Browns Ferry Unit 1 Recovery Dose and Source Term Reduction Initiatives

Overview

- **Browns Ferry Unit 1 was shut down in 1985 and remained in lay up for 17 years. In 2002, TVA made the decision to recover the unit to meet an increasing need for power. Restart of the unit is occurred in May 2007**
- **In August 2003 a review of the Dose and Source term reduction initiatives for BFN 1 was performed.**
- **The review indicated that an aggressive program was not in place.**
- **A level B PER was initiated and a High Impact Team formed to address program deficiencies.**

HIT members

1. **Component Engineer (2)**
2. **Chemistry (1)**
3. **ALARA (1)**
4. **Design Engineer (2)**
5. **Procurement (1)**
6. **Planner (1)**
7. **FME (1)**
8. **Cost/budget (1)**
9. **Mechanical Craft (1)**
10. **Senior Manager (1)**

Source Term Reduction

- **78 valves that formerly contained Stellite® were replaced with non-Stellite® material.**
- **Low pressure turbine blades (last stage buckets) were replaced with non-Stellite® flame hardened ends.**
- **185 (all) Control Rod Blades were replaced with non-Stellite® material.**
- **All replacement components and repaired components in the flow path to the reactor vessel are smeared and analyzed for residual cobalt prior to installation or closure. In cases where components were found to have residual elemental cobalt, the components were cleaned until cobalt was no longer detected.**

Source Term Reduction

- **All tools (including vendor tools) used in the reactor cavity or fuel pool were required to be cobalt free i.e.<0.5 %. If the requirement could not be met, the tools were smeared for cobalt debris and cleaned prior to placement in the cavity.**
- **Procedures were revised to include the design, procurement, planning, and maintenance of components in the flow path to the reactor vessel to ensure legacy of source term reduction.**
- **Recirculation and RWCU piping to be replaced was chemically decontaminated prior to removal to decrease worker dose and improve contamination control during removal.**
- **Prior to close out, the condenser was thoroughly cleaned to remove cobalt, copper, iron, and other impurities.**

System filling

- **The team identified that the refilling of systems using common water from units 2 and 3 could undermine some source term reduction initiatives.**
- **Refill of the Reactor vessel and the Suppression pool were accomplished via the Demineralized Storage tank to prevent cross contamination.**
- **The completion of the reactor fill revealed a small amount of soluble cobalt 60.**
- **A temporary demineralizer was placed on the refueling floor and provided a means for removal.**
- **Future system fills will be evaluated prior to the fill.**

Cobalt in Perspective

- Cobalt-60 is the principle contributor to out-of-core radiation fields in both boiling and pressurized water reactors. A hard facing alloy trade name Stellite®, which has high cobalt-59 content, is identified as the primary source of cobalt-60 in reactors. Cobalt is released through erosion, corrosion, friction, and through debris left from work on components containing Stellite®. When cobalt is released in systems with a flow path to the reactor, it can become activated to cobalt 60. Cobalt-60 is a high energy gamma emitter with a 5.3 year half life. This contaminant plates out in plant piping systems and produces long term high radiation areas in the plant.
- 1 gram of cobalt-60 is equal to 1,132 Curies of radioactivity and as a point source (a metal sphere 6 mm in diameter) emits a radiation field of 1,500 R/hr at 1 meter.

Cobalt in Perspective

- **Chemistry sampling on BFN operating units indicated 800 gm/yr of cobalt 59 was being input into the reactor via turbine blades, valves, control rod blade pins and rollers, jet pump components, and stellite® debris from maintenance activities.**
- **The majority of this is deposited on the fuel and vessel components. However, a portion is deposited on associated piping in the drywell and reactor building.**
- **Based on EPRI research, 70% of the dose accrued on BFN operating units is due to cobalt-60. This is equal to 330 man-rem for FY 04.**
- **For each gram of cobalt introduced into the reactor, $1000/yr of depleted zinc (DZO) injection into the feed water is required to suppress the deposition on plant piping systems.**
- **Less than 1/10th of a gram of cobalt-60 is removed during chemical decon of the drywell recirculation piping at a cost of $2 million.**

Cobalt in Perspective:

1 gram of Cobalt simulated for demonstration purposes

1 gram of Co-60 = 17,000 R/hr at contact!

