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Presentation to the NWTRB: Fuel Drying Activities by the Environmental Management Program at Idaho National Laboratory

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Three Mile Island (TMI) Fuel Storage Project
Drying Disrupted Fuel and Debris

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Test Area North (TAN)

- Constructed to support the Aircraft Nuclear Propulsion Program in 1951-1961.
- Hot Shop, Hot Cell, Warm Shop, Pool
- March 1979 accident at Three Mile Island (TMI), Pressurized Water Reactor
- Three Mile Island Fuel was received for storage from 1986-1990

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TMI Dry Storage Project

- 1995 Settlement Agreement SNF consolidation, wet to dry storage transfer by June 1, 2001.
- Construction of an NRC licensed Dry Storage System at Idaho Nuclear Technology and Engineering Center (INTEC)
- Operation at Test Area North (TAN) to prepare fuel for storage
  - Retrieve Fuel from Test Area North Pool (1999-2001)
  - Dewater (filter water using ion exchange)
  - Dry 344 TMI Canisters
  - Load Dry Shielded Canister, weld shield plug and lid
  - Transport to from TAN to INTEC (25 miles) and store in Horizontal Storage Module

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TMI Canisters

- 341 of 344 canisters, 12 TMI canisters per Dry Shielded Canister
  - diameter 14 inches
  - length 150 inches (12 1/2')
- Canister Maximum Decay heat Power per Canister $\leq$ 60 Watts (29 avg.)
- Burn-up 3175 MWD/MTU
- Post Irradiation Cooling Time $\geq$ 19 years

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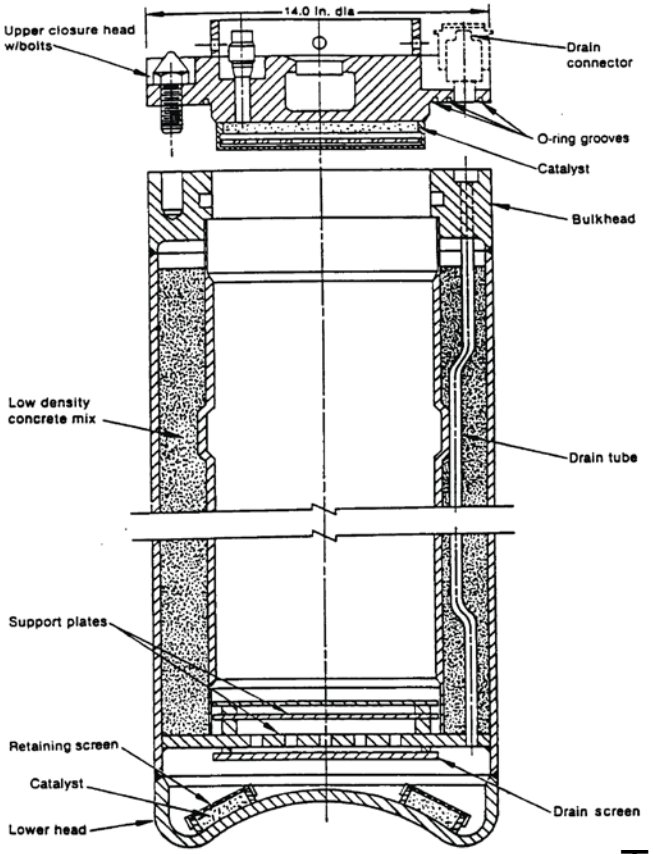
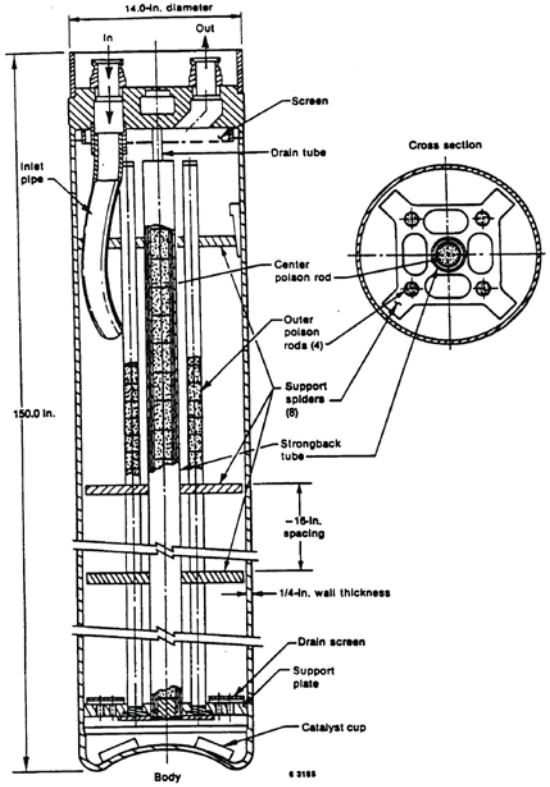
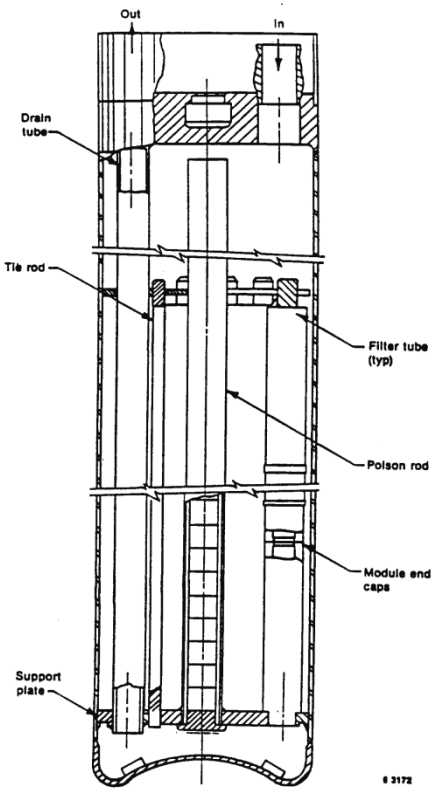
TMI Canisters



