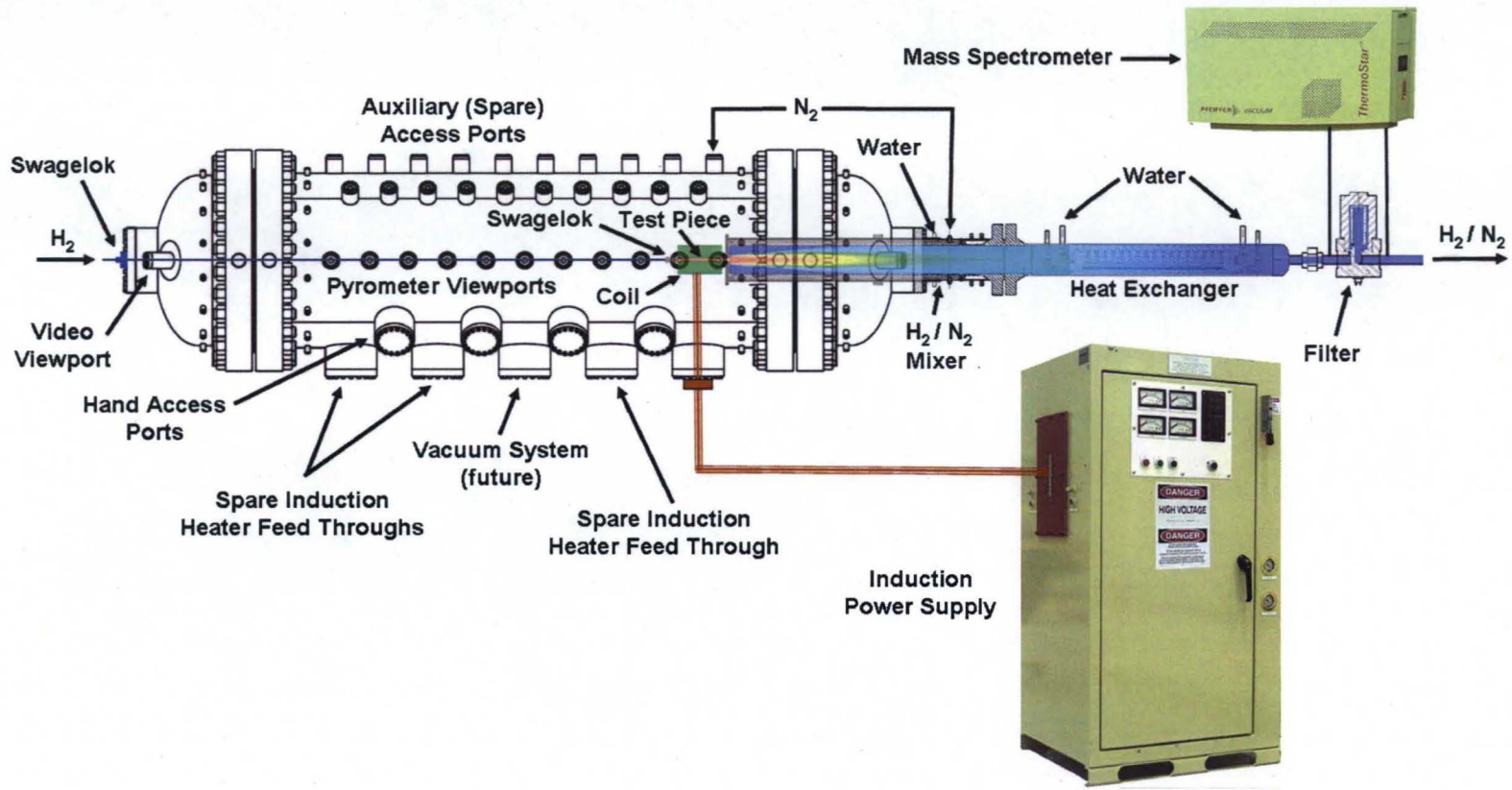
General Description:

- Water cooled ASME coded test vessel rated for 1050 psi
- GN_2 (facility) and GH_2 (trailer) gas supply systems
- Vent system (combined GN_2/GH_2 flow)
- 50kW RF power supply with induction coil
- Water cooling system (test chamber, exhaust mixer and RF system)
- Control & Data Acquisition implemented via LabView program
- Extensive H_2 leak detection system
- Data acquisition system consists of a pyrometer suite for axial temperature measurements and a mass spectrometer
- "Fail Safe" design