(1 gram is equal to ~1/28 of an ounce)

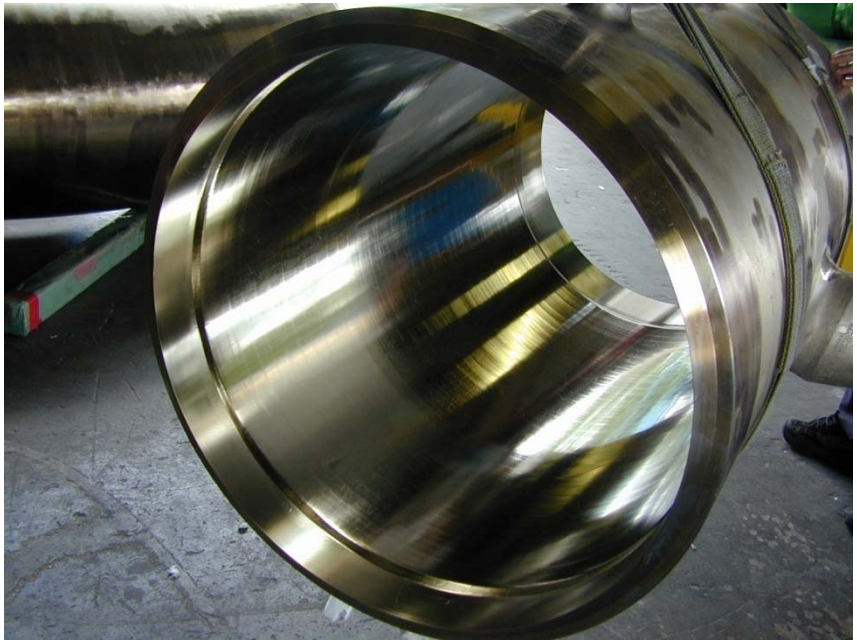
Piping and heat exchanger pre-conditioning

- **All Recirculation and Reactor Water Cleanup piping was replaced.**
- **All RWCU Regenerative heat exchangers were replaced.**
- **Prior to installation the new piping and heat exchangers were mechanically polished, Electro-polished, and Pre-oxidized.**

Electro-polished Heat Exchanger Tubing/Tube Sheet

Piping Electro polishing & PreOx

Finished Spool (Recirc Piping)



Pre-conditioning of valves and pumps

- 12 valves in the RWCU system were replaced.
- 2 valves in the RHR system were replaced.
- 2 RWCU pumps were replaced.
- Prior to installation the valves and pumps were mechanically polished, Electro-polished, Stabilized chrome applied, and pre-oxidized.
- These valves and pumps were identified to have high dose rates on the operating units at BFN.

