# Commercial Power Reactor Experience in Getting Fuel From Wet to Dry Storage

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# Agenda

- Introduction
- Basic plant information
- Dry Fuel Storage technology selected
- General licensing approach
- Fuel drying Technical Specifications and administrative limits
- Process highlights
- Summary of lessons learned
- Closing

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# Introduction

- Primary focus – Connecticut Yankee
- Additional data:
  - Maine Yankee
  - Yankee Rowe

# Basic Plant Information

- Connecticut Yankee Atomic Power Company's Haddam Neck Plant (HNP)
  - Located in East Hampton, CT on the Connecticut River
  - 1825 MWth four-loop Westinghouse PWR
  - 1968 – 1996 – commercial operation
  - 1996 – ceased commercial operations due to economic considerations
  - 1997 – 2007 – decommissioning
  - Current end state:
    - Physical decommissioning completed in 2007
    - Used nuclear fuel and GTCC waste stored in 43 containers in an on-site Independent Spent Fuel Storage Installation (ISFSI)
    - NRC license terminated (except for ISFSI footprint)

# Basic Plant Information

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- HNP used both stainless steel clad and Zircaloy clad fuel assemblies
  - Westinghouse, Babcock & Wilcox (B&W), B&W (GUNF), Gulf General Atomic, and NUMEC supplied stainless steel clad fuel assemblies
  - Gulf General Atomic, NUMEC, B&W, and Westinghouse supplied Zircaloy clad fuel assemblies
  - Fuel assemblies had rods with an initial enrichment of uranium dioxide that did not exceed 4.61 weight percent of Uranium-235
  - 1019 total fuel assemblies (~71 “damaged”)

# Dry Fuel Storage Technology Selected

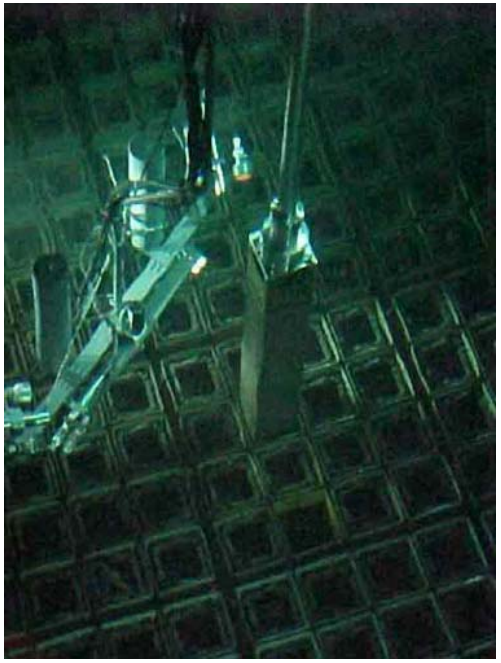
- NAC International, Inc. (NAC) multi-purpose canister (MPC) spent fuel cask storage system (NAC-MPC)
  - Designed for both storage and transport
  - Listed by NRC under 10CFR72 (COC 72-1025)
  - Vertical storage configuration

# General Licensing Approach

- 10 CFR 50 License Holder
  - ISFSI General License is granted under 10 CFR 72.210
  - NAC MPC listed under 10 CFR 72.214 for use by ISFSI General Licensees
  - NRC issued C of C 1025 approving the use of the system for used nuclear fuel
    - NAC maintains the C of C and SAR
    - Site satisfies the 10 CFR 50 and 72 General License requirements

# Technical Specifications

- Canister Maximum Time in Vacuum Drying
  - Commences following canister draining and terminates after dryness verification and He backfill
  - Based on analysis of maximum cladding temperature per NRC Spent Fuel Project Office Interim Staff Guidance
    - 806ºF for SS clad and 752ºF for Zirc clad
  - If drying time cannot be met, then canister must be backfilled with He and cooled (forced air or water) prior to continuing the vacuum drying process

