Catawba Nuclear Station
Chemical Decontamination of the Chemical & Volume Control Letdown Line

Presented by: David Lloyd

- Catawba Nuclear Station is a Four Loop Westinghouse Ice Condenser PWR with a MDC (Maximum Dependable Capacity) of 1145 MWE.
- Catawba is located in York, South Carolina and sits along the Catawba River approximately 15 minutes from Charlotte, North Carolina.

Overview

- NRC Generic Letter 2004-02
- Catawba's Old Emergency Core Cooling System Sump Vs. Catawba's New Enercon Sump Design
- Major ALARA Concerns (C&VC Letdown Line)
- Challenges and Solutions
- Historical Approaches to Dose Rate reduction
- ALARA Planning/ Proposed Resolutions
- Chemical Decontamination Overview
- Catawba's Implementation of Chemical Decontamination
- Results Summary

Brief History (Generic Letter)

Following NRC bulletin 96-03, “Potential plugging of Emergency Core Cooling Suction Strainers by Debris in Boiling Water Reactors”, the NRC became concerned that post LOCA debris blockage may occur at a PWR.

After extensive research, the NRC opened Generic Safety Issue 191.

GSI 191 is an assessment of PWR sump performance based on debris accumulation.

Based on the findings of GSI 191, The NRC issued generic letter 2004-02, Which is “The potential impact of debris blockage on emergency recirculation during design basis accidents at PWR’s”.

History

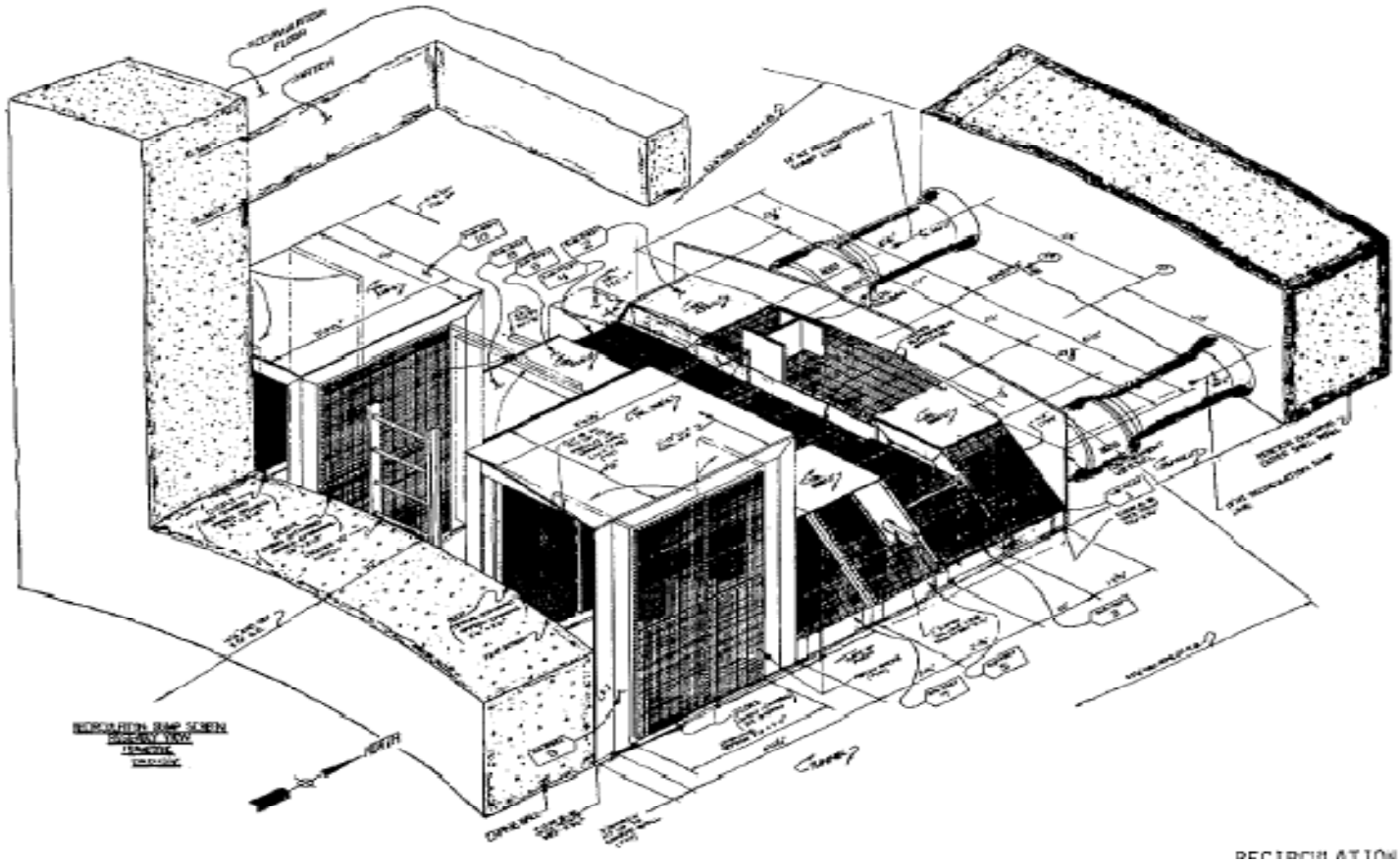
Generic letter 2004-02 required all PWR owners to verify that their sump screens could accommodate projected debris quantities following a LOCA and , if necessary, implement the required plant modifications.