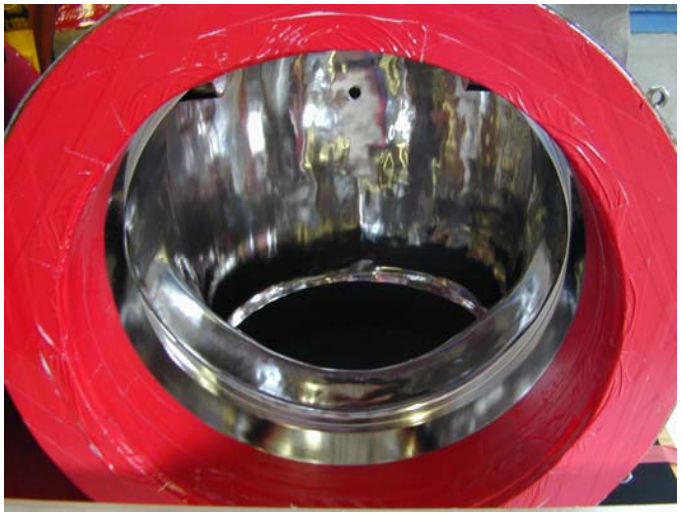
6 inch RWCU inlet valve body

As Received

Post Chrome Application

Post Electro polish

24 inch RHR testable check valve



As Received

Post Chrome Application

Post Electro polish

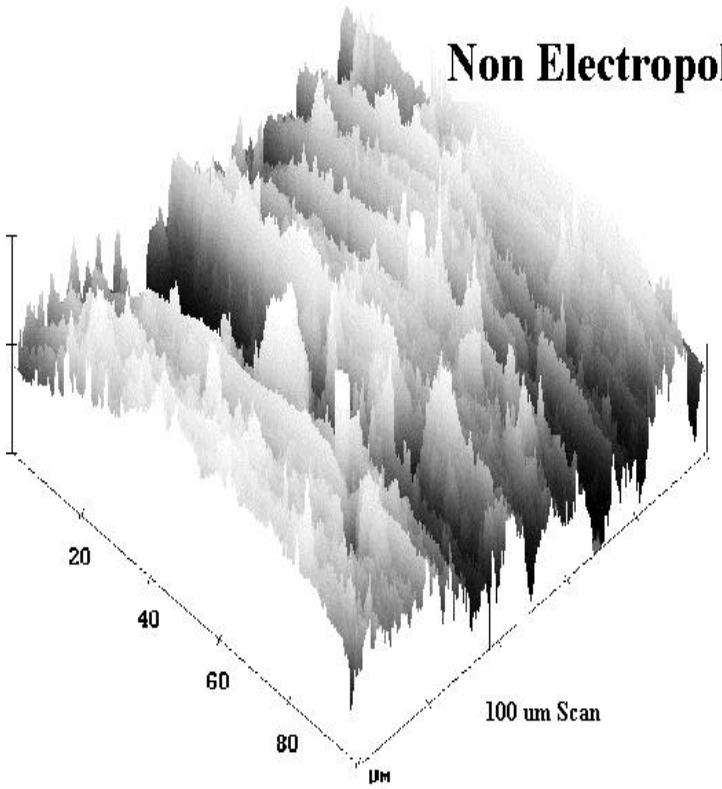
RWCU Pump

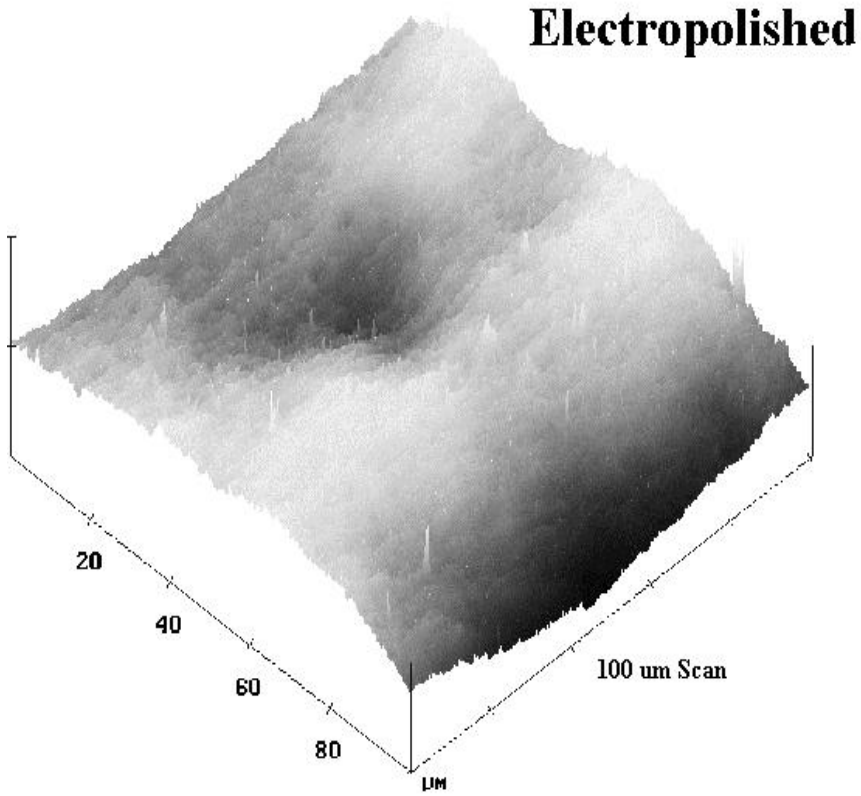
As Received

Post Cr Application

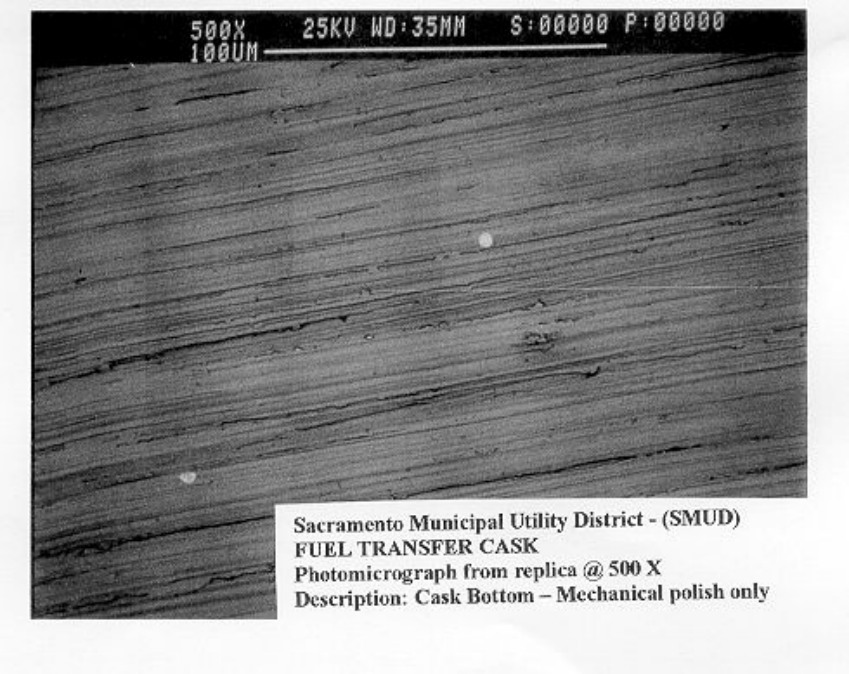
Post Electro polishing