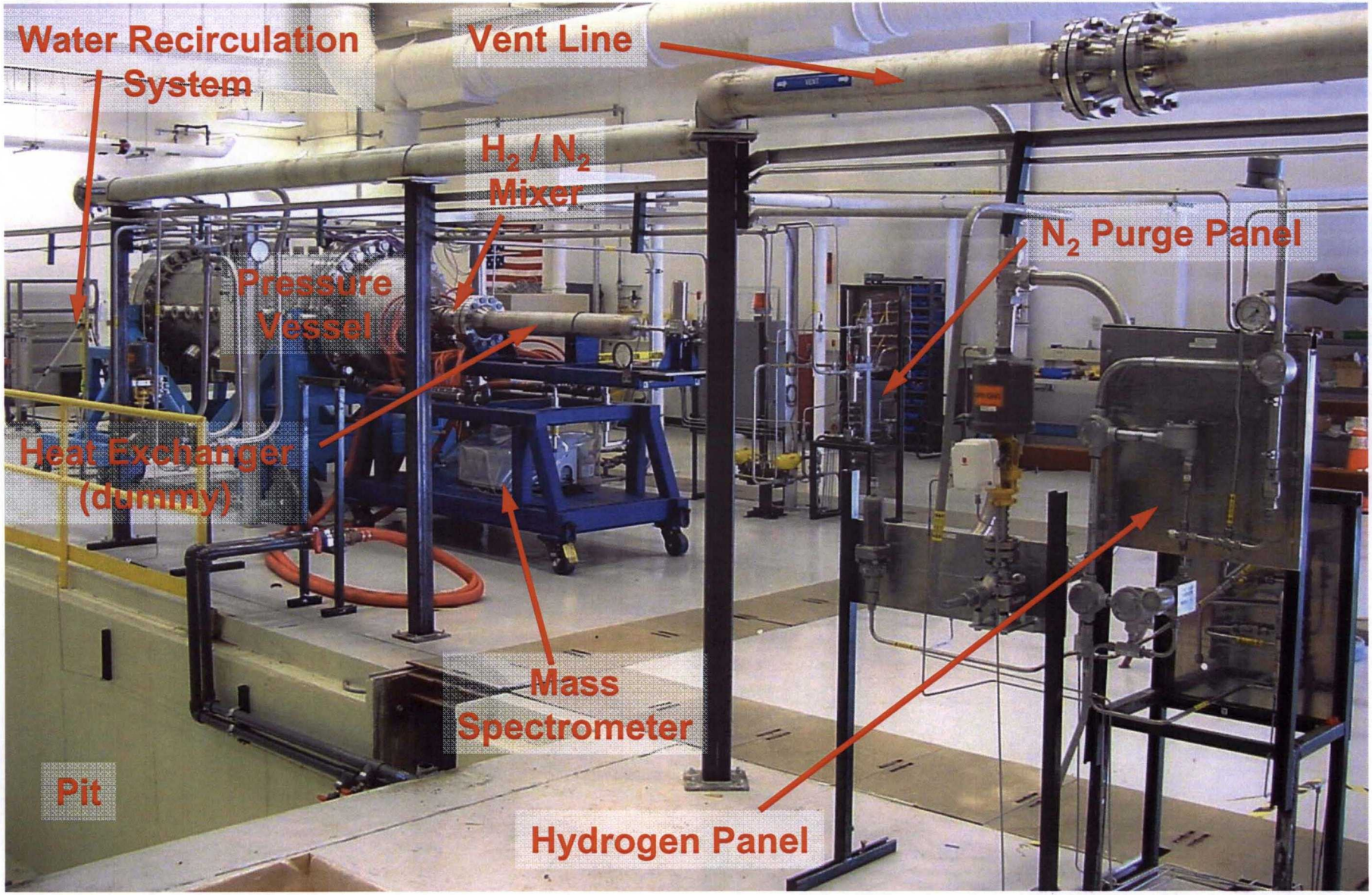
NTREES Layout – Laboratory Hardware
Test Chamber and RF System

Key components on test chamber setup:

- 50 kW RF power supply (NTREES is sized to accommodate up to 4 MW of RF power)
- Exhaust mixer system and heat exchanger to cool and dilute hot hydrogen flow
- Backpressure control instrumentation, valves, and filters
- Mass spectrometer on vent gas system
- Pyrometers to measure test specimen surface temperatures

