Sandia National Labs Annular Core Research Reactor Outage Lessons Learned

(July 04 – Feb 05)

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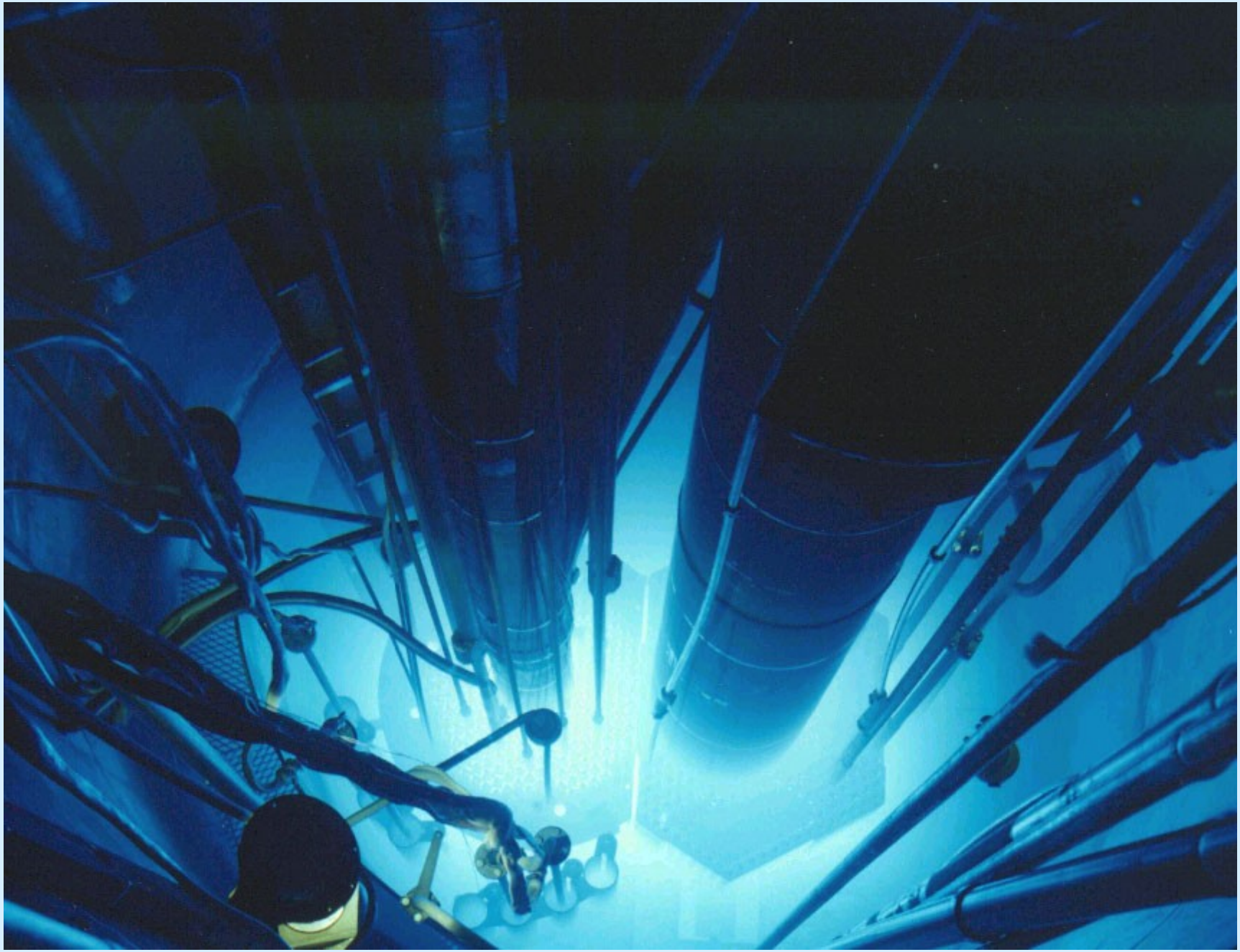
September 16, 2005



ABSTRACT

In July of 2004, the Annular Core Research Reactor (ACRR) commenced an outage primarily to upgrade its Plant Protection System (PPS). Upgrades were also made to the Bulk Cooling System, Cleanup Loop System, Cooling Tower System, Storage Pool Liner, and Neutron Radiography Facility. In total, $3.5 million dollars in upgrades occurred during this outage originally scheduled to end in December of 2004. Such an undertaking with a staff of 2 Reactor Supervisors and 7 Reactor Operators put a strain of the facility's resources.

During these equipment upgrades, the ACRR Safety Basis (Safety Analysis Report and Technical Safety Requirements) was being updated. Review and approval of this document to include the new PPS upgrade took longer than originally scheduled. In addition to changes in the Safety Basis due to the PPS upgrade, several Conditions of Approval and Specific Administrative Controls were required to be implemented on non-PPS systems before resuming programmatic operations of ACRR. Because of this delay and additional reviews by the Defense Nuclear Facilities Safety Board, the outage lasted an additional 3 months. This presentation captures these lessons learned from this outage.

Annular Core research Reactor (ACRR) Outage

- ACRR performs approx. 450 pulse (35,000 MW max) and steady state (2.4 MW max) operations per year.
- Staff size: 7 Reactor Operators and 2 Reactor Supervisors.
- Prior to outage, last experiment conducted July 04.
- Outage for the upgrade of the Plant Protection System. Other facility upgrades also scheduled.
- ACRR startup originally scheduled for Dec 04; finally occurred April 05.

4 Major Projects:

	Cost
• Plant Protection System (PPS) Upgrade	$175k
• Storage Pool Liner Project	$750k
• Neutron Radiography Facility Upgrade	$250k
• Cooling Loop Modification	$2.3M

PPS Upgrade

- ThermoGamma-Metric's Plant Protection System.
  - Designed to operate for 40 years under normal operating conditions.
  - Neutron flux measurement from less than 1% power to Pulse power levels.
  - Indication of fuel temperature.
  - Processing scram logic.

PPS Upgrade

- ACRR specific design requests included:
  - Interchangeable power range detectors
  - Scram time response of 50ms.
  - Specialized/Non-Standard thermocouples.
  - Human Factors improvements.

PPS Upgrade

Interchangeable power range detectors.

- Self powered Cadmium detectors require high amplification.
- Fission Chambers require high voltage biasing.
- Capability for two detectors combined in one circuit.
- Engineering compromises (time response vs noise immunity) resulted in a longer time-response when using a Cad detector.

PPS Upgrade

Time Response.

- Time response: Excellent.
- One exception: The Cadmium detector.
  - Cadmium detector performed at 168 msec vice the 50 msec specified.
  - ACRR safety basis requires a 500 millisecond time response.
  - Non-conformance report submitted to accept as built.
  - Manufacturer could fix the time response but at the expense of noise immunity.