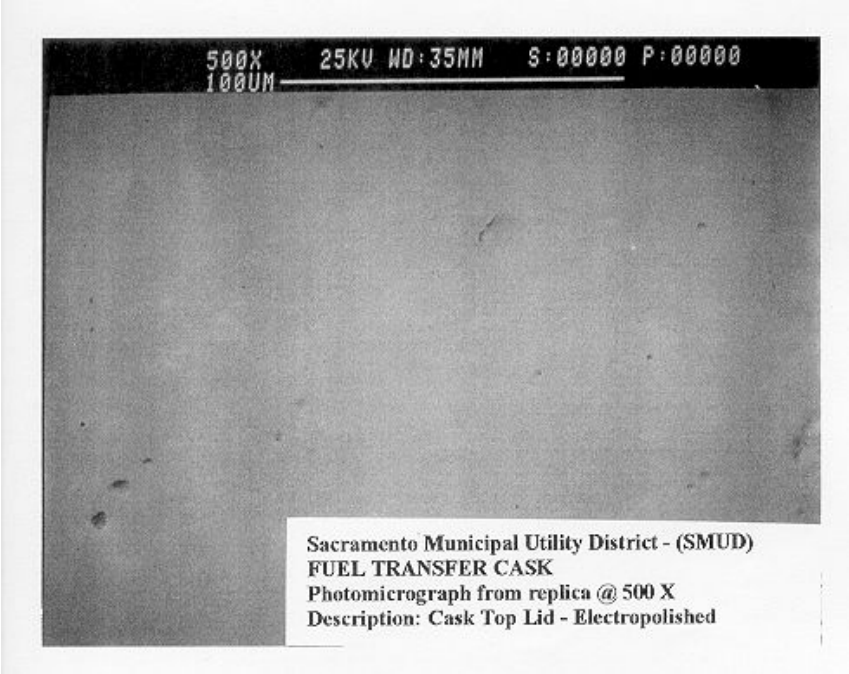
Magnified examples





Magnified Examples of EP

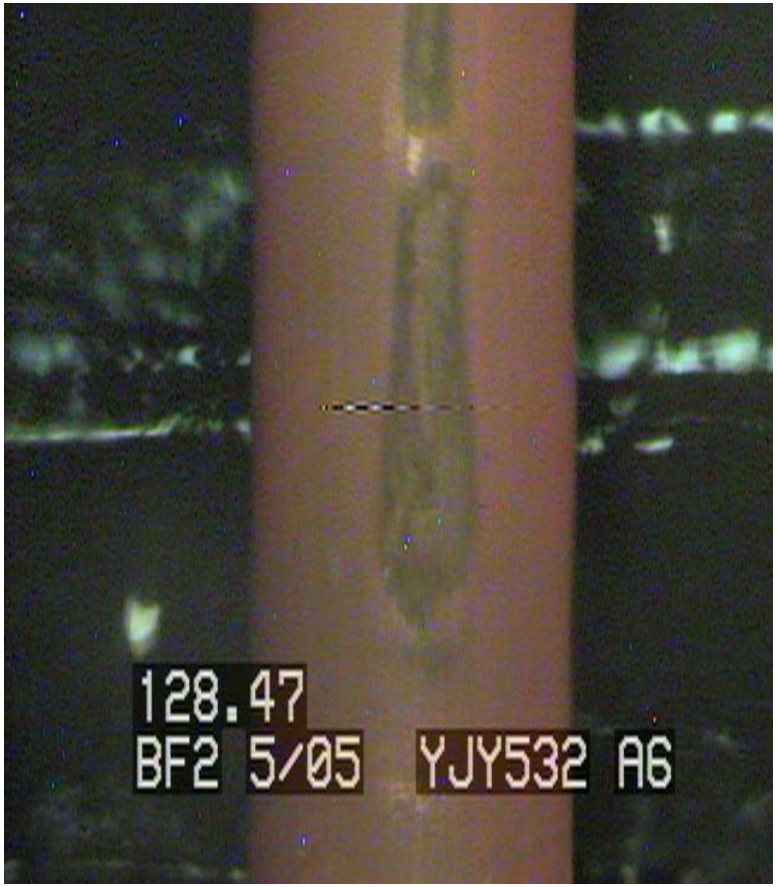




Ultrasonic Fuel Cleaning

- **At start up BFN 1 loaded 36 once burned and 56 twice burned fuel from BFN 2.**
- **The team identified this as a means of transferring source term from the operating units.**
- **In June 2005 BFN performed ultrasonic cleaning of the 92 bundles.**