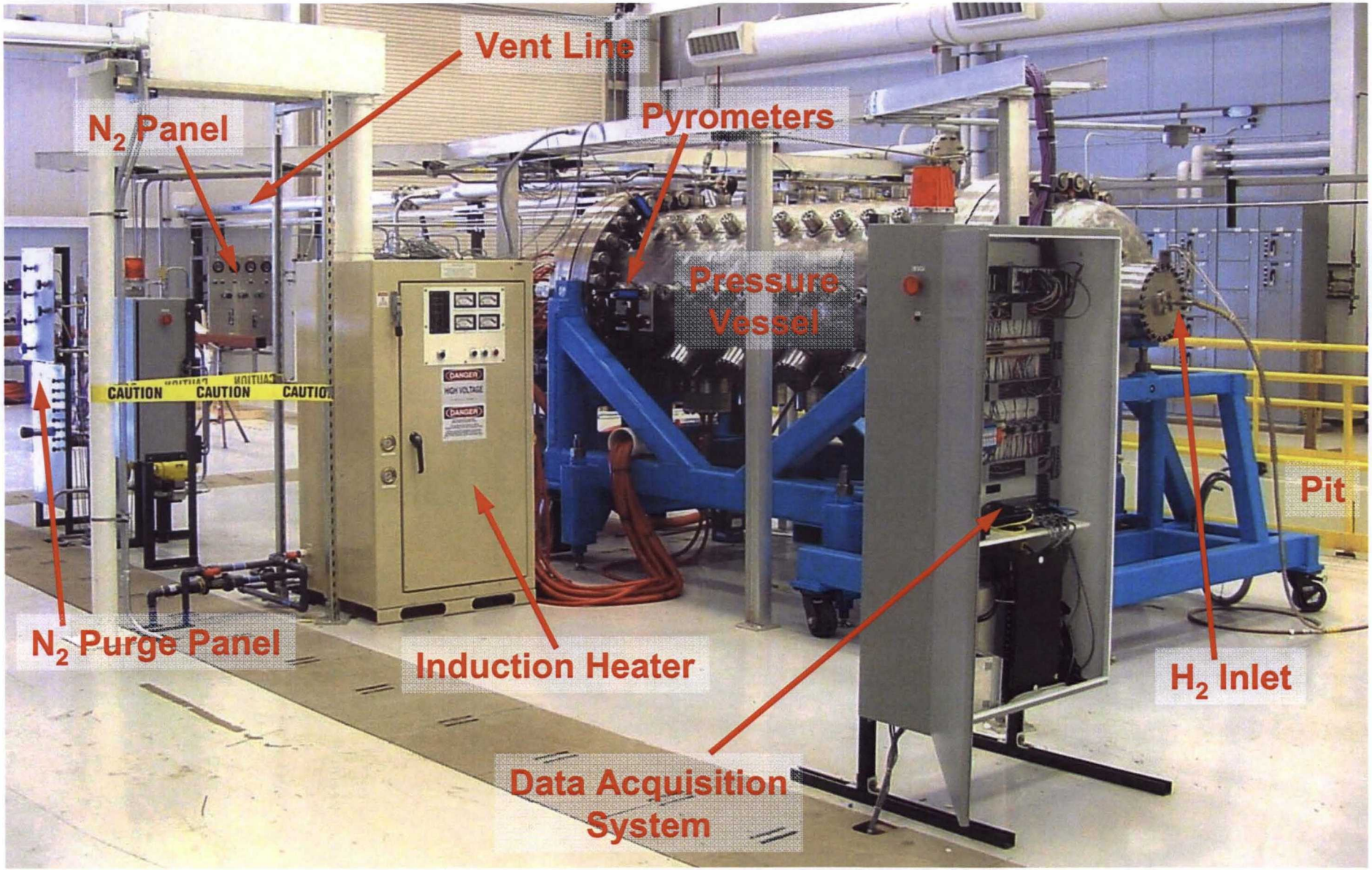


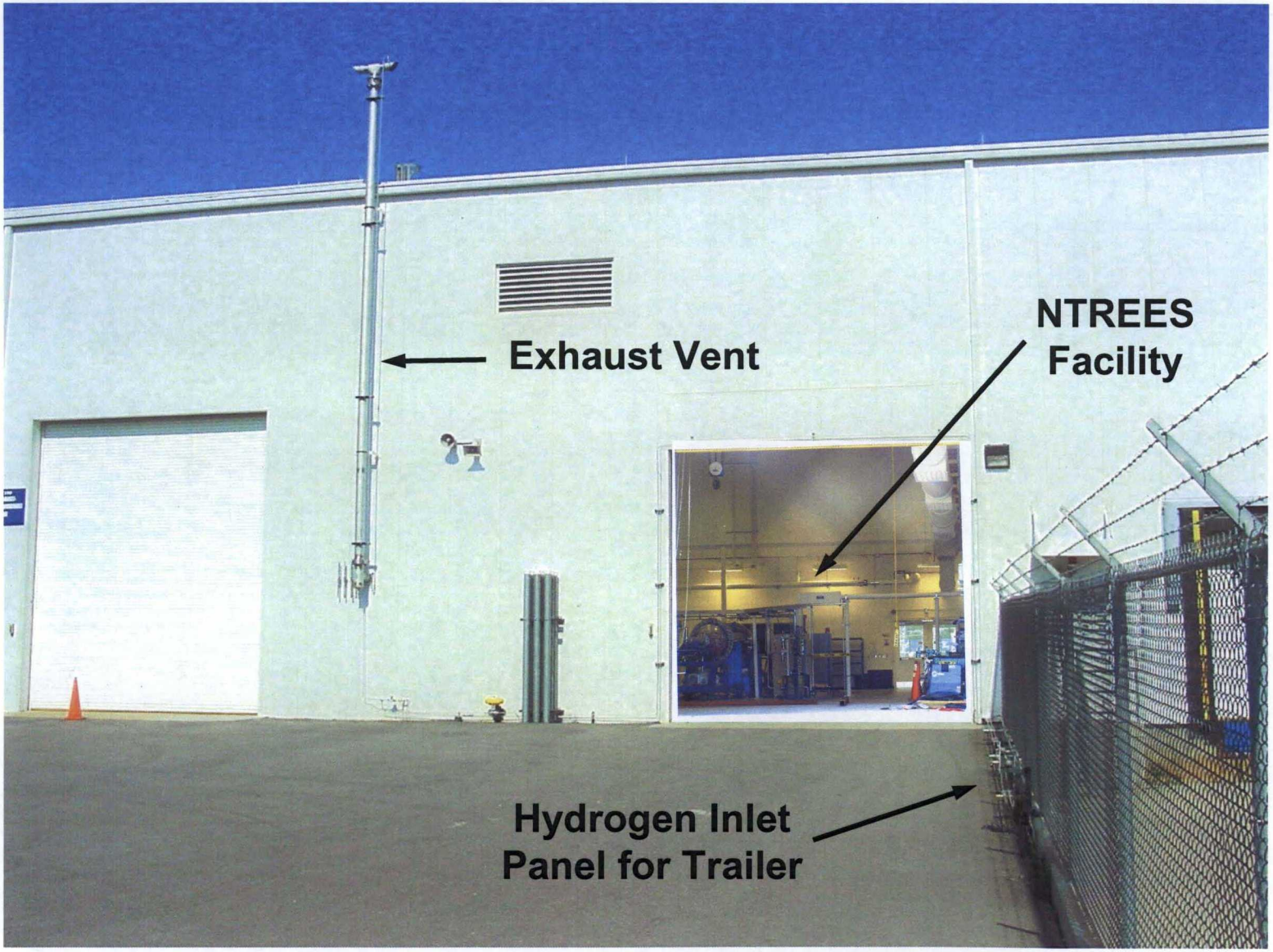
NTREES Facility in the PRDL



NTREES Facility in the PRDL

ER24/Nuclear Systems Branch