TMI-2 Fuel Canister



TMI-2 Knockout Canister



TMI-2 Filter Canister

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TMI Canisters cont.

- TMI-2 *Fuel* canisters (large pieces of core debris).
- TMI-2 *Knockout* canisters (fines generated from the use of the debris vacuum system)
- TMI-2 *Filter* canisters (fines generated from the use of the debris vacuum system and defueling water cleanup system)

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TMI Canisters cont.

- Can contents: Retrieved materials from the TMI-2 core include:
  - Rubble bed debris.
  - Partially intact fuel assemblies.
  - Debris bed stratified material.
  - Miscellaneous core component pieces (e.g., fuel rod segments, spacer grids, end fittings, control rod
  - assembly spiders, springs, fuel pellets, etc.).
  - In-core instrument assemblies.

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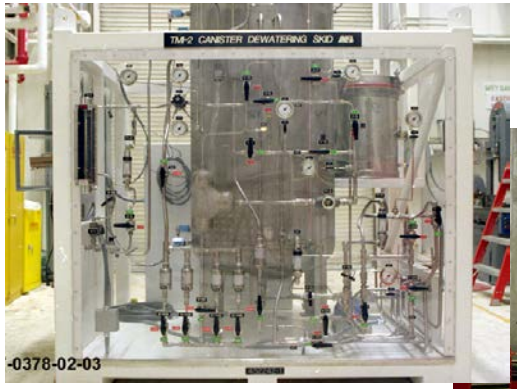
Dewatering Skid

- Ion exchange module was developed
  - Critically-safe
  - Drop analysis was performed
  - Water returned to storage pool



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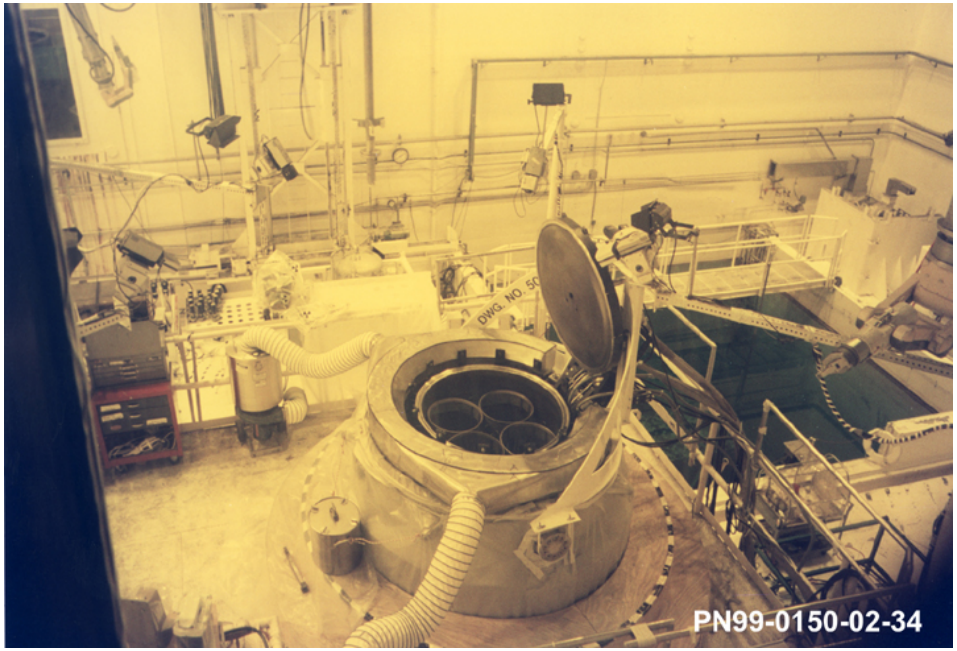
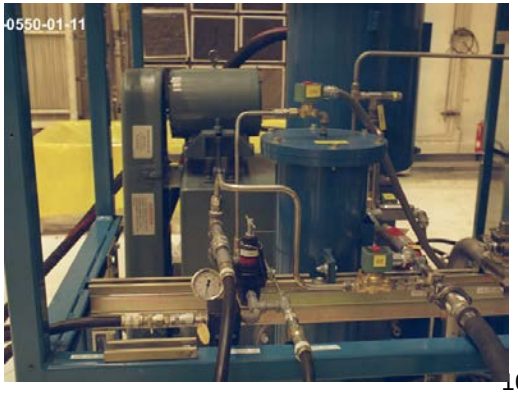
Heated Vacuum Drying System