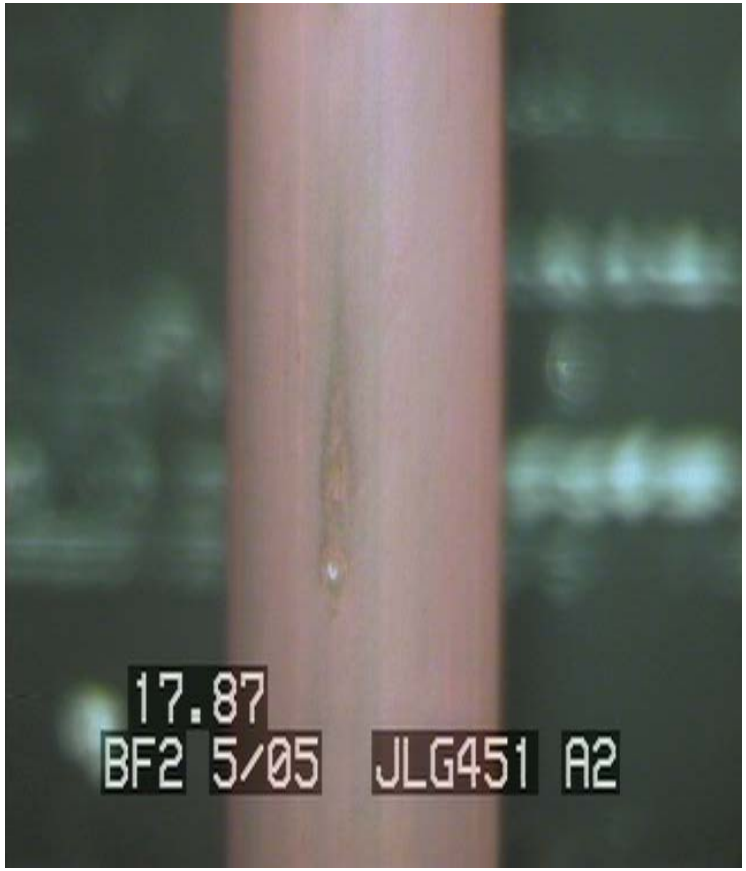
2nd Burn Rod



As removed/Brushed

Post UT cleaning

1st Burn Rod



As Removed/Brushed

Post UT cleaning

Fuel cleaning 2nd Burn Assembly

As Removed

Post UT cleaning

Fuel Cleaning 1st Burn Assembly

As Removed

Post UT cleaning

Permanent Shielding

- **Permanent Shielding was installed on Recirculation piping. This initiative was put in place on the operating units at BFN and received a TIP award in 2002.**
- **Additional shielding measures such as the Reactor coolant sample panel were replaced.**