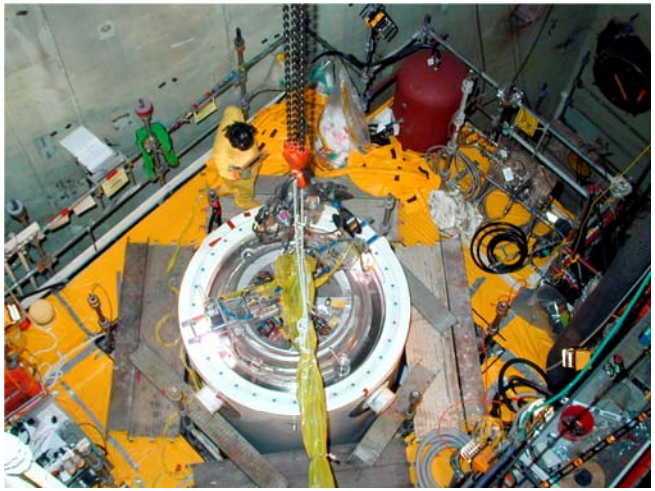


# Technical Specifications

- Canister Vacuum Drying Pressure
  - <10 torr for 10 minutes by NRC CoC
  - Administrative limit <3 torr for 10 minutes
  - Instrument uncertainty a significant factor

# Process Highlights

- Facility modifications were required
  - Single failure proof crane
  - Canister processing areas
  - Support systems (He, N2, air, argon, etc.)
  - ISFSI facility
  - Haul road improvements
- NRC-required dry runs
  - Demonstrated all aspects of process including lid welding
  - Conducted on mock-ups and GTCC canisters



# Process Highlights

- 24/7 critical path operation
  - Union craft
  - Worked 12 hour shifts, four days on, four days off
    - Required Union Leadership agreement
- Utilized two transfer casks
  - Allowed parallel activities and saved significant critical path time
  - Additional equipment and labor costs offset by overhead costs associated with overall decommissioning project execution

# Process Highlights

- Production rates achieved
  - One canister completed every four days (at peak)
- Key issues
  - Equipment breakdowns
    - SFP Crane
    - Heavy haul trailer
  - Weather
    - Wind
    - Cold temperatures

# Lessons Learned

- Canister draining enhancements
  - Ability to tilt canister toward drain tube
  - Pressurized N2 blowdown with short hold times
- Vacuum Drying System (VDS) enhancements
  - Quality and versatility of equipment
    - Original skids were completely manual
    - Robust capacity and redundancy of components is critical
    - Technology has advanced substantially

# Lessons Learned

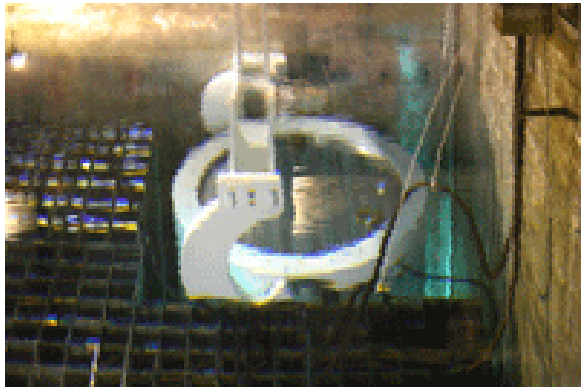
- Vacuum Drying System (VDS) enhancements

# Lessons Learned

- EMS Solutions, Inc.
  - 665 E. MORELOS STREET SUITE 103
  - CHANDLER, ARIZONA 85225
  - 480-899-8486
- E1000 VDS
  - Local and remote touch screen controls
  - Initial Canister Flood
  - Partial Drain Down
  - Hydrogen Monitoring
  - Inert Gas Purging
  - Circulation Cooling
  - Drain And Blow Down Of Canister
  - Vacuum Drying
  - Gas And Or Water Pressure Testing
  - Inert Gas Backfill
  - Reflood

# Lessons Learned

- Other Vacuum Drying enhancements
  - Some canister designs allow the use of external heaters
  - Minimize mechanical connections to limit leaks
  - Heat trace/insulate VDS piping to eliminate condensation
  - Periodic N2 purges have proven to help transport some moisture
  - Maintain SFP near upper temperature limits during canister loading



# Lessons Learned

- Other Vacuum Drying enhancements
  - Review fuel assembly designs for water pockets
    - CY fuel includes a 15” “dashpot” to provide a hydraulic cushion during control rod drops
    - For fuel assemblies with no control rod inserted, a 15” column of water would have remained
    - NAC CoC was amended to allow the insertion of a 15” stainless steel solid rod to displace the water