- Heated Vacuum Drying System (125-B Cask used as Shielding
- 4 canisters per drying iteration
- 87 total drying iterations
- Sintered metal filters were used to filter off gas from each canister
- Maximum temperatures;
  - Heater- 900 F
  - Canister wall- 600 F





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Heated Vacuum Drying System (HVDS)

Sources of water in the canisters

- Free water – not chemically bound and not physically adsorbed. Free water includes interstitial water in pores of solids or beds of fine material
- Chemically bound water of hydration
- Physically absorbed water
- Licon layer in annulus around fuel canister storage port contained both chemically and physically bound water

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TMI-2 Drying

Initial Drying Objective

< 8.8 X10^{-5} gm water/cm^3 fuel plus 100% hydrogen atmosphere (initial criticality safety analysis)

Initial Drying Criteria

- When furnace pressure declined below one torr then isolate furnace.
- If furnace pressure increased to no more than three torr in one half hour it was dry.

Disadvantages:

- Drying times exceeding 80 hours
- Furnace pressure does not provide sensitive measure of dryness
- Furnace pressure during isolation indicated water but not amount remaining
- No relation between drying criteria and remaining water

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TMI-2 Drying

Second Criticality Safety Analysis

- Bound water remaining in Licon considered
- Canisters remain safely subcritical with up to 8 L water remaining in fuel
- Less than 8L water per canister after drying and storage uptake (vented storage allows moisture ingress)
- Storage uptake determined to be <1 L per canister
- Drying procedure modified to ensure canisters contained less than 7 L (= 8L – 1L) water following drying
- Bound water in fuel
- Free water in fuel

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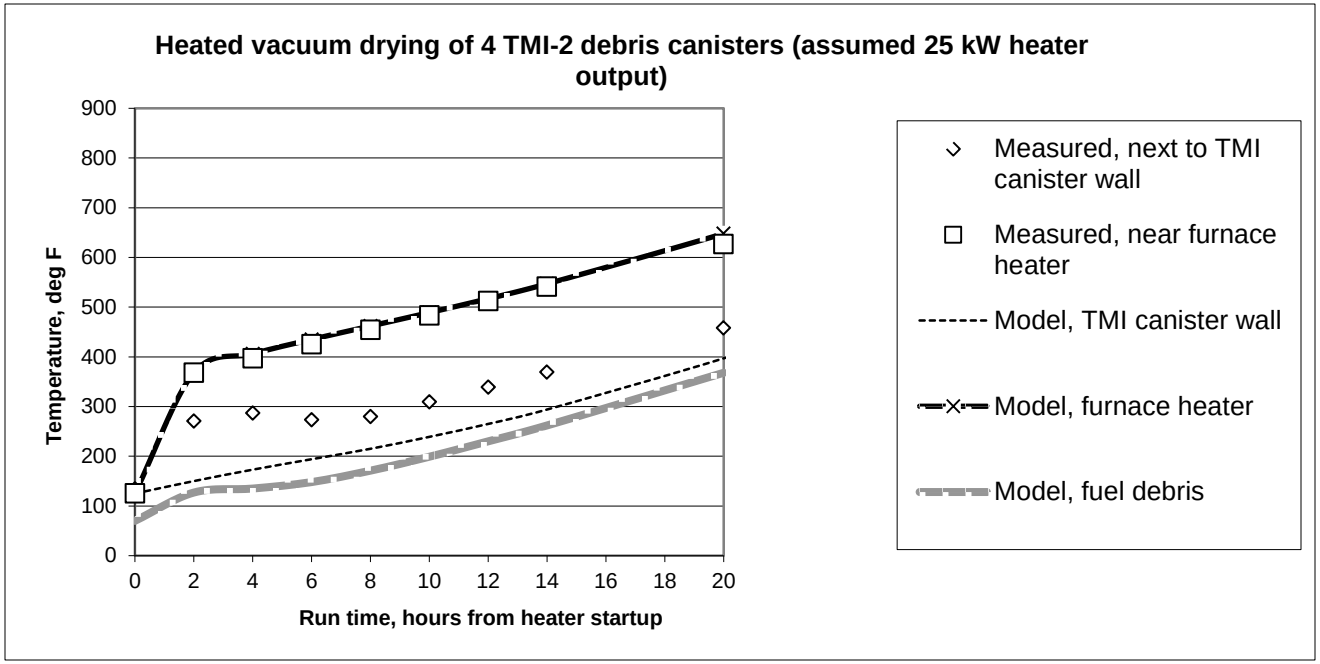
Bound Water