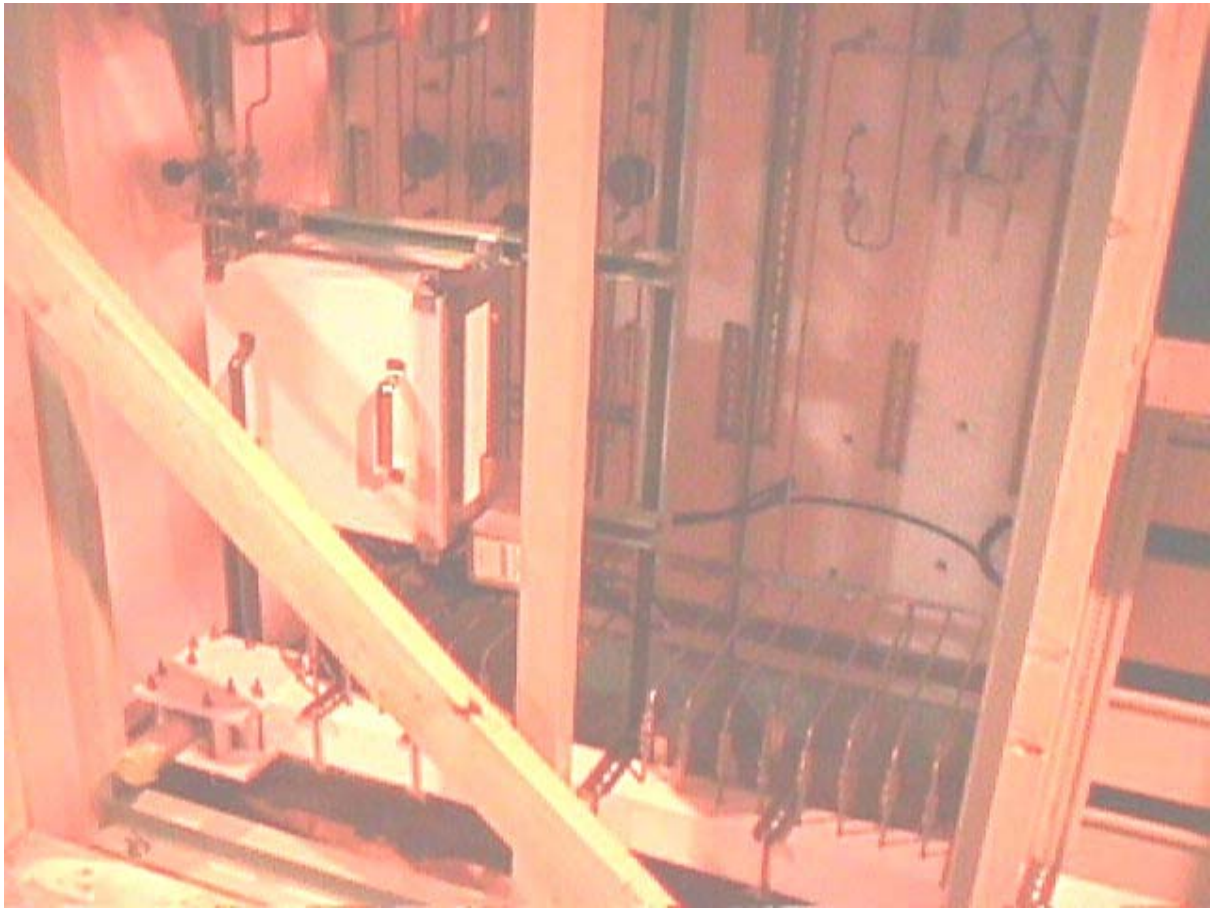
Recirculation piping permanent shielding

New Reactor Water Cleanup sample panel

Features include

1. **½ inch lead shielded drain line**
2. **¼ inch lead shielded cabinet**
3. **½ inch lead enclosed instrumentation cabinet**
4. **Sample lines and drain lines can be hydrolyzed**
5. **Leaded glass for technician dose reduction**
6. **Built in corrosion product samplers**
7. **Reduced elbows and connections on the drain line. Stainless steel piping was heated and bent vs. threaded connections.**