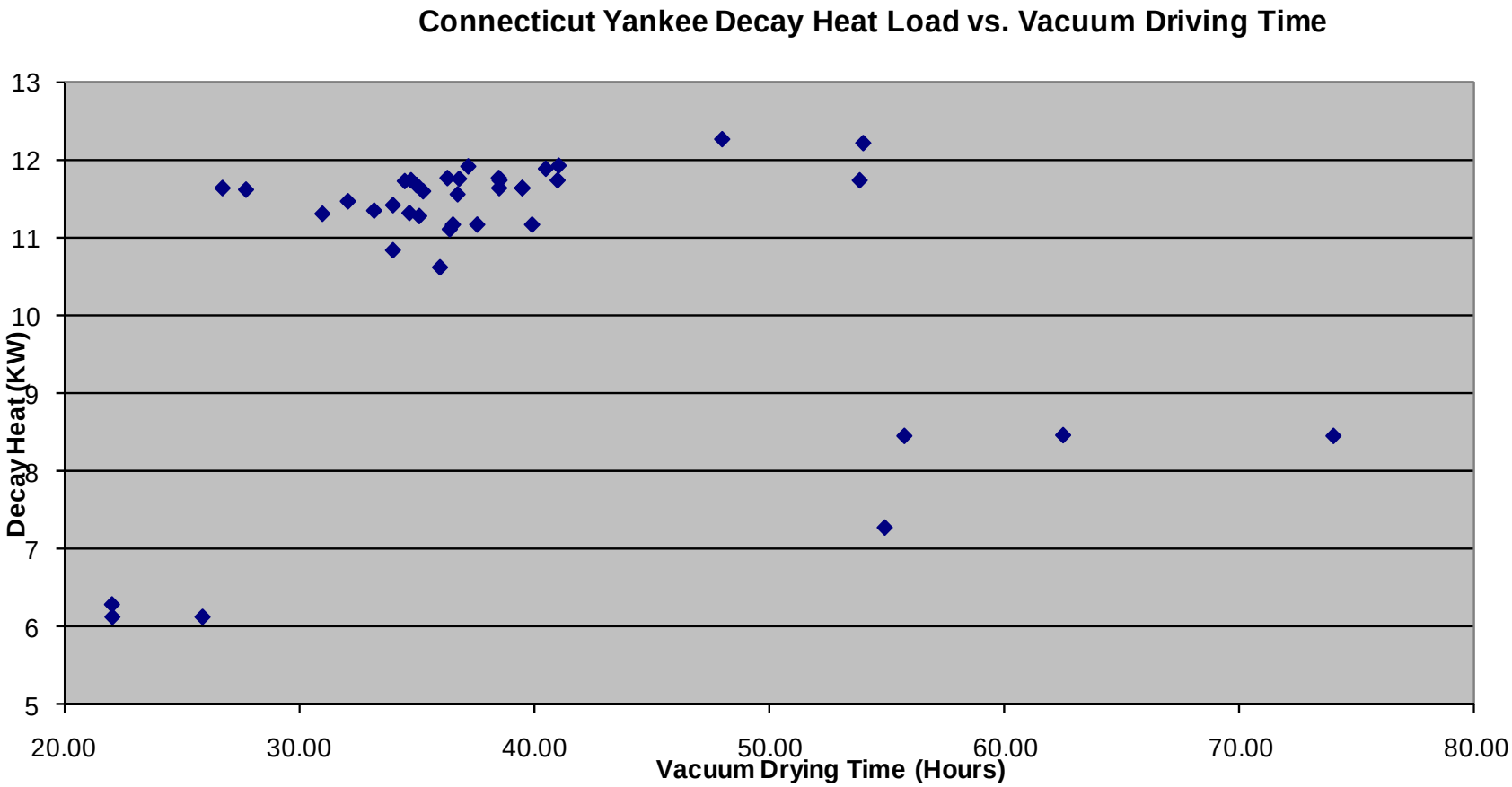
# Lessons Learned

- Relationship of Decay Heat to Vacuum Drying Time
  - Conventional wisdom holds that more heat is good
    - Limits freezing that may occur at low pressures
  - Many variables exist that complicate actual practice
  - Data from CY, MY and YR does not statistically support a direct correlation
  - Experience with GTCC canisters shows that decay heat is not “required” to achieve dryness criterion