Fuel temperatures during drying modeled and measured to determine bound water content



Bound water determined from water adsorption measurements with temperature of fuel components

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Free Water

TMI-2 pressurization rate trend follows the

"falling rate" observed when drying porous solids.

Characteristics of falling rate drying are:

- Begins at a water content that is uniform for a particular solid
- Falling rate is exponential
- Gradually approaches "bound" water content defined by the fuel debris temperature and pressure
- Drying rate dependent on heat flux

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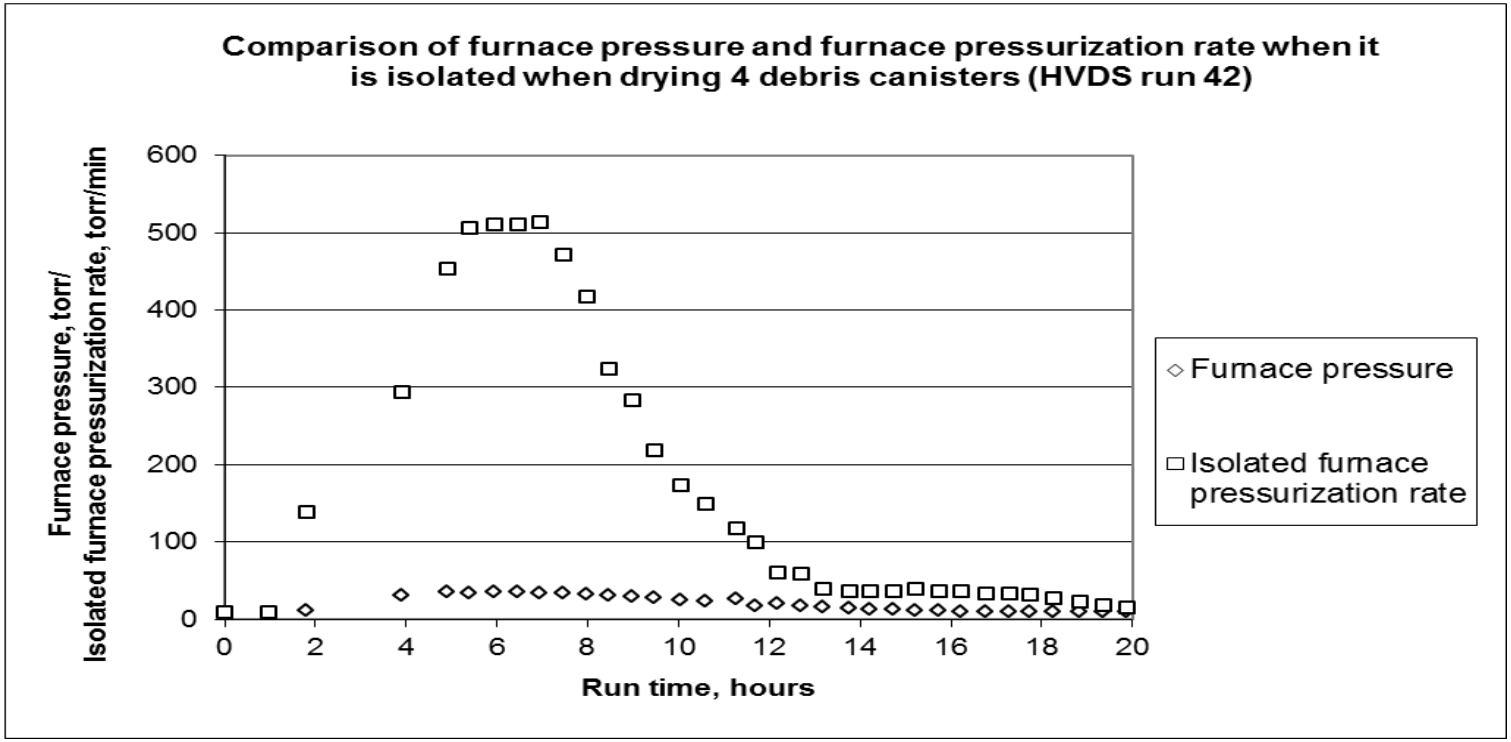
Free Water

Comparison of drying run pressure and accompanying pressure rises measured during periodic isolations



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Fuel Drying

Criteria for drying run completion

Free water:

- HVDS functional criteria (heaters, condensers, pumps)
- Minimum canister wall temperature attained
- Pressurization rate increases to maximum
- Measured pressurization rate trend continues to decline
- Final 2 pressurization rates <10% maximum

Bound water:

- Minimum drying falling rate period

Maximum water content < 2.3 L/canister

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Fuel Drying cont.