Rear View BFN 1 RWCU sample panel



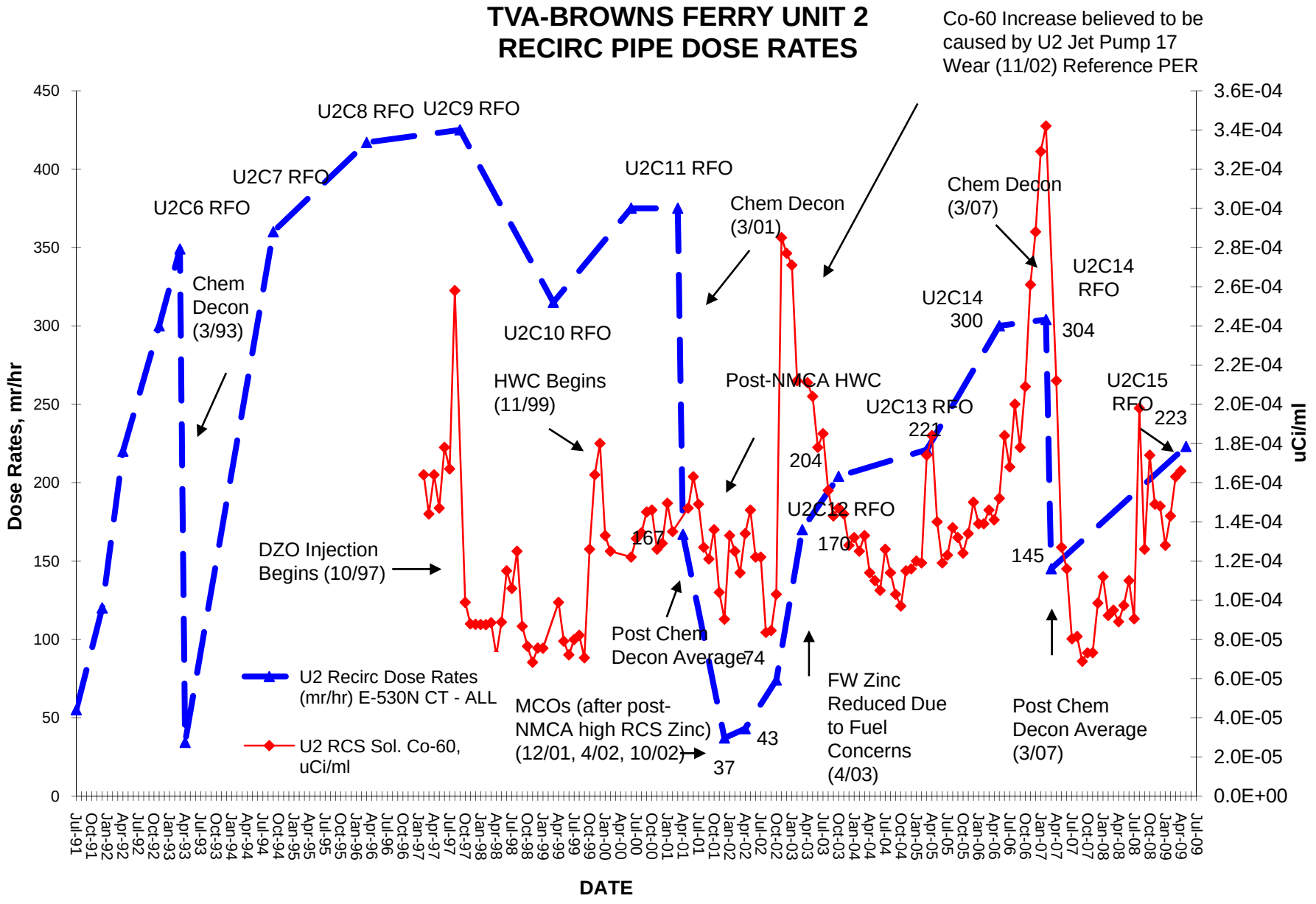
Hydrolyzing of piping

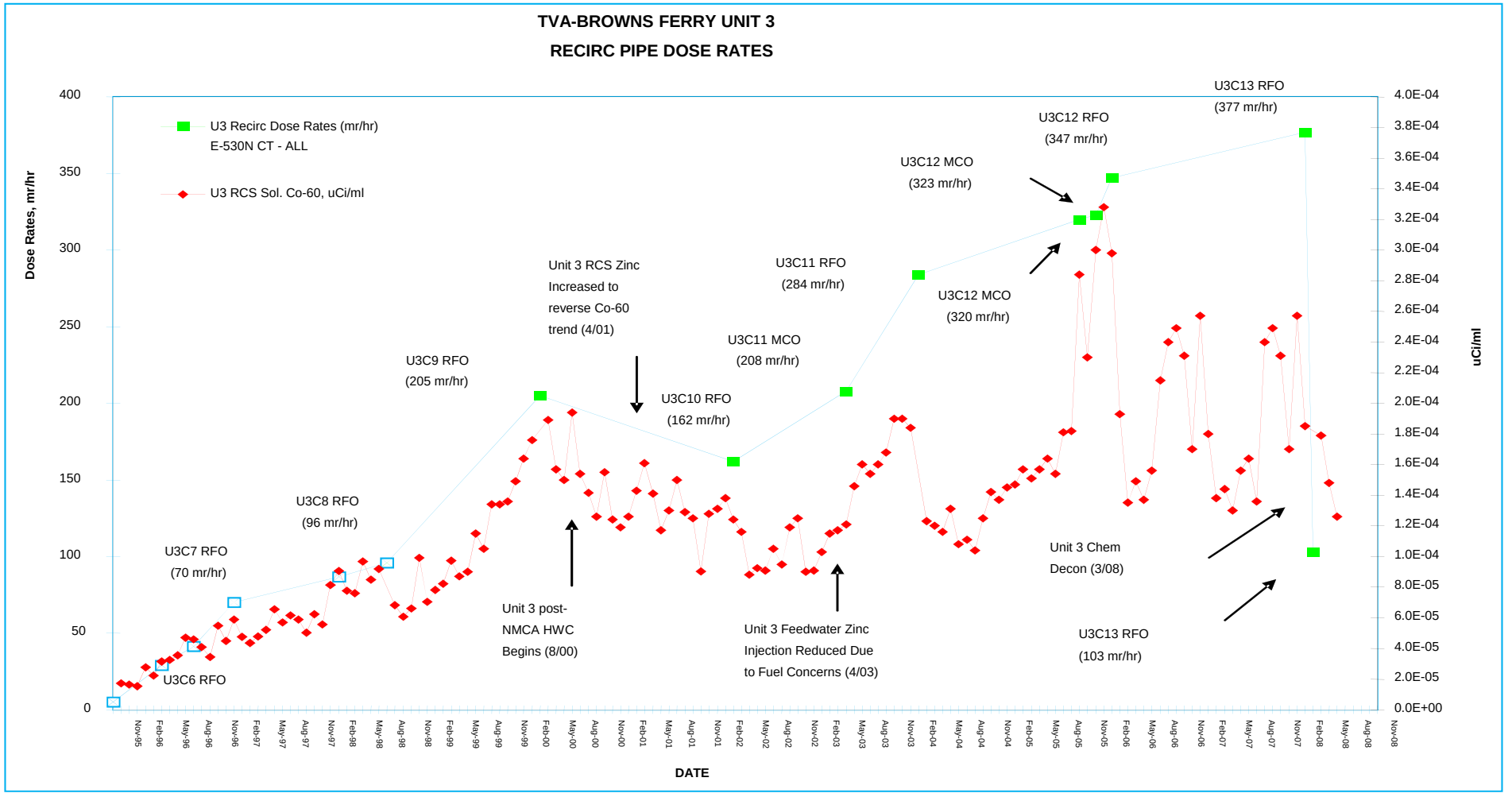
- **Three runs of piping from all 3 units Fuel Pool lines were in the general area of major worker traffic on BFN 1 and increased daily dose.**
- **Hydrolyze taps were installed in the lines.**
- **The lines were hydrolyzed decreasing dose in the general area from 4 mr/hr to 1 mr/hr.**
- **The lines will be hydrolyzed on a regular basis in order to maintain low dose rates in the general area.**