PPS Upgrade

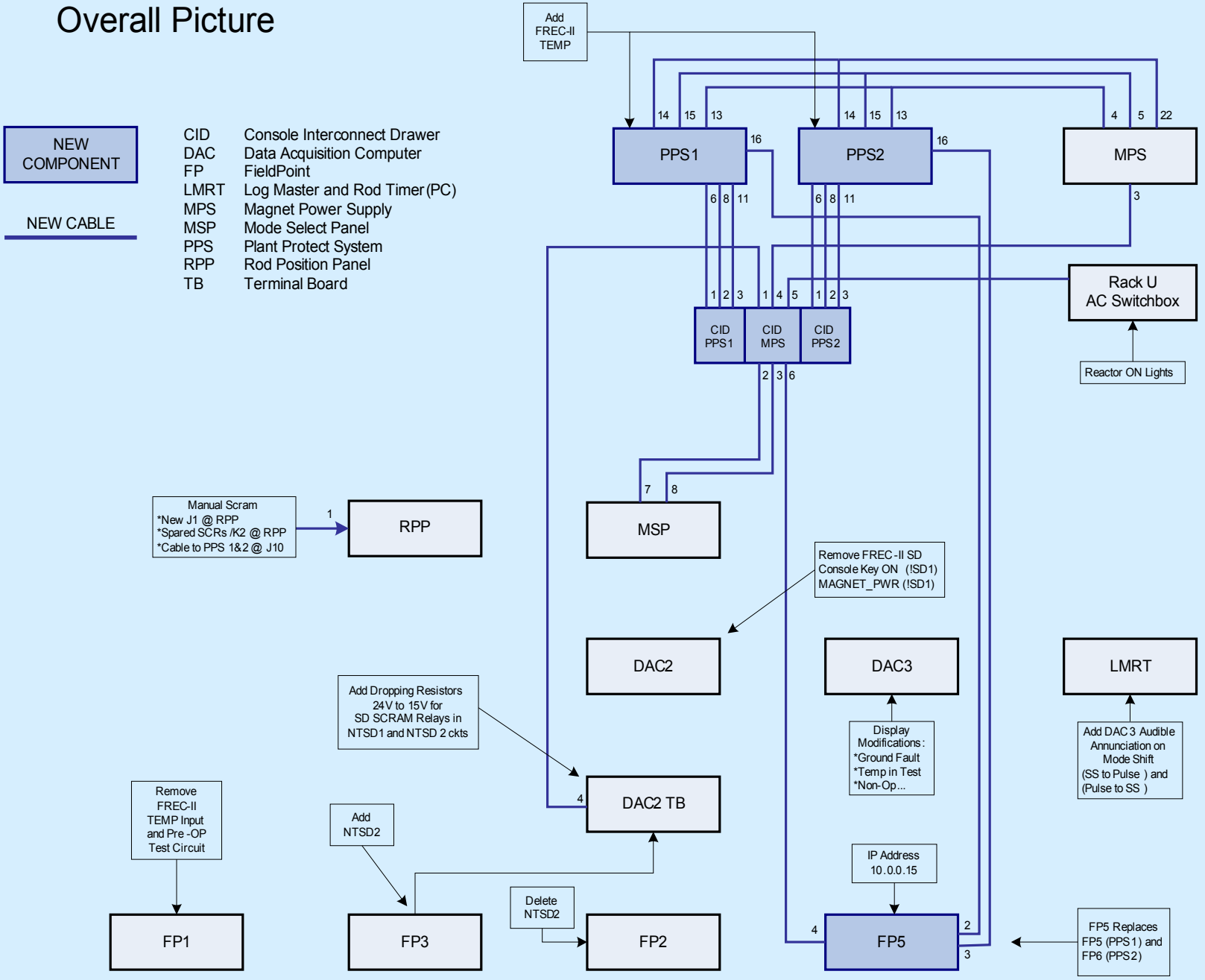
- Geminol and Tungsten Rhenium thermocouples
  - Required custom 21-point linearization.
  - Ground loop immunity improvements.

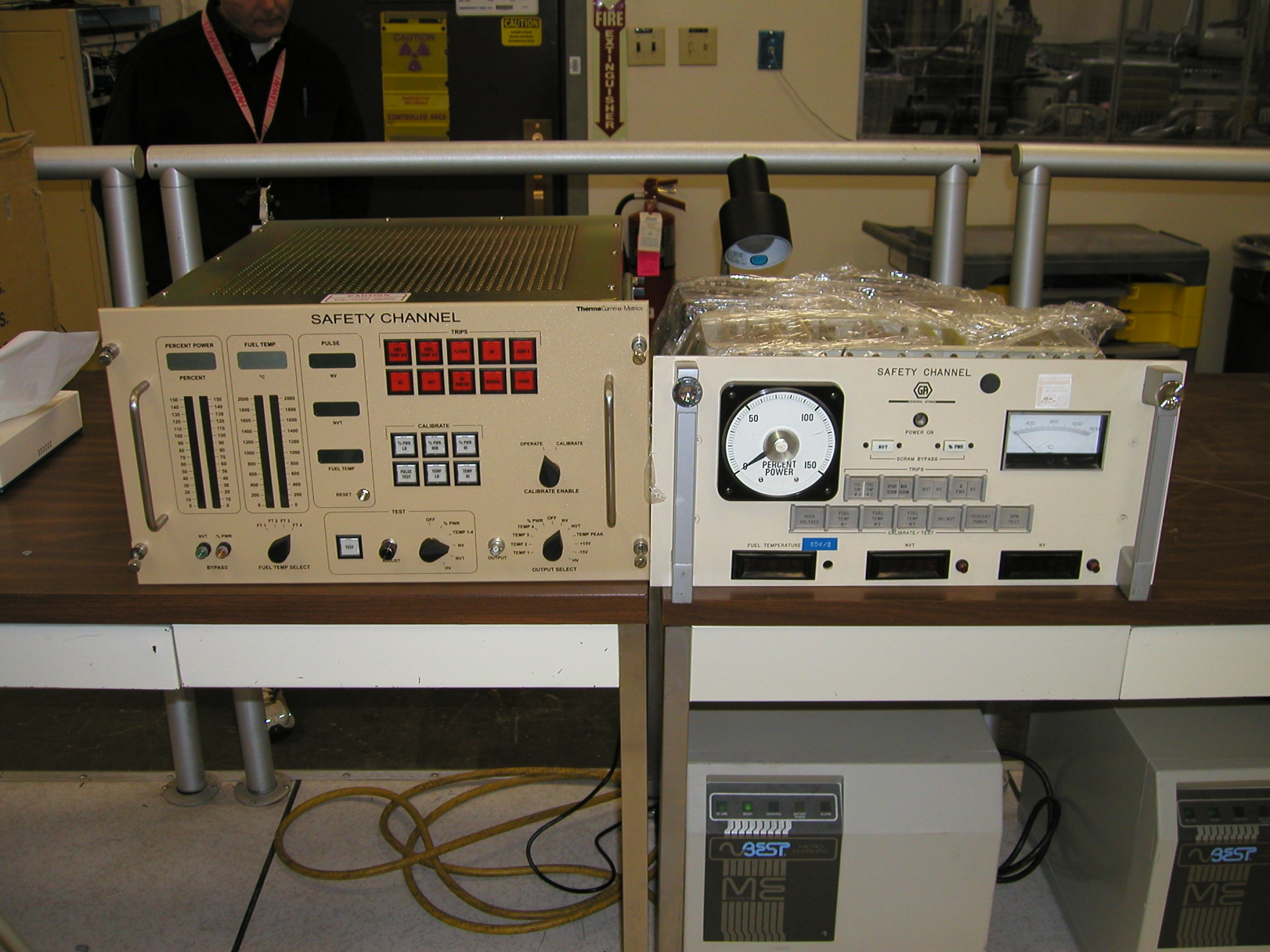
PPS Upgrade

- Human Factors improvements.
  - Improved access to adjustments.
  - Self contained calibration standard.
  - Built-in test capabilities.
  - Relocation of high voltages.
  - Logical control and indication arrangement.