Advantages of revised TMI-2 Drying Procedure

- Drying times reduced to less than 25 hours
- Estimate remaining drying time
- Performed in the presence of leaks

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Radiolysis

Radiolysis, a bounding conservative evaluation

- All canisters contain hydrogen recombiner catalysts provided during initial construction. No credit was taken. (Verification of performance could have been questioned)
- Gas generation rate is a function of quantity and location of the water and decay heat, i.e. TMI is not hot spent fuel (avg. 29 watts per canister)
- Maximum measured hydrogen generation rate < 7 cc/hr.
- Maximum calculated hydrogen concentrations during storage;
  - 1.2% in DSC
  - 4.8% in canisters

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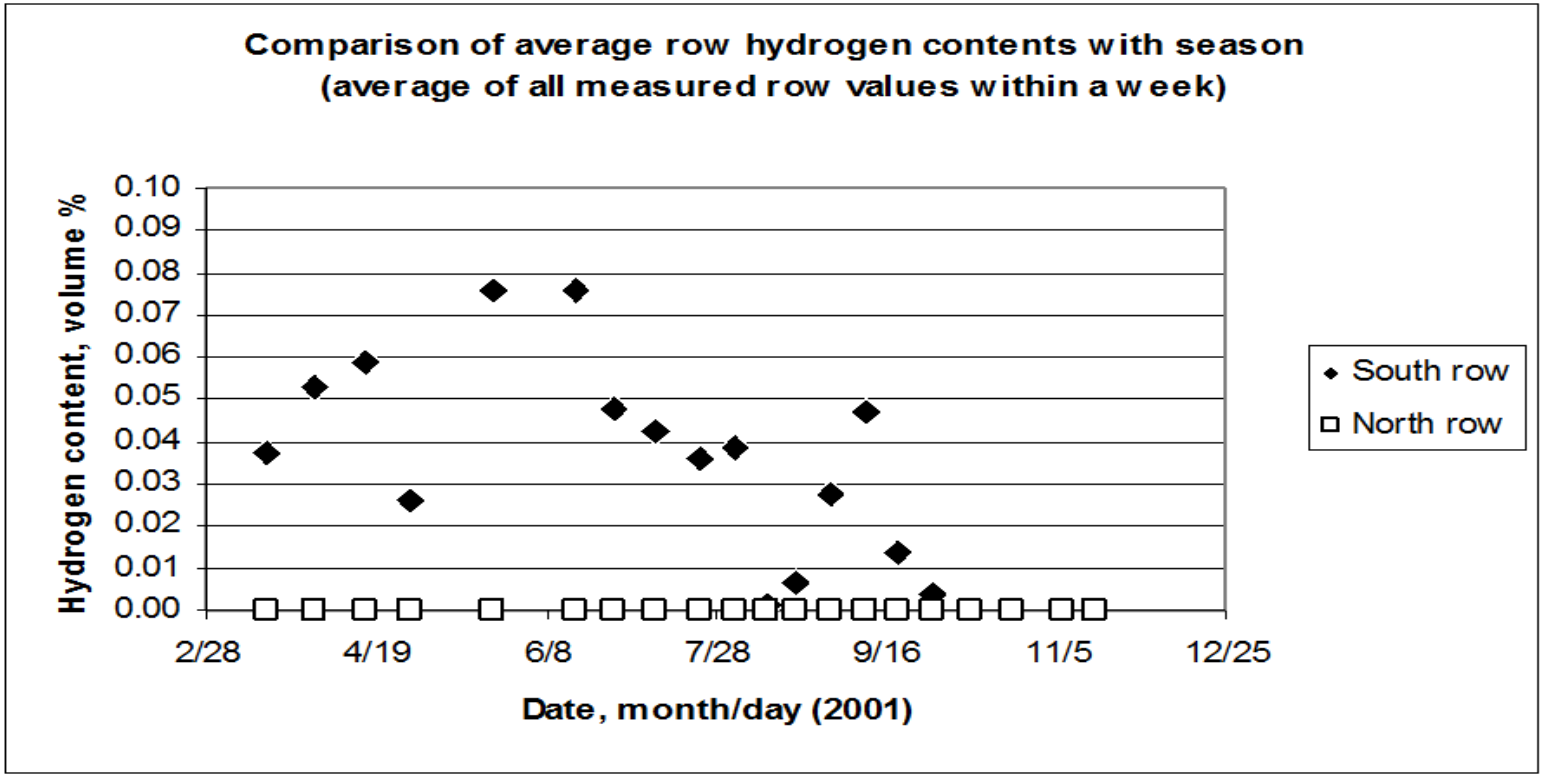
Hydrogen Concentrations in DSCs