# Lessons Learned

| Plant Site | Canister Type | # Fuel Assemblies | # Fuel Assy's/Canister | # Canisters Loaded |
|---|---|---|---|---|
| **CT Yankee**<br>1825 MWth W PWR<br>East Hampton, CT | NAC MPC | 1019 | 24 – 26 | 40 |
| **Maine Yankee**<br>2772 MWth CE PWR<br>Wiscasset, ME | NAC UMS | 1434 | 24 | 60 |
| **Yankee Rowe**<br>600 MWth W PWR<br>Rowe, MA | NAC MPC | 533 | 36 | 16 |

# Lessons Learned



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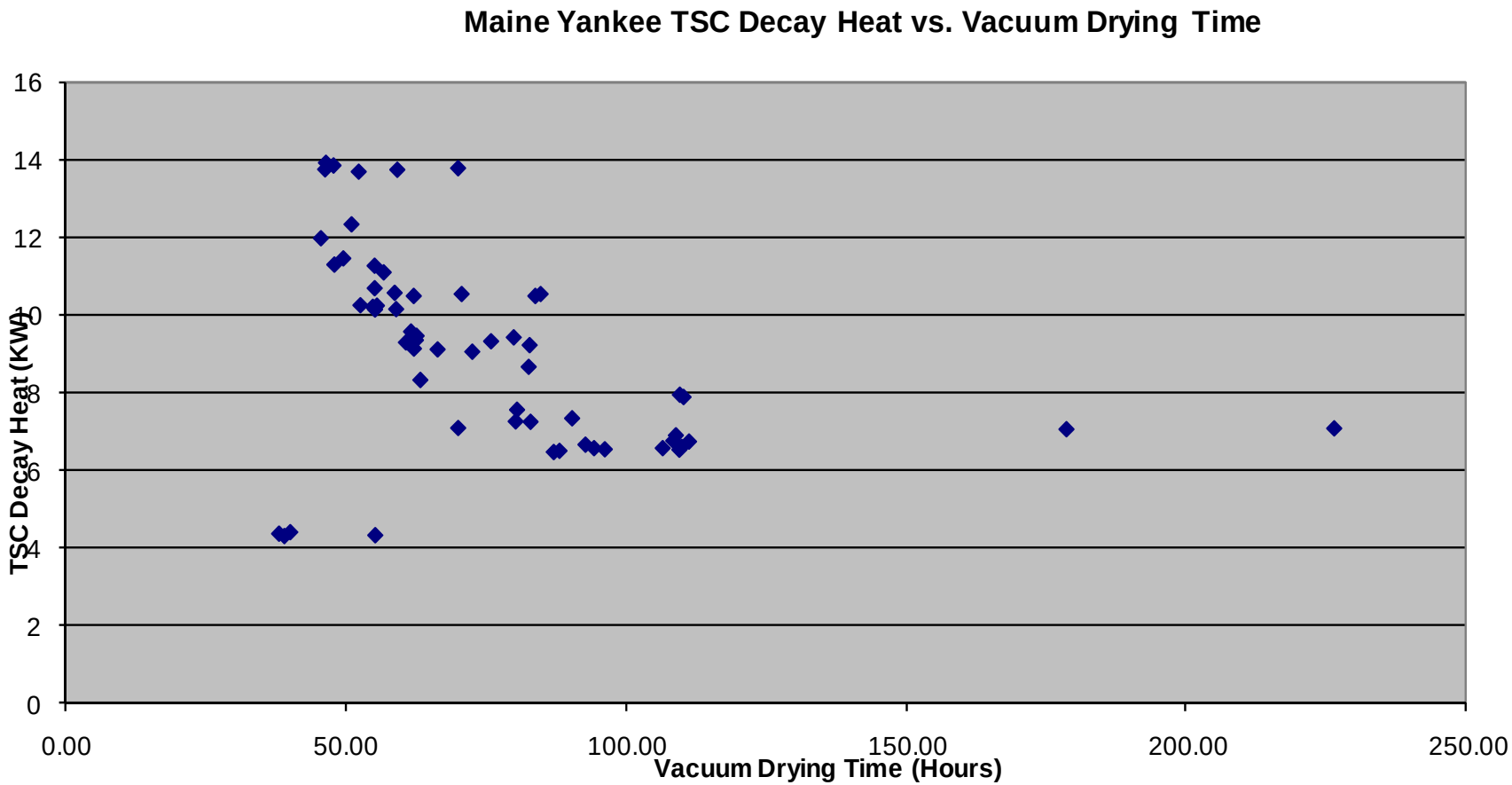