Exhaust Vent
NTREES
Facility
Hydrogen Inlet
Panel for Trailer

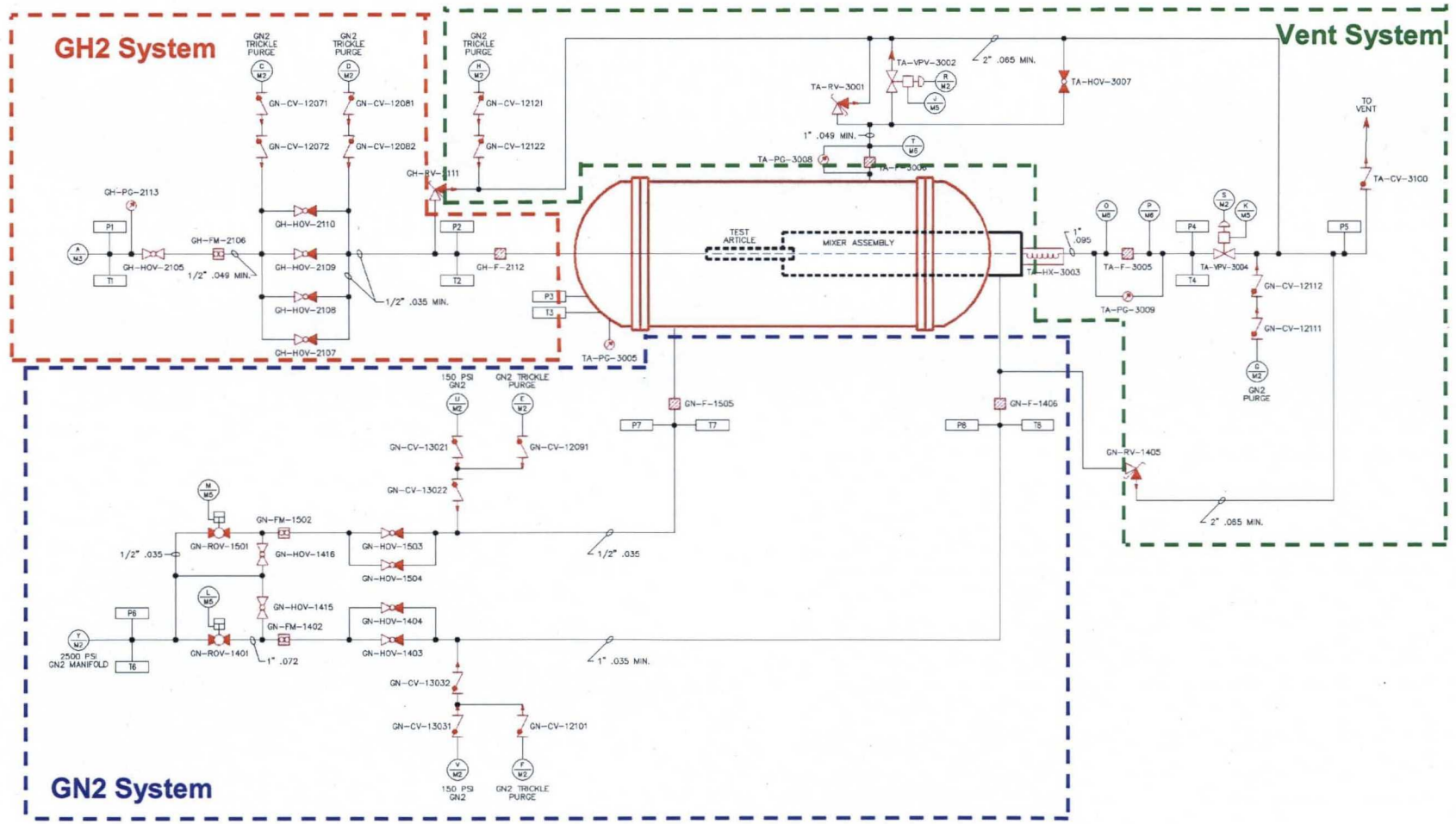
NTREES Layout – Mechanical Layout – GN2, GH2 and Vent Systems