PPS Upgrade Project
Overall Picture

10SEP04

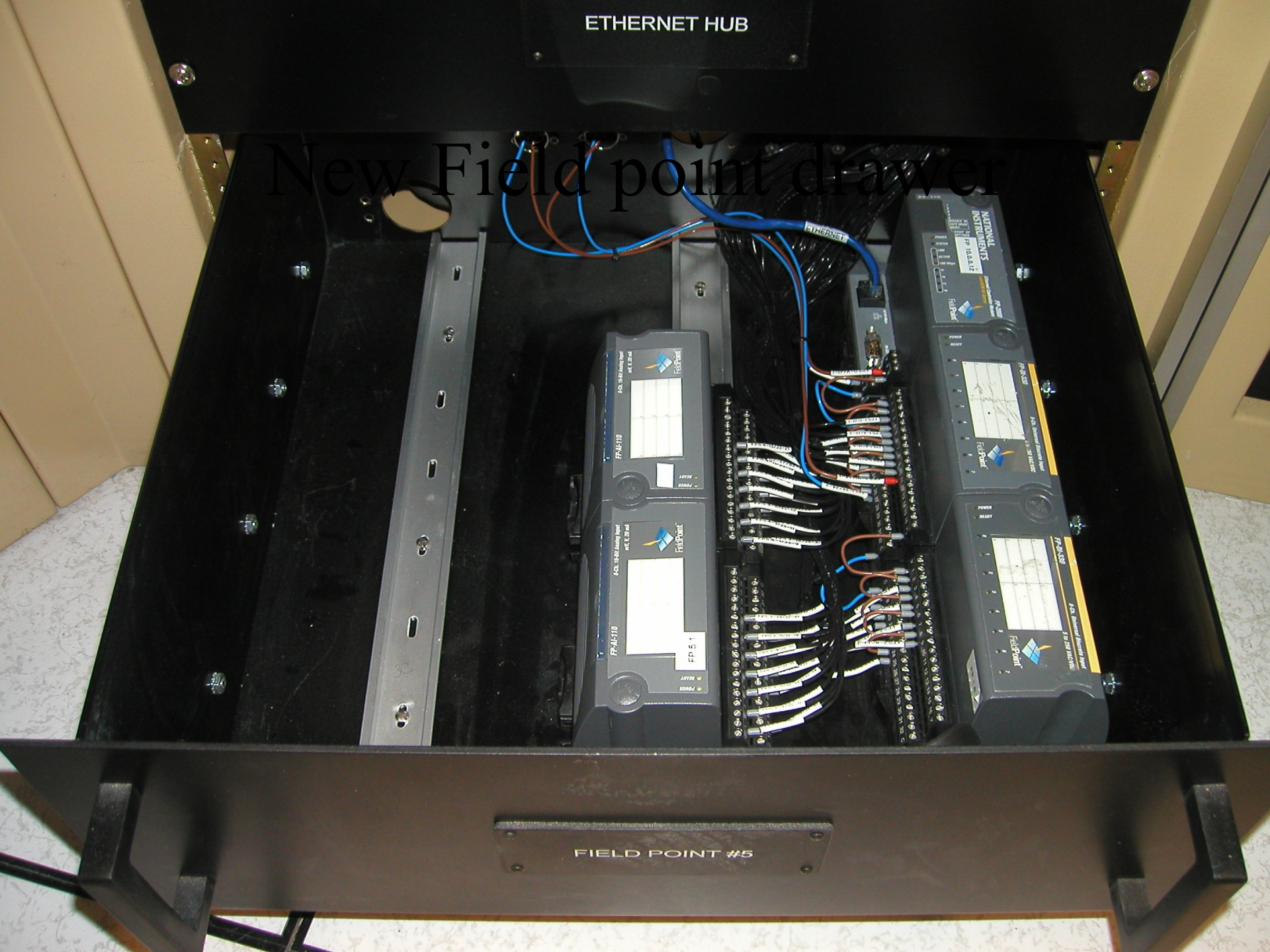



SAFETY CHANNEL
ThermoGamma-Metrics
PERCENT POWER
PERCENT
FUEL TEMP
°C
PULSE
NV
NVT
FUEL TEMP
RESET
TRIPS
CALIBRATE
% PWR LO
% PWR MID
% PWR HI
PULSE TEST
TEMP LO
TEMP HI
OPERATE
CALIBRATE
CALIBRATE ENABLE
TEST
OFF
% PWR
TEMP 1-4
NV
NVT
HV
ADJUST
OUTPUT
% PWR
TEMP 4
TEMP 3
TEMP 2
TEMP 1
OFF
NV
NVT
TEMP PEAK
+15V
-15V
HV
OUTPUT SELECT
NVT
% PWR
BYPASS
FT 1
FT 2
FT 3
FT 4
FUEL TEMP SELECT
SAFETY CHANNEL
GA
50
100
0
150
PERCENT POWER
POWER ON
NVT
% PWR
SCRAM BYPASS
TRIPS
HIGH VOLTAGE
FUEL TEMP #1
FUEL TEMP #2
FUEL TEMP #3
NV/NVT
PERCENT POWER
DPM TEST
CALIBRATE/TEST
FUEL TEMPERATURE
504/2
NVT
NV
BEST
ME
BEST
ME