Actual measured hydrogen concentrations in DSCs



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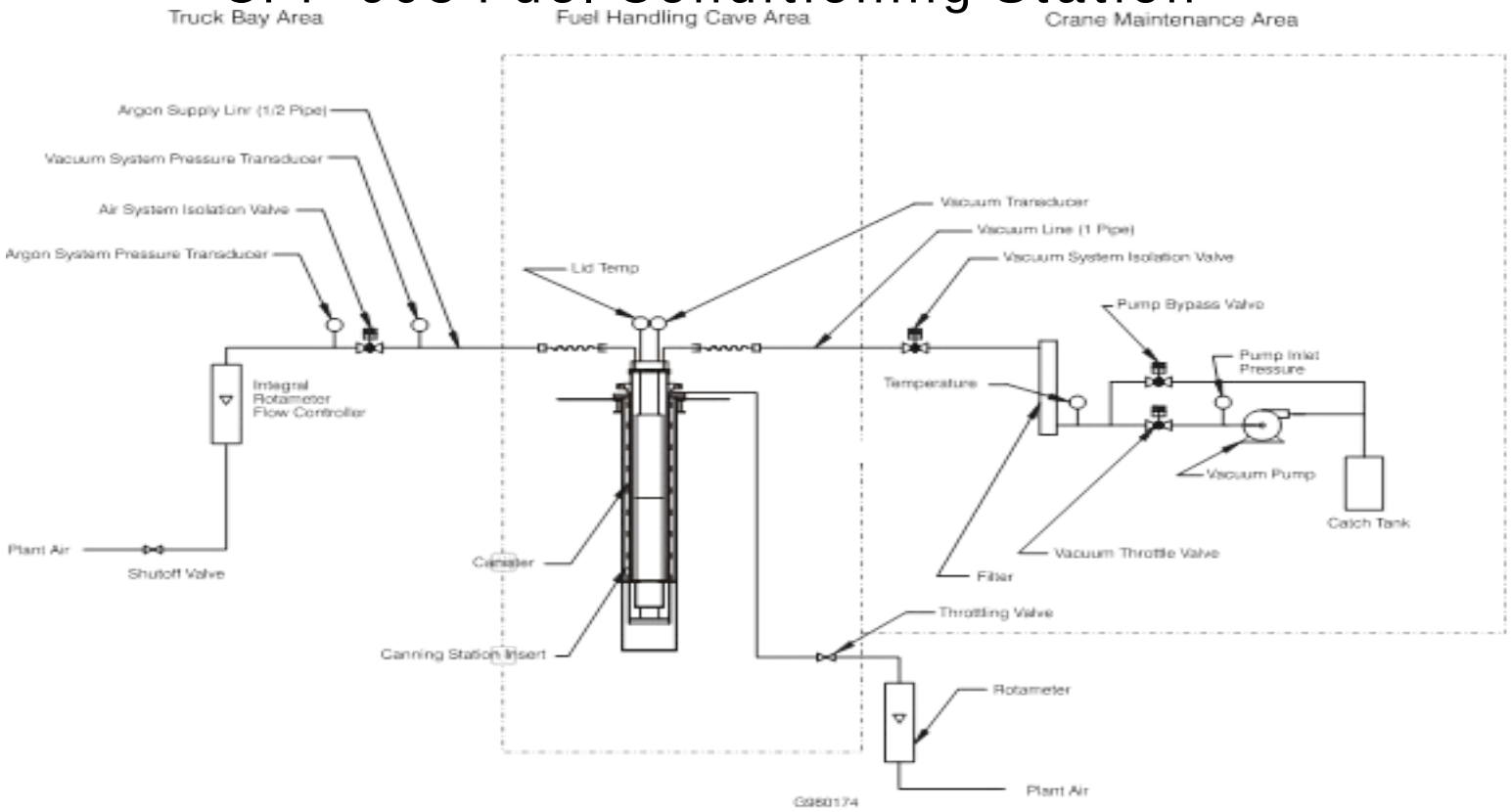
CPP-603 Fuel Conditioning Station

CPP-603 Fuel Conditioning Station



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CPP-603 Fuel Conditioning Station