ER24/Nuclear Systems Branch

Propulsion Systems Department
Engineered to Excel–Driven to Explore

Includes Nitrogen, Hydrogen, and Vent systems

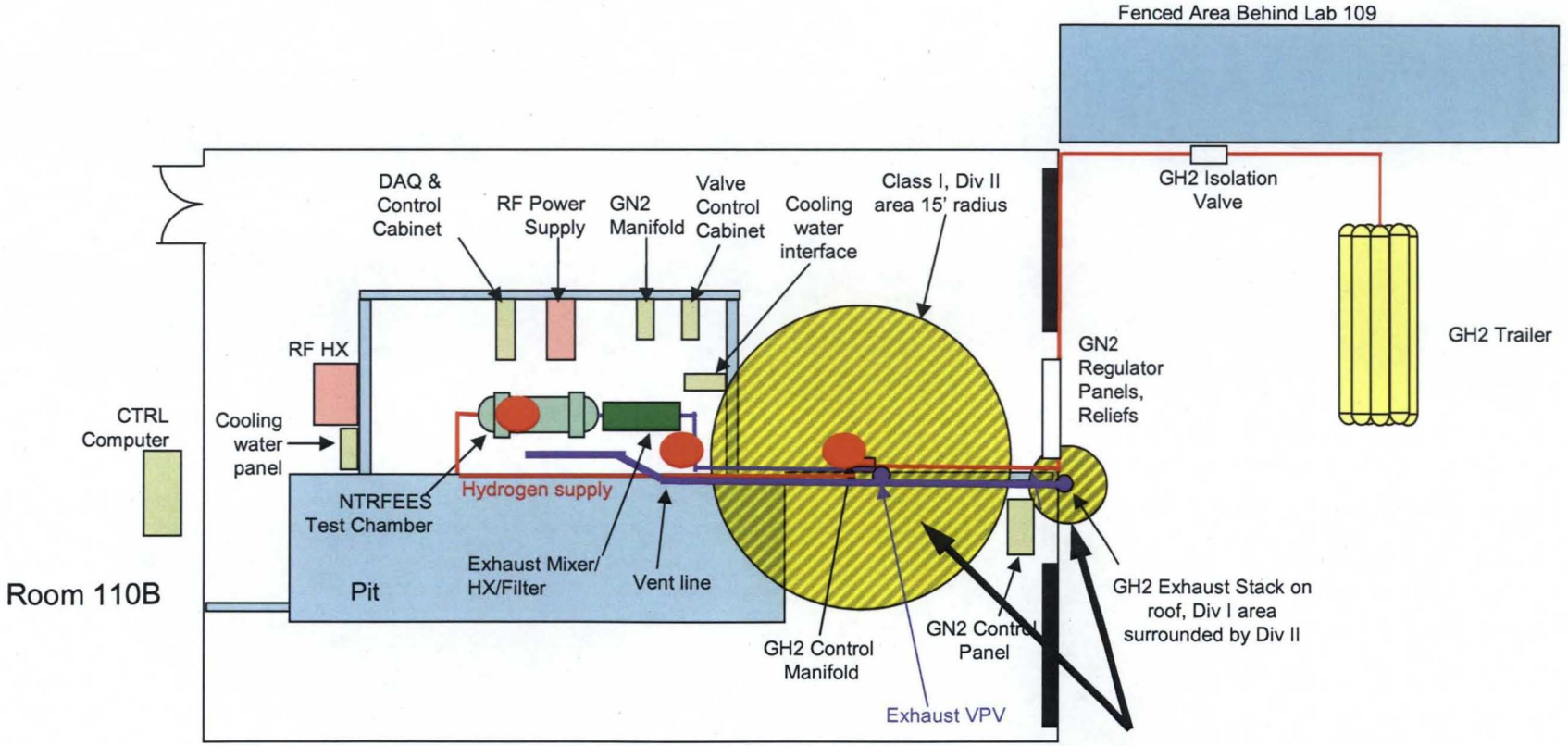
- **All components and layout are ASME certified**
- **Main chamber is ASME code stamped**