Console Interconnect Drawer (CID) Modification


OLD

NEW


ETHERNET HUB
New Field point drawer
ETHERNET
FIELD POINT #5

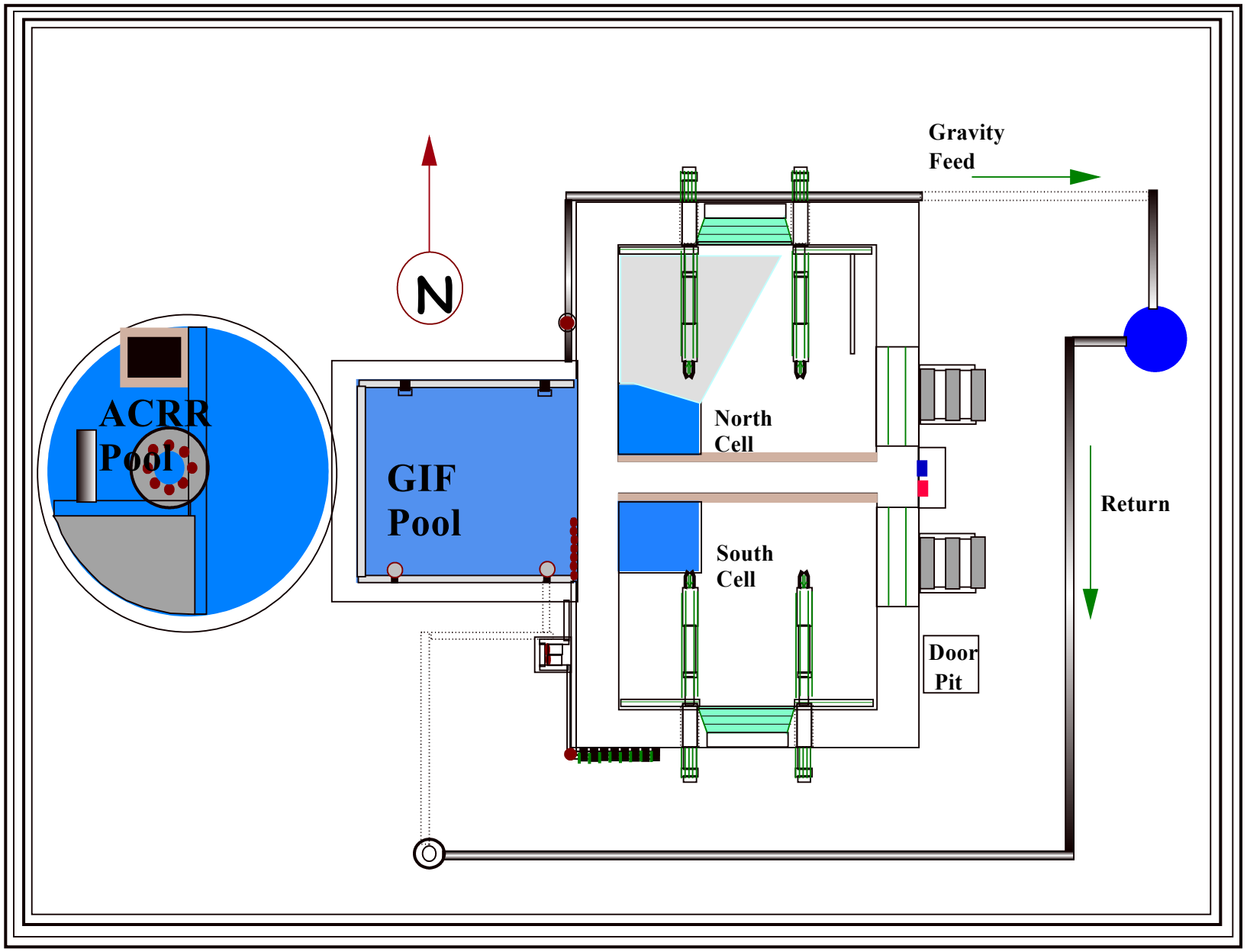
PPS Lessons Learned

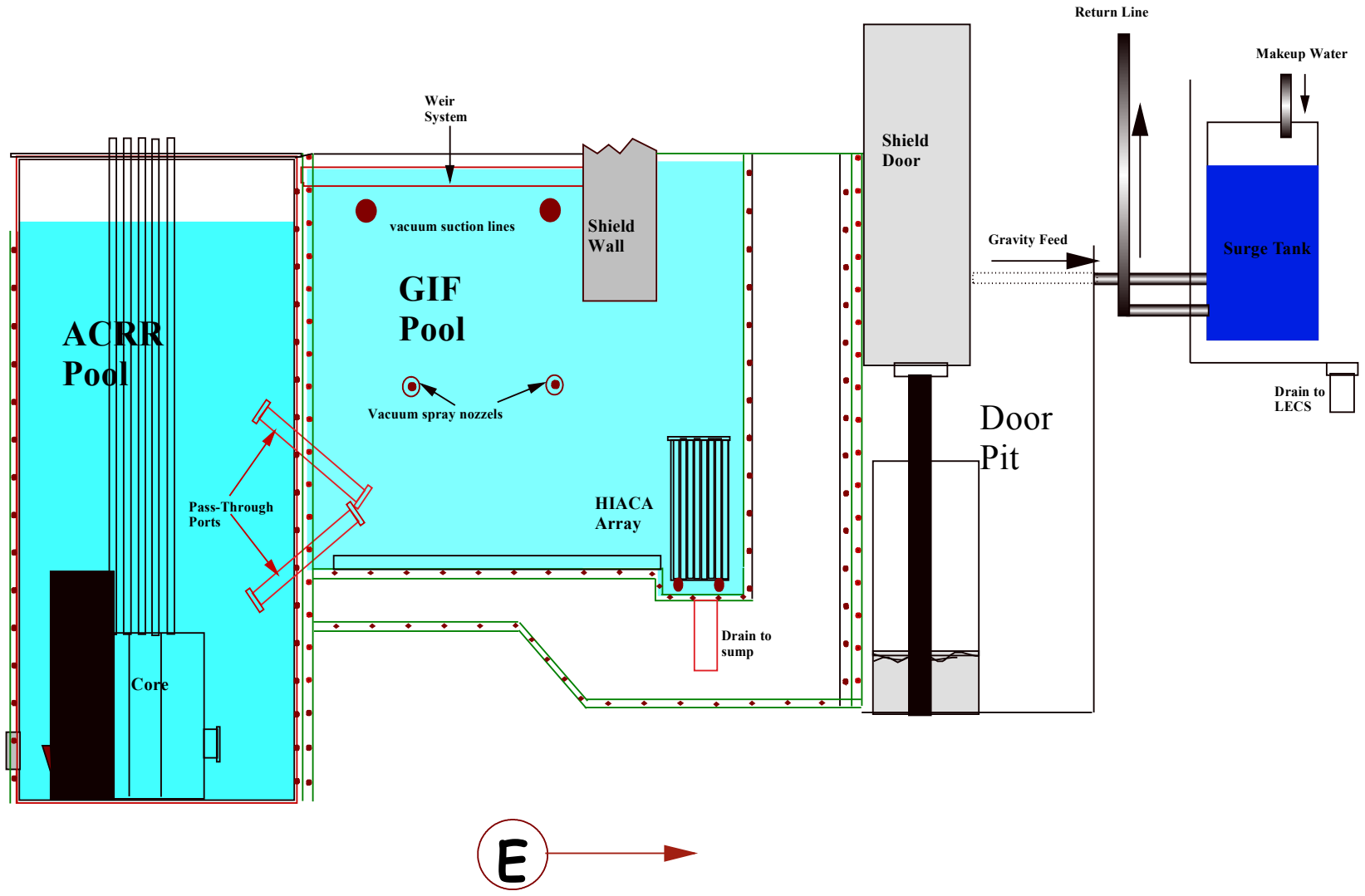
- New PPS Drawers were built 3 years ago.
- Not installed until Summer 2004.
- Delay issues due to vendor and staff turnovers
  - Factory acceptance testing not well understood.
  - Documentation not well understood.
  - Expiration of 90 day guarantee.

Storage Pool Liner Project

History

- 16,000 gallon Storage Pool as part of the Gamma Irradiation Facility (GIF).
- GIF built in 1964 and operated until 1998.
- Originally contained 75K Ci of Co-60 and 78K Ci of Cs-137 as pencil sources.
- Sources transferred to new GIF in 1998.
- Also used for reactor fuel storage after construction of ACRR.


Gravity
Feed
N
ACRR
Pool
GIF
Pool
North
Cell
South
Cell
Return
Door
Pit

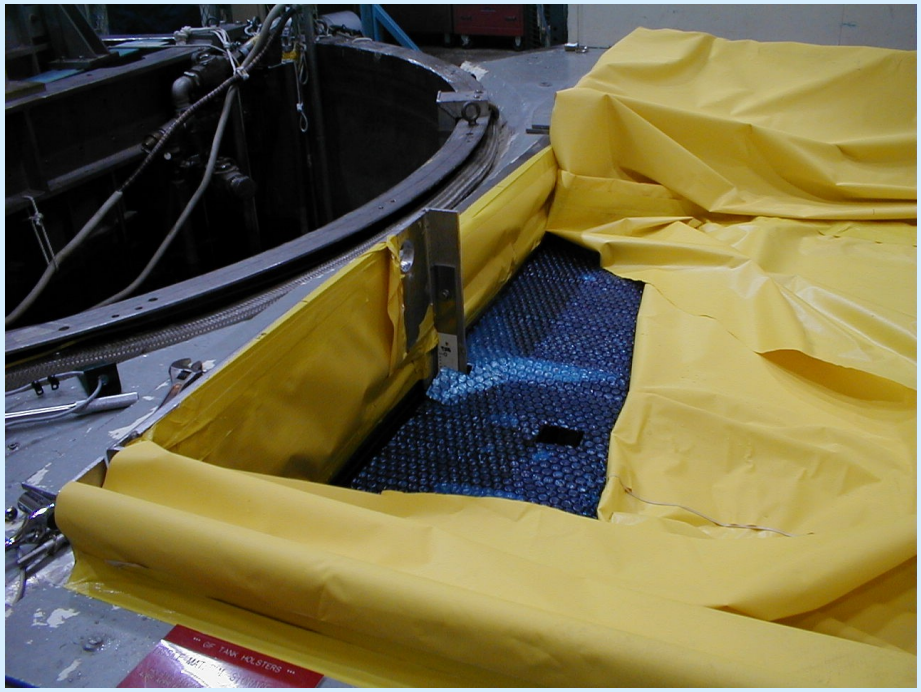

Return Line
Makeup Water
Weir System
Shield Door
vacuum suction lines
Shield Wall
Gravity Feed
Surge Tank
GIF Pool
ACRR Pool
Vacuum spray nozzles
Drain to LECS
Door Pit
Pass-Through Ports
HIACA Array
Drain to sump
Core
E

Operational/Programmatic Problems

- Old age
  - Elevator hoist/mechanical problems (hoist cables breaking).
  - DU shield wall rupture contaminated pool.
  - Water leak to environment detected December 1998.