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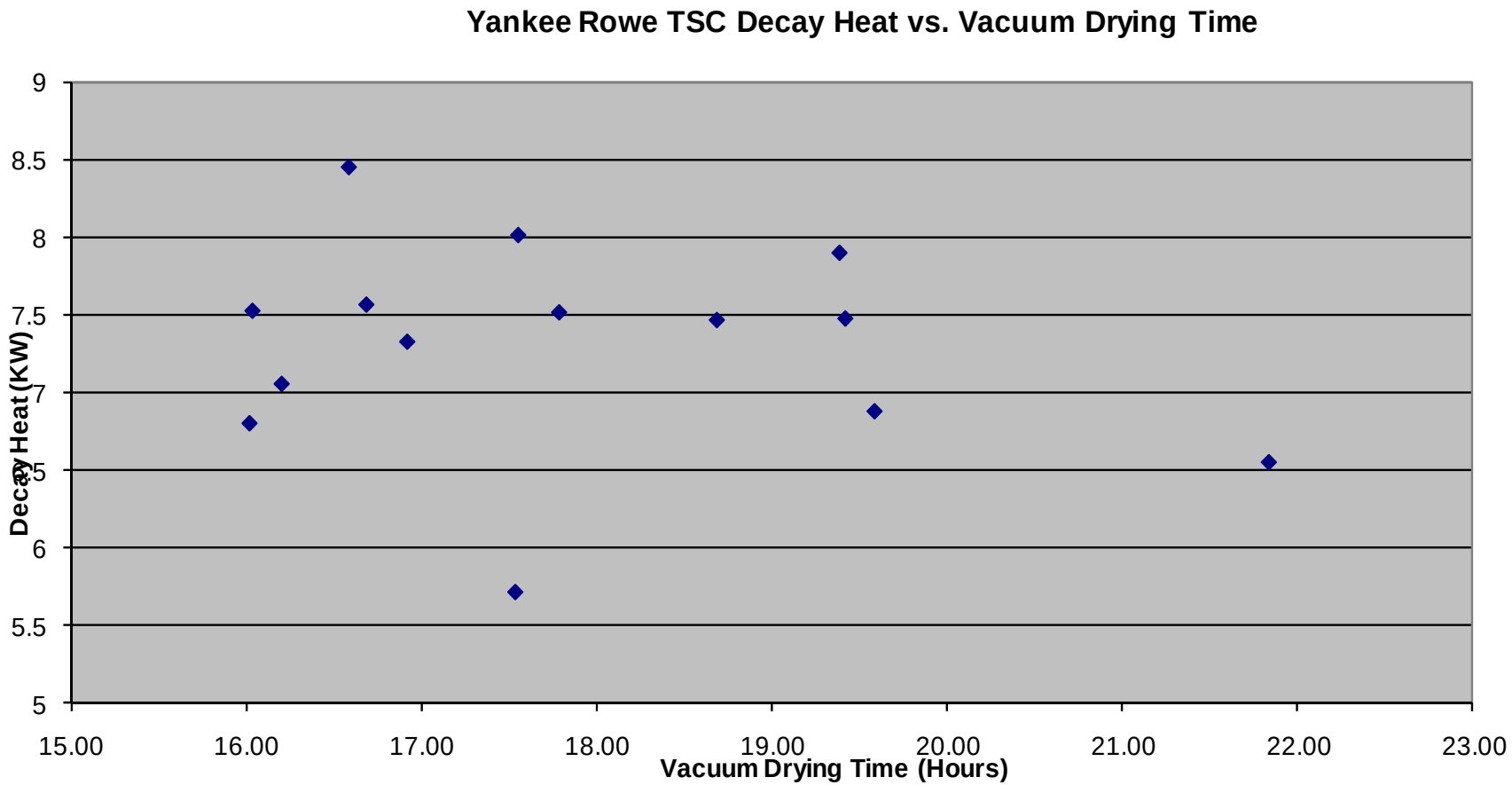