NTREES Layout
Laboratory Hardware Components

Primary hardware items placed on laboratory floor:

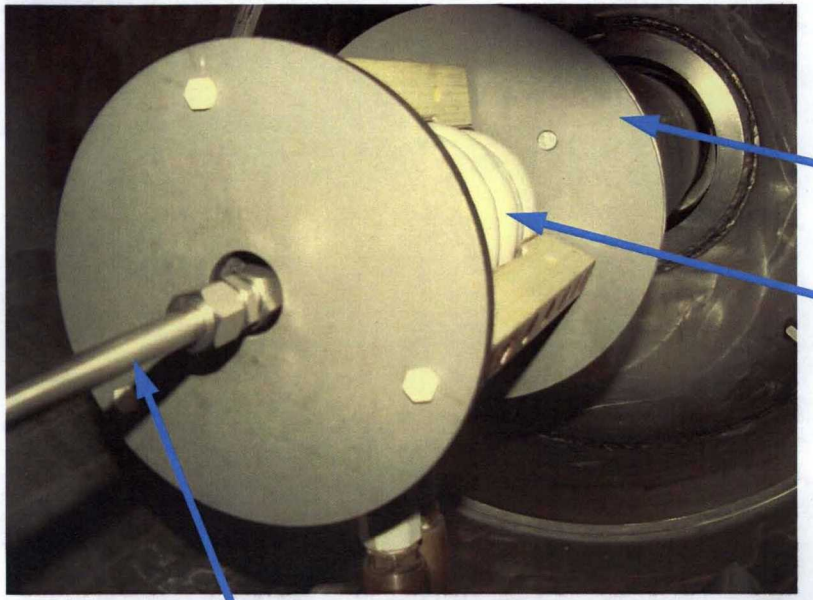
- **Hazardous Classification of areas around GH_2 panels and external vent**
- **Hydrogen supply from trailer (external); only hooked up during tests**
- **H2 detectors strategically located**



Bldg 4205, Room 110

All electrical components are explosion proof in these zones

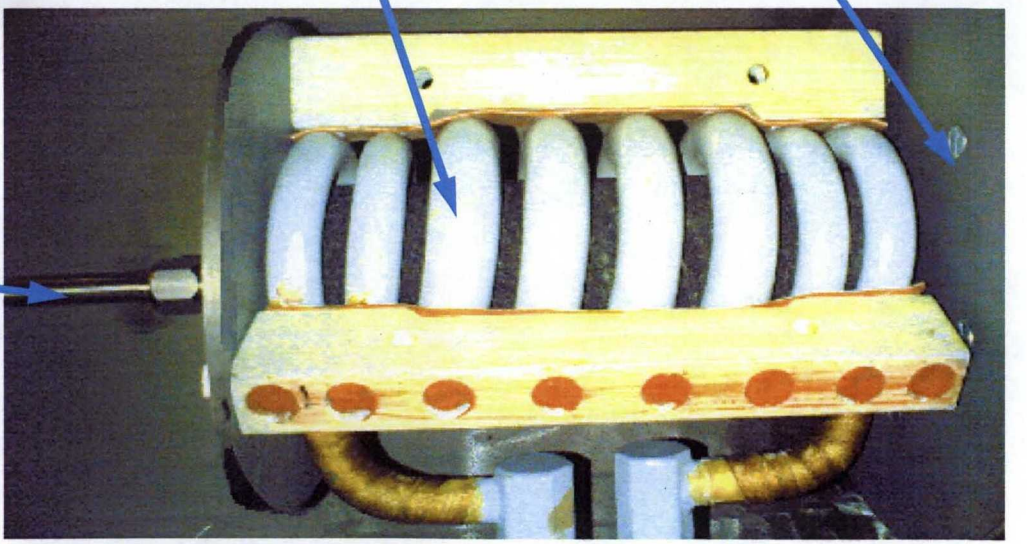
NTREES Induction Coil Mounted in Chamber with H_2 / N_2 Mixer Assembly