Leak Corrective Actions

- 1 yr study to determine leak rate from pool.
- Decontaminate DU from pool, stored fuel, and sources.
- Transfer sources and fuel from Storage Pool.
- Began planning phase of Storage Pool Liner Project.



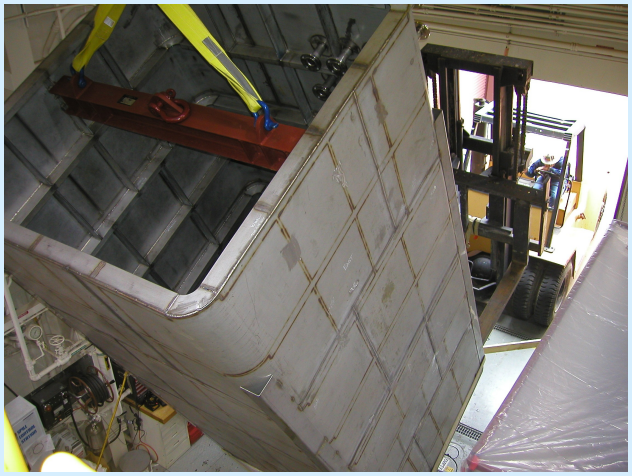
Storage Pool Liner Project Planning Phase

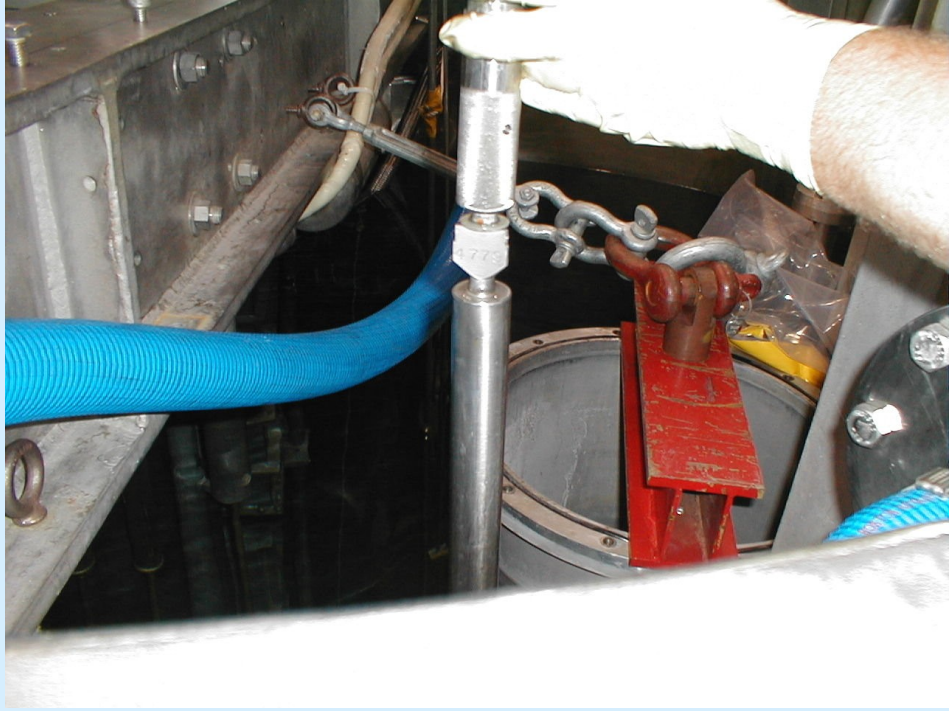
- Began in 1999.
- Obtained funding in 2001.
- Cost estimates grew from $136k to $750k.
- Original time estimate for liner:
  - Liner design – 3 months
  - Fabrication – 3 months
  - Installation – 2 weeks.

Storage Pool Liner Project Design Phase

- Problems with scope creep.
  - Incorporated permanent water cleanup system
  - Added 2” air gap around liner
  - Removal of fuel pass-through ports to ACRR Pool
  - Decontamination and demolition grossly underestimated.

Storage Pool Liner Project
Execution Phase






DANGER
DANGER
KEEPER
KEEPER
KEEPER

Pool liner doesn’t fit!

- Original Engineering drawings correct.
- Vendor’s Fabrication shop drawings were rotated 90°.
- Vendor agreed to build another liner.

SPL Lessons Learned

- Vendor QA:
  - measure twice, cut once.
- Pipe welders are not plate welders.
  - 90% of liner welds failed NDT and required rework.
- Schedule and cost growth.
  - SNL Facilities/Contractors not familiar with increased rigor required for nuclear facility work.
- Staff turnover:
  - 4 different project leads and 3 different project managers.
  - Caused some discontinuity.

Neutron Radiography (NR) Facility Upgrade

History

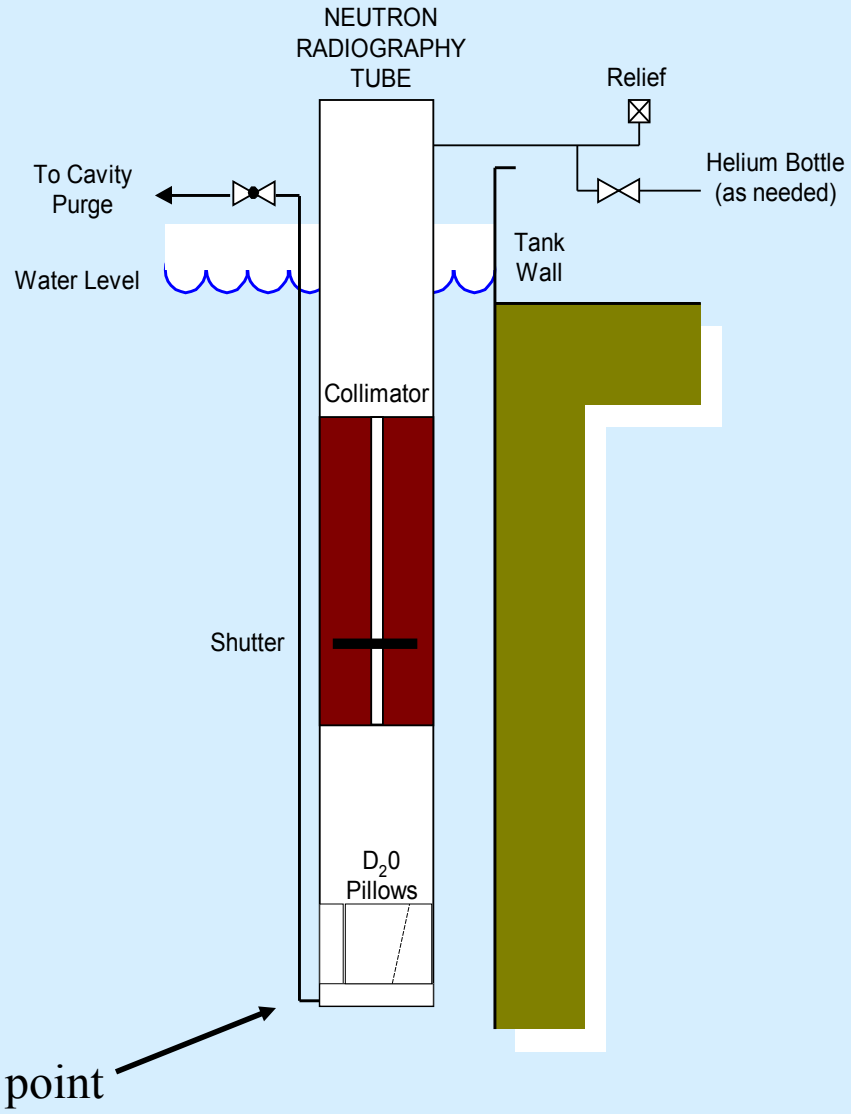
- NR Facility built in 1970's.
- Operates 100-150 hours/yr in campaign mode.
- Last operation Feb 04, 2002.
- Water intrusion caused corrosion of internals and eventual malfunction.