- Heated vacuum drying system operated similar to HVDS
- Fuel dried in IFSF storage canister, then stored in IFSF
- Maximum temperatures
  - Heating system < 500 deg C
  - Maximum fuel < 250 deg
- Passivate potentially reactive fuels (175 deg C)
- Campaigns:
  - CPP-603 (aluminum, TRIGA, uranium alloy fuels)
  - MTR canal debris
  - Fermi driver, Pathfinder, Borax
  - ATR, other aluminum test reactor

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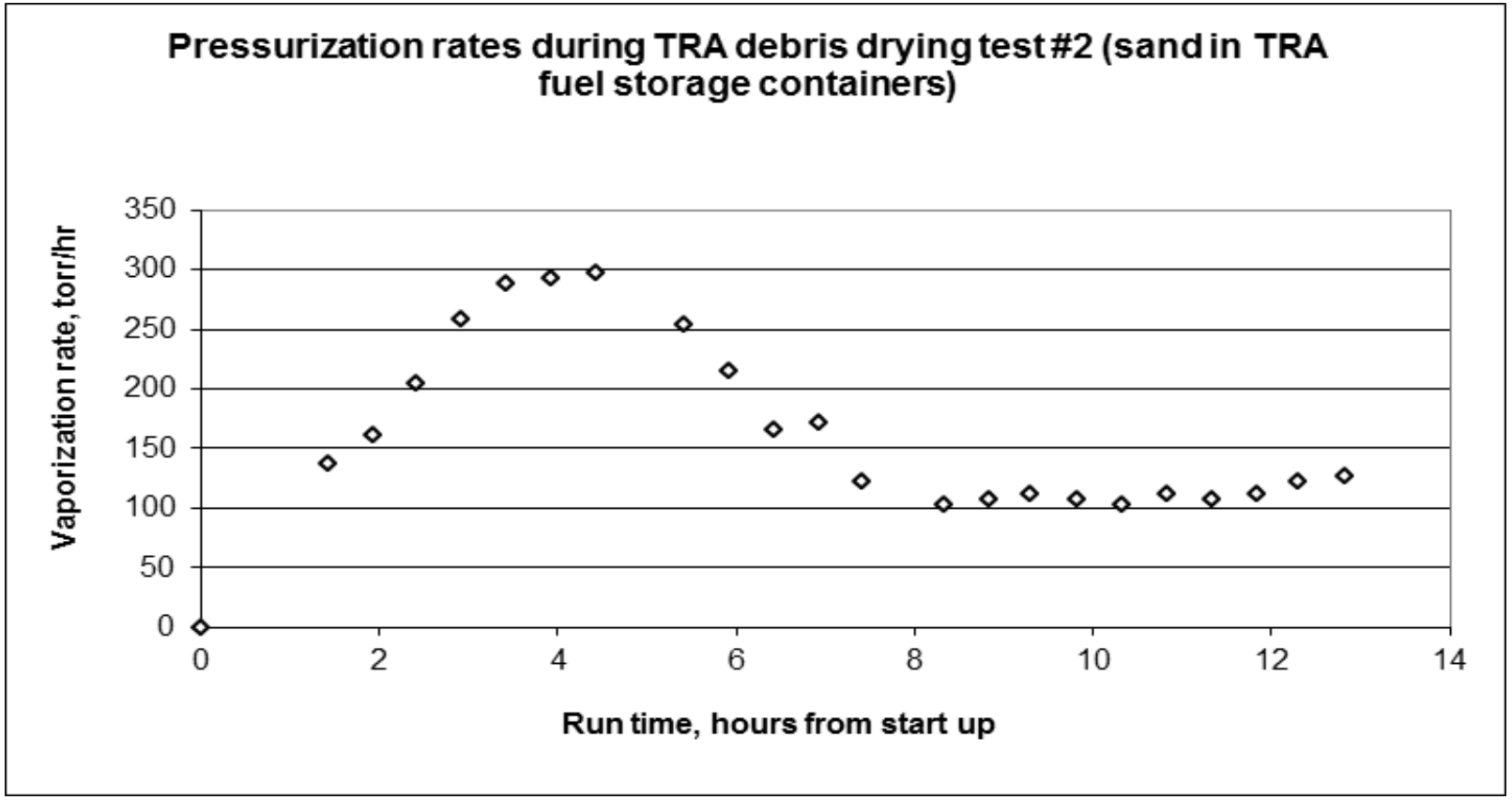
CPP-603 Fuel Conditioning Station