H_2 / N_2 Mixer

Coil Assembly

H_2 Inlet

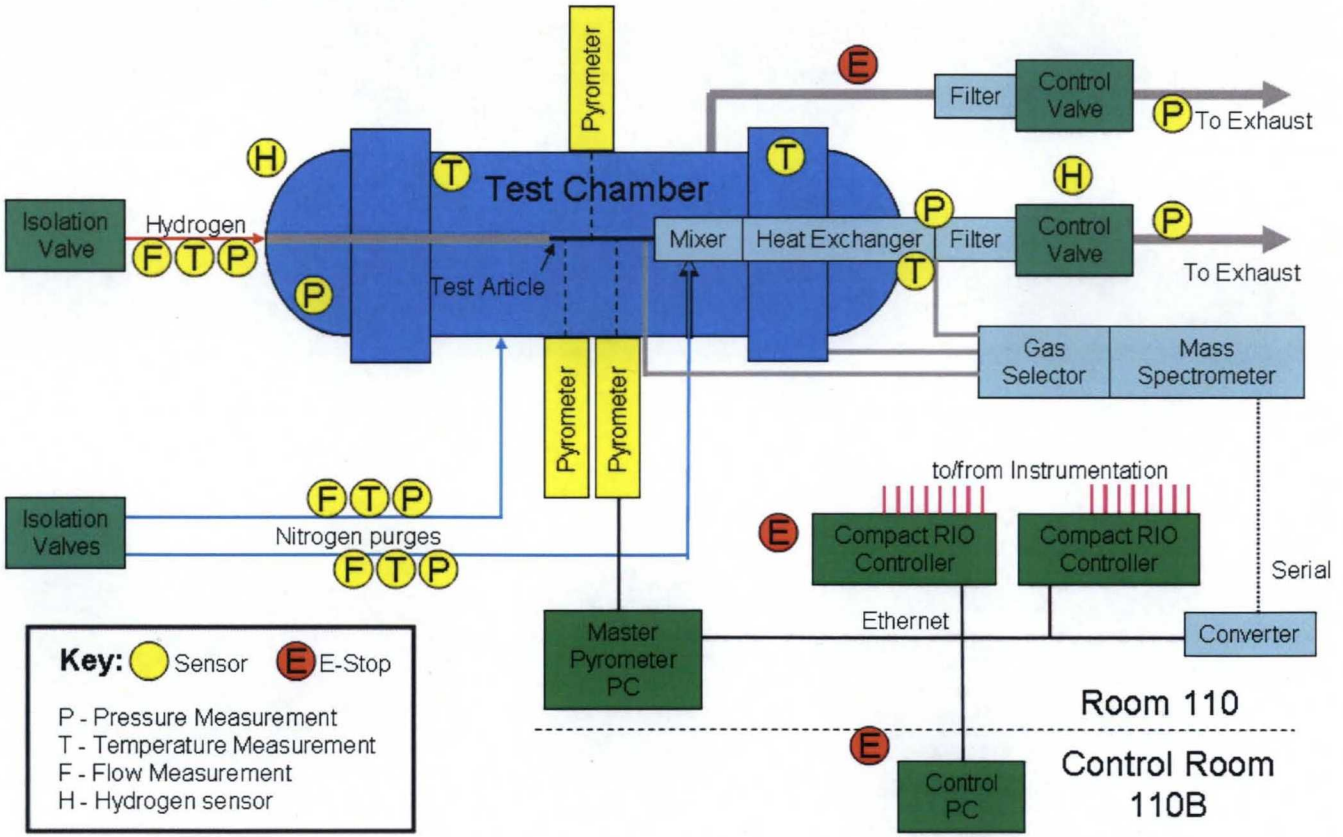


NTREES Data Acquisition and Control

ER24/Nuclear Systems Branch

Provides the following

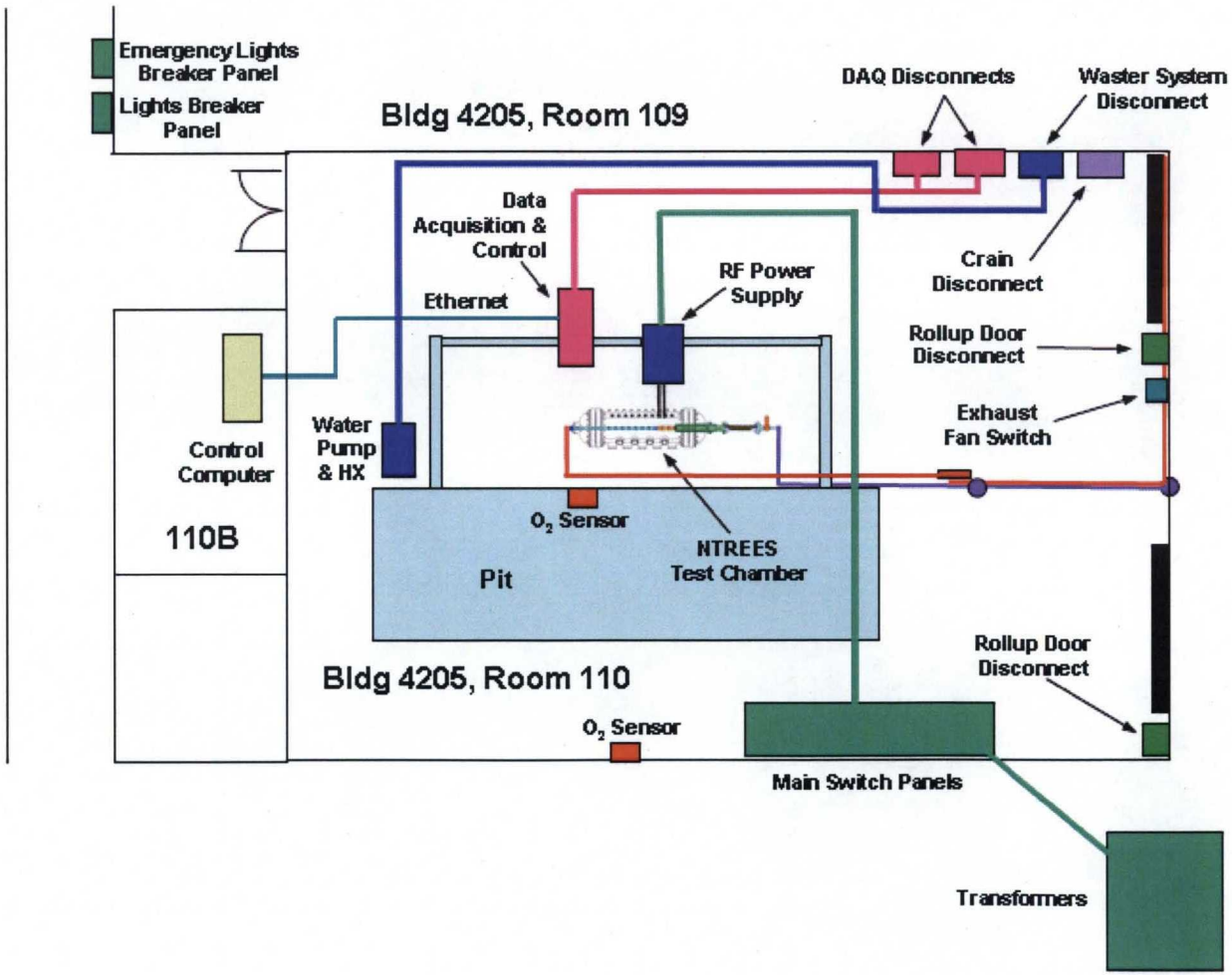
- System monitoring with 7 RTD's, 8 pressure transducers, & 3 flowmeters
- Active system to monitor and control test operations
- Automatically shuts down the system when anomalous conditions or redline cuts are detected (e.g. pressure too high or too low, over temperature, high H_2 concentration, low N_2 flow, etc.)



NTREES Electrical/Power System Layout

A number of power system panels are located in room 110

- Some power system panels feed the NTREES system (e.g. water, DAQ, etc.)
- All other panels will be locked out during testing (e.g. lights, crane, etc.)



NTREES Power Reserve in PRDL

Lab has capability of providing up to 5 MW of power for induction heating

- **Two 2.5MW Transformers**
- **High power switch gear**
- **High power conduit going to opposite side of room**

Switch Panel

Transformers

NTREES Operation – Safety Controls

- **Fail-Safe Components**
  - Relief valves on pressurized equipment
  - High pressure gas supply lines with fail-closed valves (loss of power/pneumatics)
  - Back pressure control valves (vent)
    1. Proportional control for chamber and test article pressure
    2. Fail open
    3. Pneumatically controlled, safer for GH_2 environment
- **Emergency Shutdown**
  - Actively set to safe condition by real-time controllers
  - Real-time controllers operation includes:
    1. Termination of RF Power
    2. Closing of GH_2 supply valve
    3. Opening of outlet vent valves to relieve chamber and test article pressure
- **Emergency Shutdown Criteria include:**
  - Any room/chamber GH_2 sensor exceeding limit
  - Loss of cooling water flow
  - Any E-Stop button activated (pressed)
  - Watchdog timeout (both controllers monitor each other)
  - Chamber pressure or delta pressure (too high or erratic behavior)
  - Pressure (too low) in chamber sampling stream (GH_2 sensor location)

Conclusions

- The NTR Element Environmental Simulator is complete and will allow fuel elements or other components to be tested in a hot hydrogen environment with or without internal heat generation and enables:
  - High temperature (> 3000 K) operation in flowing hydrogen
  - A wide range of instrumentation for monitoring test article behavior under extreme conditions
  - High pressure operation up to 1050 psi
  - Close personnel access during operation resulting from forced cooling of the chamber
- Due to a lack of funding, the NTREES facility is currently sitting in a standby condition pending future authorization to proceed to testing

Summary

The NTR Element Environmental Simulator is operational at MSFC and is available to begin testing fuel materials and other components under prototypical NTR operating conditions