NR FACILITY

- Used for non-destructive testing and imaging capability.
- A source of thermal or fission spectrum neutrons.
- Became non-operational March 2003.
- Numerous requests for services rejected.
  - Fuel element inspections
  - Single Event Upset testing
  - Spin Rocket Motor testing
  - Explosive Component testing
  - Thermal neutron detector development
- Significant interest in an operational NR facility exists.

NR FACILITY

- NR facility not incorporated in the original ACRR design, causing some design constraints.
- Cavity Purge piping appears to be the source of the leak.
- Leak caused damage to the collimator rendering it inoperable.

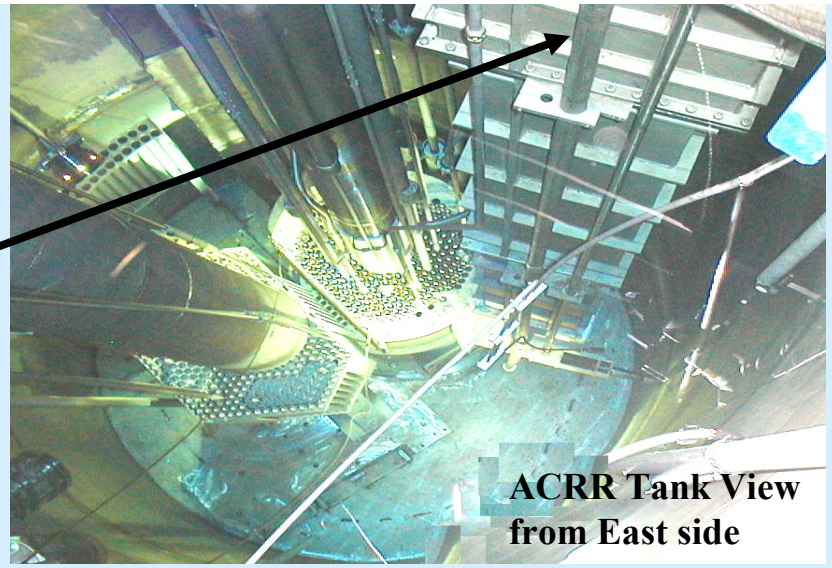


NR FACILITY

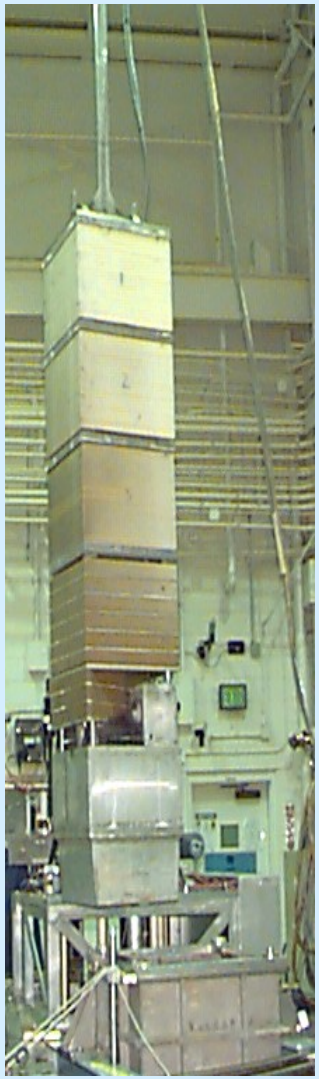
•On the lower image note the two inch diameter steel pipe. This steel pipe connects to the lower chamber of the NR tube so that radioactive gases can be removed during operation. This connection was the source of the water leak and subsequent damage to the collimator.

Cavity Purge Piping

ACRR Tank View from West side



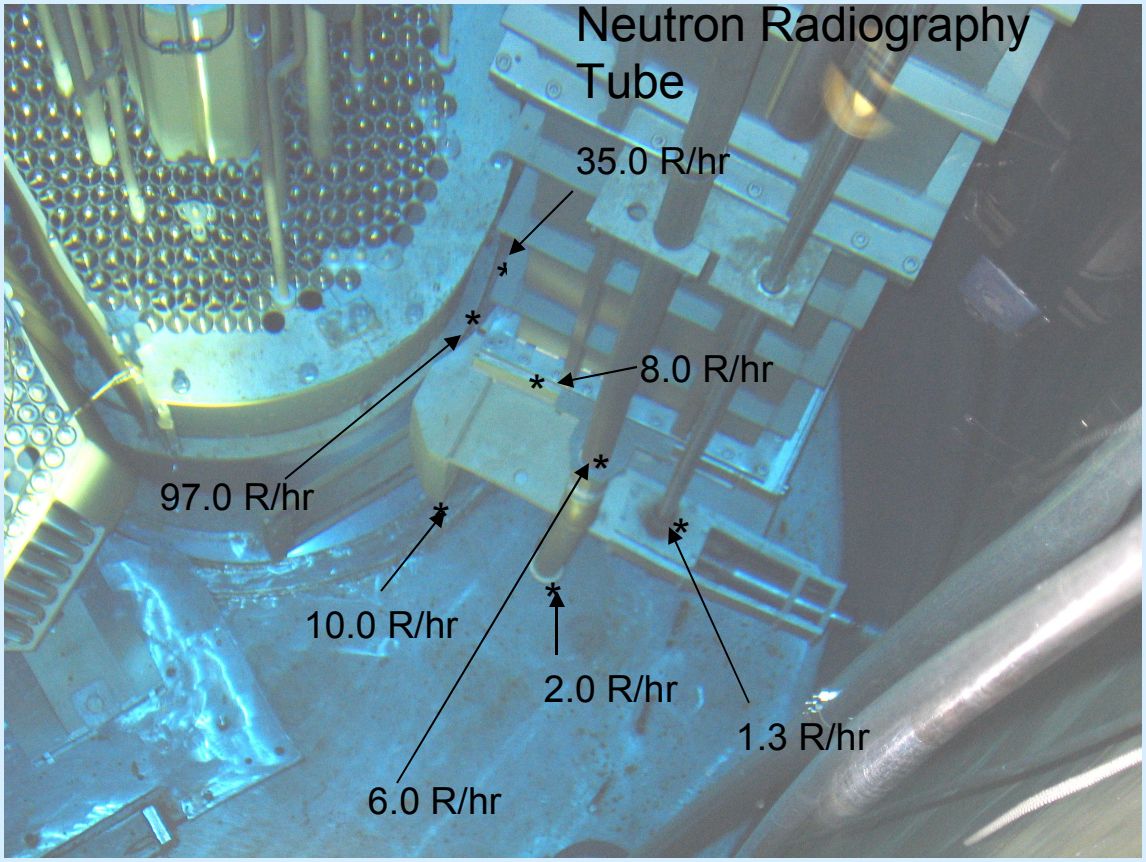
NR FACILITY



- Damage is clearly visible.
- Operating mechanisms and structural strength of the collimator are questionable.