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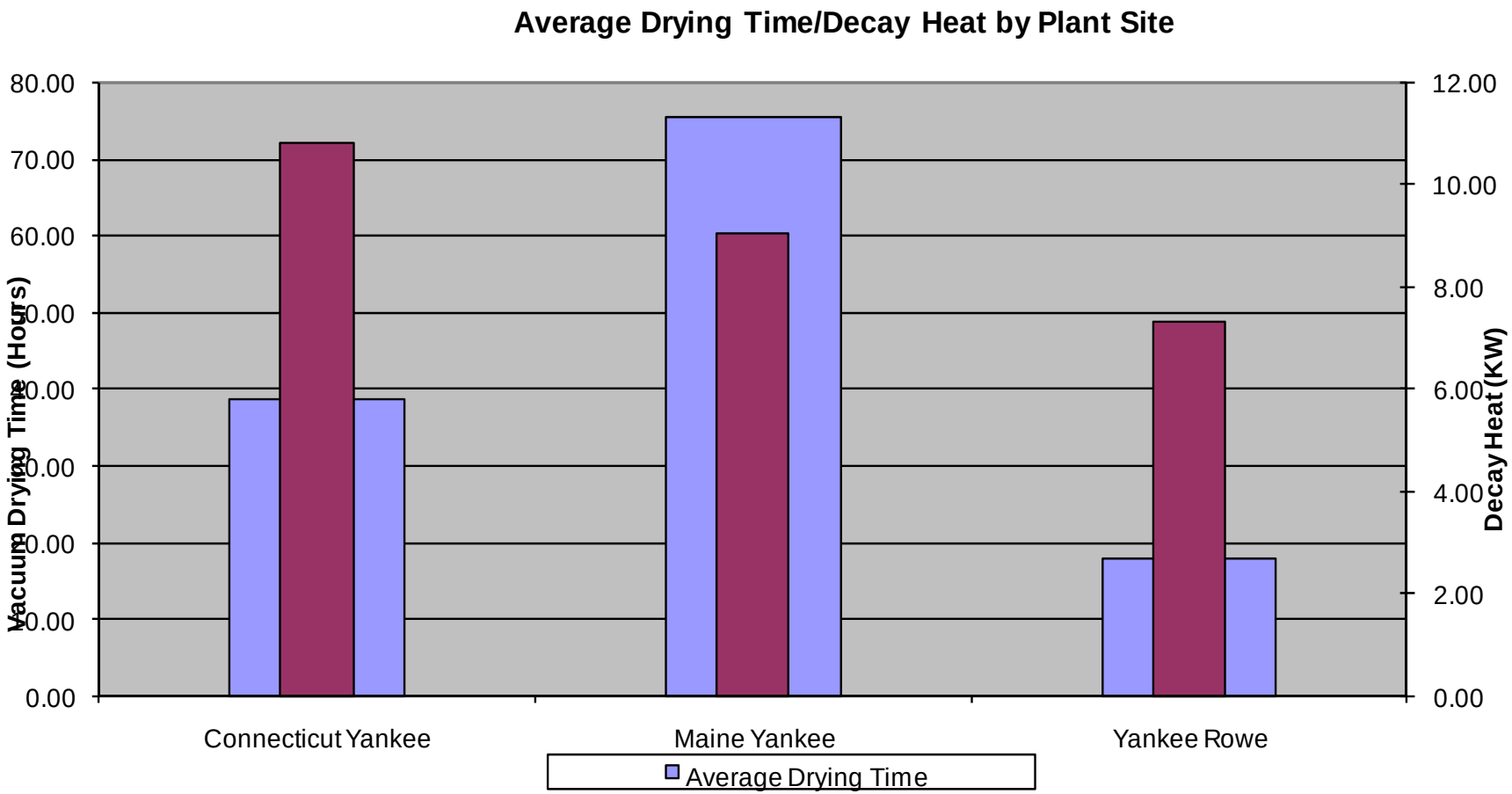

# Lessons Learned

- Other items
  - Aggressively monitor and maintain key equipment
    - SFP Cranes are complex and can have unexpected failure modes
      - Oil viscosity at low temperatures resulted in failure modes unknown to the trolley manufacturer
    - VDS screens/booms can accumulate boron buildup
    - VDS discharge paths and internal components can develop radiological hot spots
  - Invest in redundancy to preclude process interruptions

# Closing

- Vacuum drying is an “art” rather than a science to those who work the systems in the field
  - Everybody has a theory
- Fuel and canister design will significantly influence drying times
  - Voids, gaps, surface area, defects, etc.
- The expanded use of dry fuel storage continues to support advances in the technology

# Closing

- Thank you for the opportunity!