Pre-planning for dose reduction

- **A thorough decontamination plan was laid out at the onset of work. Several areas including most areas of the drywell were decontaminated to a level where c-zone clothing was not required. This decreased worker stay times and increases production.**

So…How’d All That Work Out For Ya’???


TVA-BROWNS FERRY UNIT 2
RECIRC PIPE DOSE RATES
Co-60 Increase believed to be caused by U2 Jet Pump 17 Wear (11/02) Reference PER
U2C6 RFO
U2C7 RFO
U2C8 RFO
U2C9 RFO
U2C10 RFO
U2C11 RFO
U2C12 RFO
U2C13 RFO
U2C14 RFO
U2C15 RFO
Chem Decon (3/93)
Chem Decon (3/01)
Chem Decon (3/07)
HWC Begins (11/99)
Post-NMCA HWC
DZO Injection Begins (10/97)
Post Chem Decon Average
MCOs (after post-NMCA high RCS Zinc) (12/01, 4/02, 10/02)
FW Zinc Reduced Due to Fuel Concerns (4/03)
Post Chem Decon Average (3/07)
U2 Recirc Dose Rates (mr/hr) E-530N CT - ALL
U2 RCS Sol. Co-60, uCi/ml
Dose Rates, mr/hr
uCi/ml
DATE
300
304
204
221
167
170
74
43
37
145
223


TVA-BROWNS FERRY UNIT 3
RECIRC PIPE DOSE RATES
U3 Recirc Dose Rates (mr/hr)
E-530N CT - ALL
U3 RCS Sol. Co-60, uCi/ml
Dose Rates, mr/hr
uCi/ml
DATE
U3C6 RFO
U3C7 RFO
(70 mr/hr)
U3C8 RFO
(96 mr/hr)
U3C9 RFO
(205 mr/hr)
U3C10 RFO
(162 mr/hr)
U3C11 MCO
(208 mr/hr)
U3C11 RFO
(284 mr/hr)
U3C12 MCO
(320 mr/hr)
U3C12 RFO
(347 mr/hr)
U3C13 RFO
(377 mr/hr)
U3C13 RFO
(103 mr/hr)
Unit 3 RCS Zinc
Increased to
reverse Co-60
trend (4/01)
Unit 3 post-
NMCA HWC
Begins (8/00)
Unit 3 Feedwater Zinc
Injection Reduced Due
to Fuel Concerns (4/03)
Unit 3 Chem
Decon (3/08)

Drum Roll, Please…..

Unit 1 BRAC Values as Measured During U1C7 RFO = 14.7 Mrem/hr