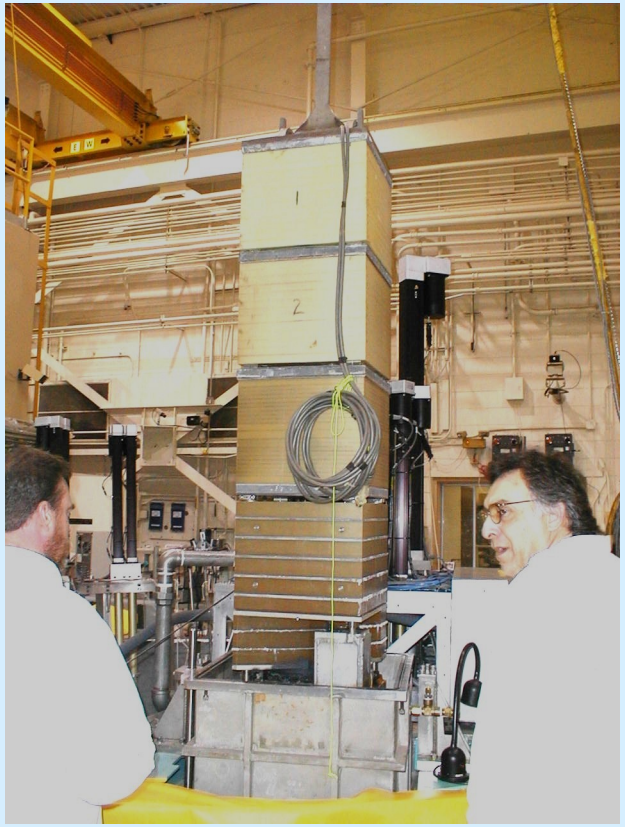
Measured dose rates before removal from ACRR pool

RADIOLOGICAL SURVEY MAP



O indicates smear location * indicates contact radiation reading indicates LAW location All radiation readings are gamma in mrem/hr unless noted otherwise.
SOP indicates Step Off Pad location AS# indicates Air Sample location and number Static Count

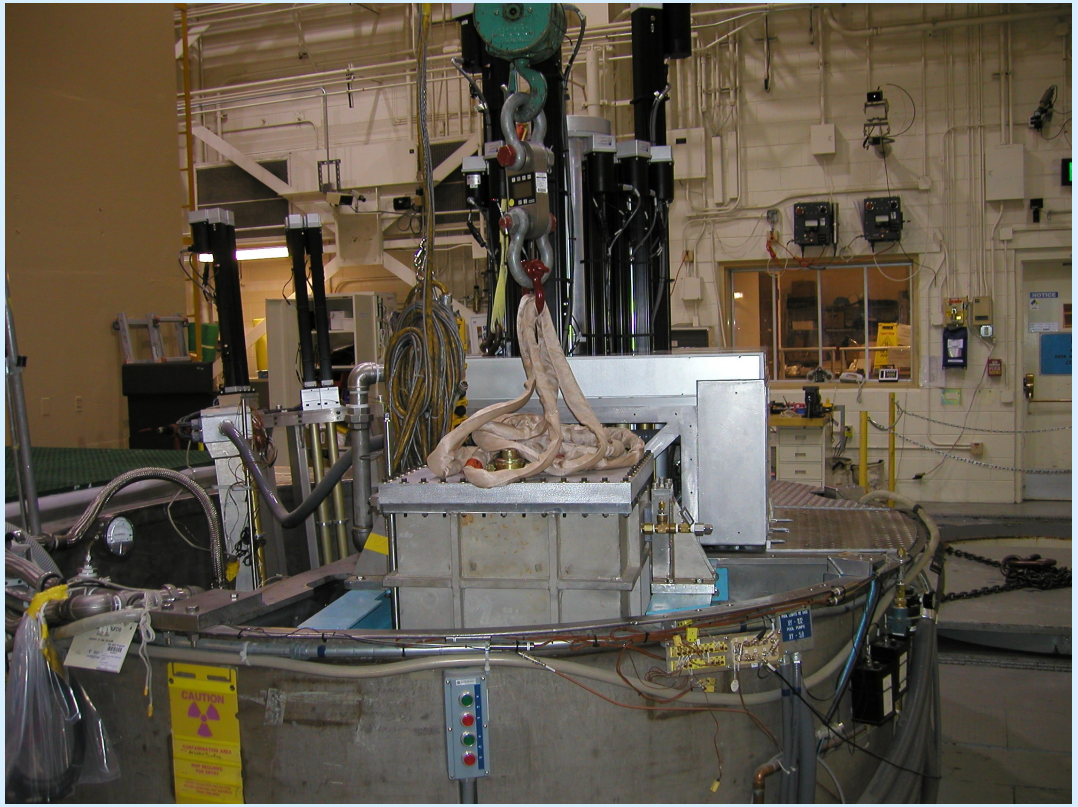
NR Facility Removal



Old collimator

NR Tube assembly

NR Re-Installation



NR Lessons Learned

- ACRR staffing levels moderately strained while providing project lead support.
- High degree of difficulty in cost estimating due to the age of the NR tube and other unknowns.
- A larger laydown area would make future NR tube repairs more convenient.

Cooling Loop Modification

HISTORY

- 1977 system for cooling the ACRR core refurbished.
- Cooling tower, water-to-water HX, pumps, piping & controls replaced.

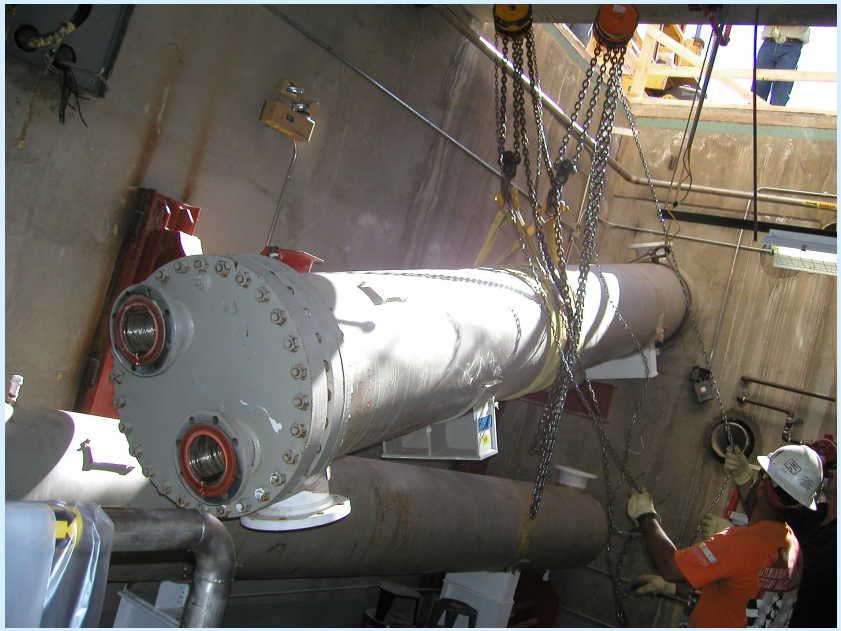
CLM PROJECT SYSTEM OVERVIEW

- Design criterion to keep reactor pool water below 55 °C at full power.
- Cooling capacity upgraded to 4.7 MW

CLM PROJECT SYSTEM OVERVIEW

Bulk Loop Refurbishment:

- 6” piping replaced with 8” piping to reduce fluid velocity.
- The pool suction pipe extended and diffuser (8”x14”) added.
- Two shell and u-tube heat exchangers replaced with a single all-welded plate and frame heat exchanger.
- Prime standard flow/energy meter installed.
- SDD written.