Fuel Conditioning Station test run



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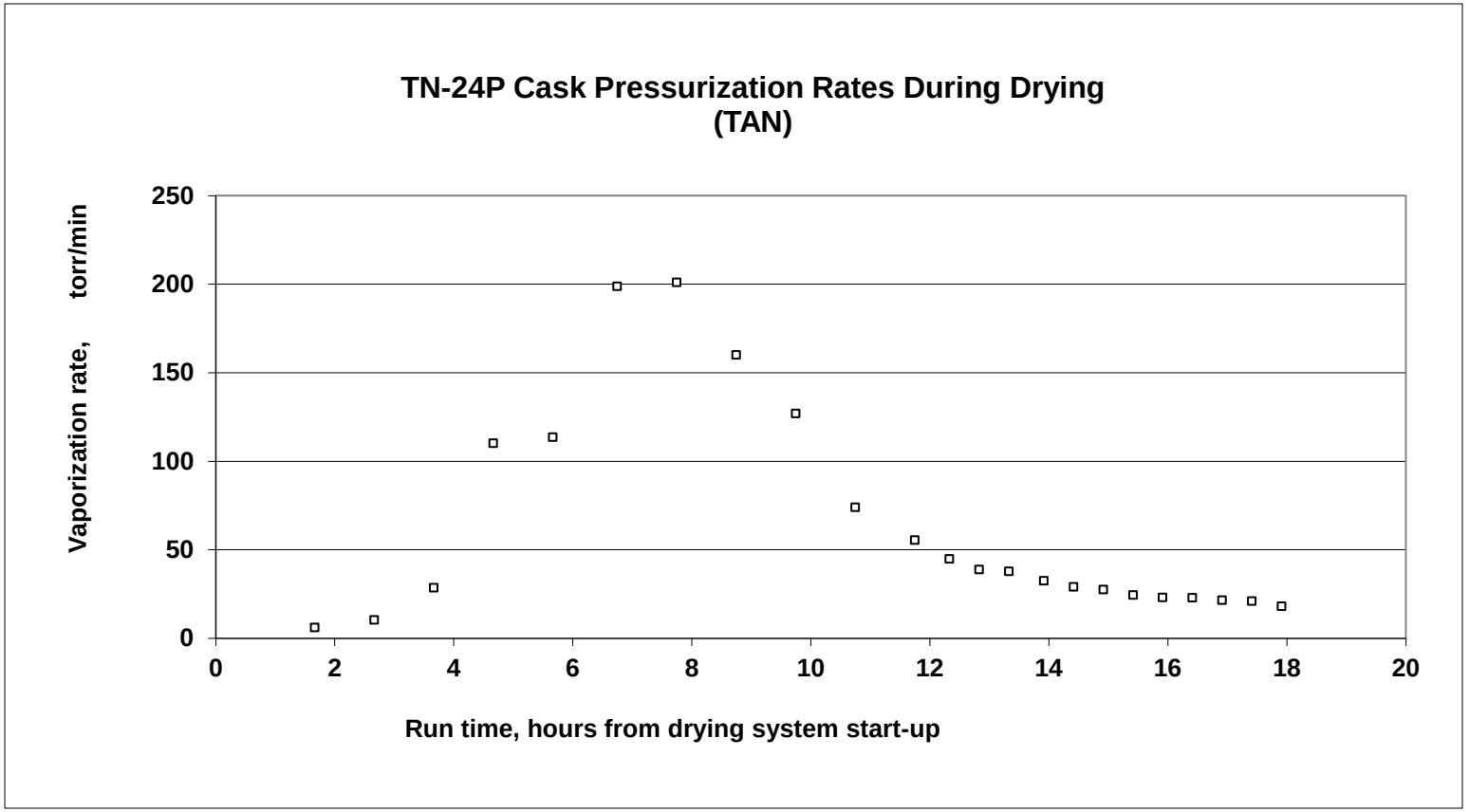
Cask Drying

Casks dried at TAN



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Conclusion

- Although significant effort was invested in drying the TMI canisters, the DSCs are vented through drum HEPA filters
- The Advanced Test Reactor Fuel, an aluminum fuel, is also dried prior to storage in vented canisters in the Irradiated Fuel Storage Facility (CPP-603). Extensive mock-up testing of the drying unit was a key to its success. More information is available upon request.
- Dried casks are sealed and stored at INTEC
- Not all casks stored at INTEC are dried

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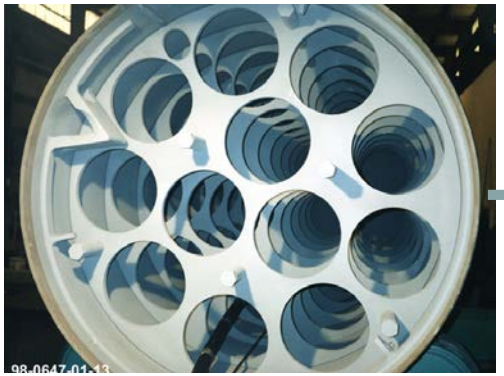
Background:

TMI Storage System- NUHOMS®



12 Position Basket within Dry Shielded Canister (DSC)

DSC

Closure Weld of Dry Shielded Canister

On-site Transfer Cask, OS-197

DSC Loading into Horizontal Storage Module