CLM PROJECT SYSTEM OVERVIEW

Cooling Tower Modifications:

- 2 MW tower replaced with 5 MW tower
- Two independent fans in separate cells.
- Two 60 HP fans replaced previous 50 HP fan.
- Underground sump replaced with above ground sump.
- Chemical treatment sys. installed for corrosion protection, incorporating feed/bleed controls.
- All external piping heat trace protected.
- Prime standard flow/energy meter installed.
- SDD written.

CLM PROJECT SYSTEM OVERVIEW

Clean-Up System Modifications:

- New demineralizer with bottom drain/fill connections.
- New pump, flow meter, pH & conductivity meters.
- SDD written.

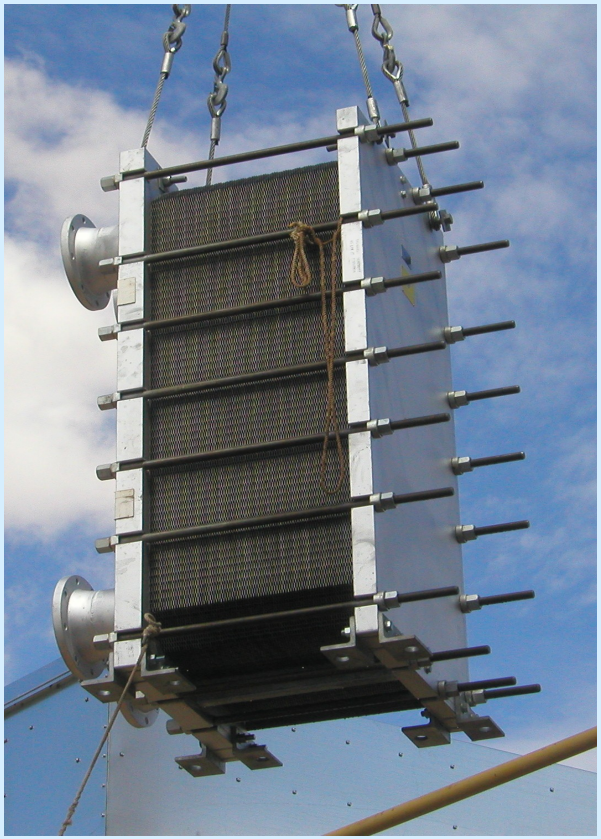
Electrical Service Modifications:

- New Motor Control Center installed.
- Level sensor for Equipment Pit sump pump cutout installed.

Instrumentation & Controls:

- New BOP control panel installed for new systems control.

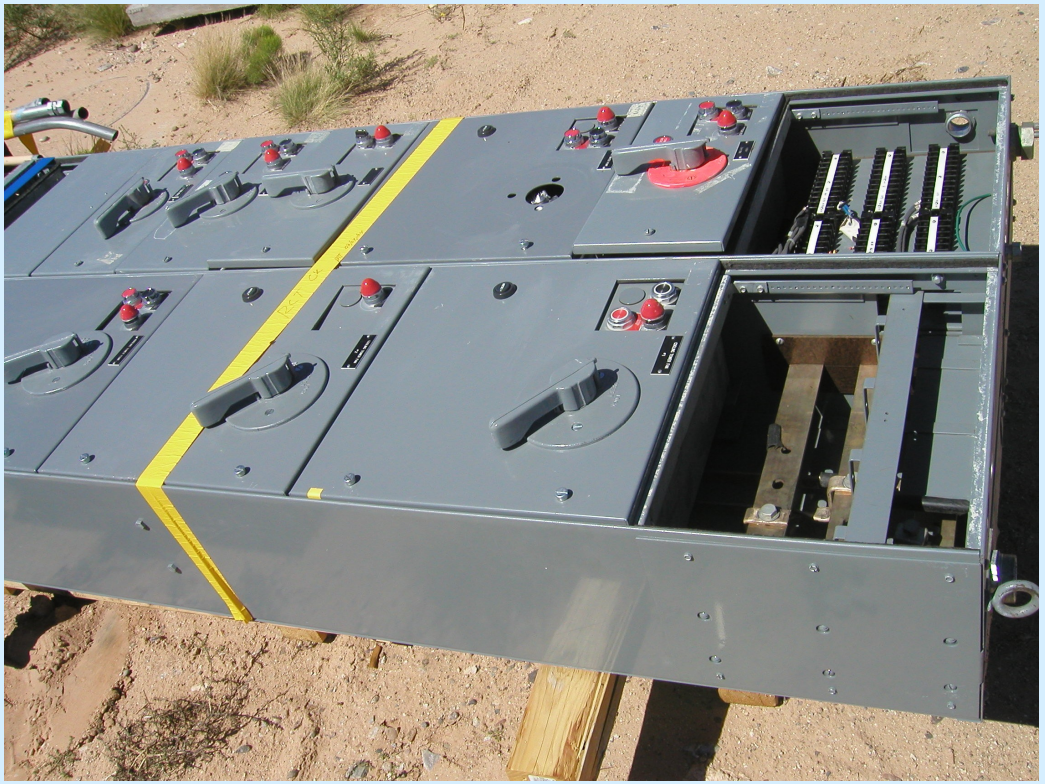
New Components



Heat Exchanger

Cooling Tower

New Motor Control Center



Old Motor Control Center

CLM Lessons Learned

- Reactor Supervisor was Project Manager
  - Difficult to perform both functions well at the same time.
  - Required many hours of overtime.
- Behind schedule by several months:
  - Project Integration: Design Engineer received bad data from pump and HX manufacturers (pump curves wrong, HX ΔPs incorrect, etc). Caused significant test and balance problems.
  - I&C: System as a whole under-specified by Contractor: engineering design/drawings poor, inadequate sensors, Vendor did incorrect initial set-up of processors.
  - Structural prints of facility: 50 year-old building with many modifications, and abandoned equipment. “As-built” condition nearly impossible to ascertain.
  - Cooling Tower Sump volume undersized.

CLM Lessons Learned

- Sandia specifications for epoxy required redesign of pump vibration pads.
- No walk-down by Design Engineer for electrical distribution modifications.
- Lightning Protection not resolved, Sandia standards not well specified.

Other – DSA Issues

- DSA Issues
  - Originally submitted “annual update”
  - Then expanded to include changes for PPS upgrades
  - DOE timeline stretched
  - Additional reviews added significantly to the approval process

Other - Time

- The longer we were down the more difficult it became to get back up.
  - Time impacts everything
  - Skepticism naturally builds over time

Other - Resources

- We did not give enough thought to the resources available from a project management standpoint.
  - Charged into these four projects with a very positive attitude, focused on all the "good reasons" for why it made sense to take on all four simultaneously
  - Wanted to minimize the impact on our nuclear weapon customer base
  - Did not account for potential snags outside of our control and each project’s impact on the other three

Other – Regulator Interface

- We did not anticipate that these facility “upgrades” to make the facility better (i.e. more reliable, more efficient, etc.) would cause so much consternation and concern from our regulator on the back end.
  - Significant difficulties getting DSA and other paper approved
  - Our “upgrades” to make old things new, more reliable, modern, state-of-the-art seen by regulator as “major modifications”
    - Potentially dyer consequences until proven otherwise
    - Justifications required were often ridiculous, at least from our vantage point
- Kept FR in the loop all along the way
  - Perhaps not enough communication within regulator organization

Other

- DNFSB
- CDNS
- Personnel Changes
  - TA-V Management
  - Facility Management
  - DOE Management