A debris survey was conducted at Catawba Nuclear Station and it was agreed that Catawba was impacted and would perform a sump replacement modification by December 31, 2007.

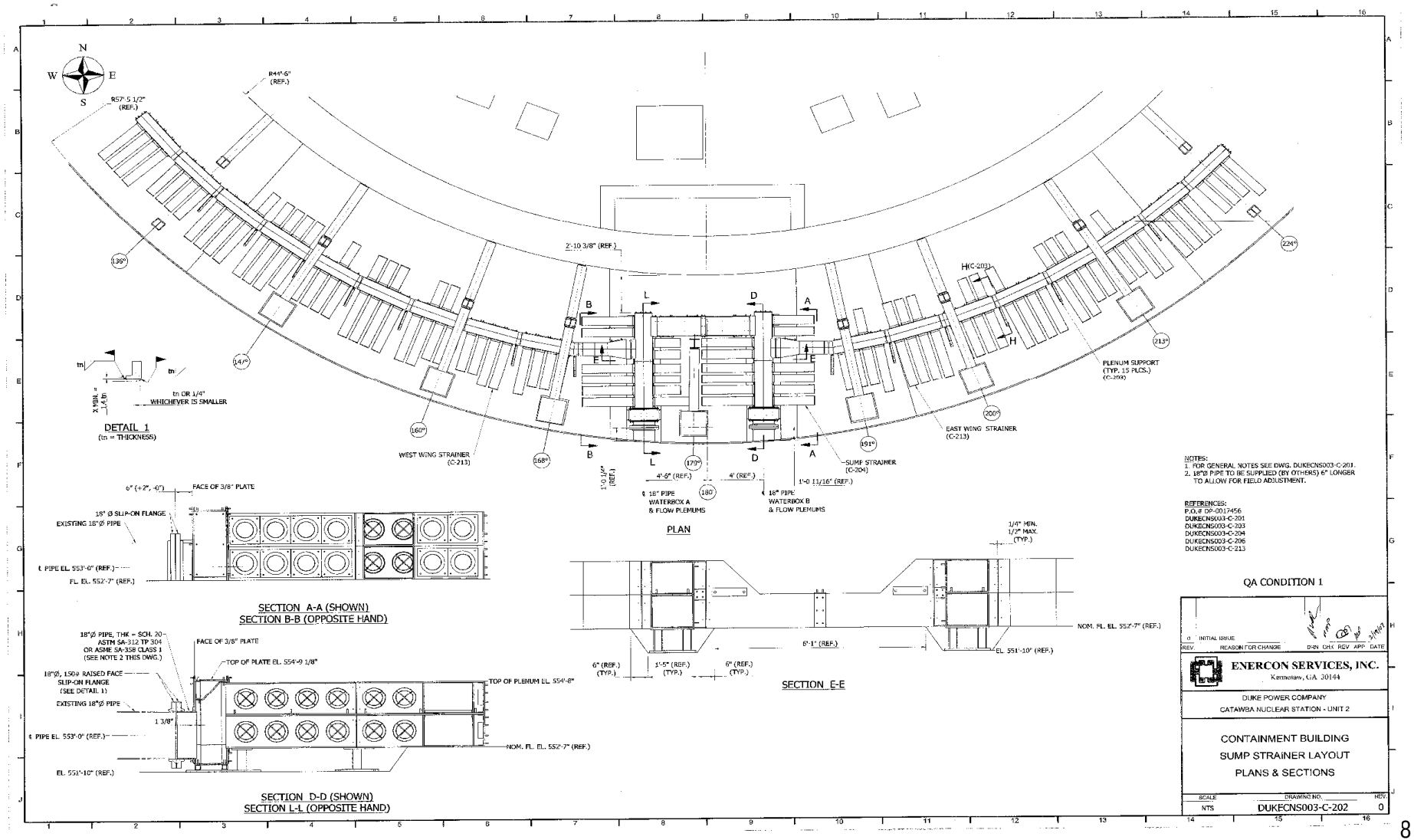
Old ECCS Sump Vs. New ECCS Sump

ALARA had many concerns about the sump replacement project because of the design, location and close proximity of the new sump structure to the Letdown Line

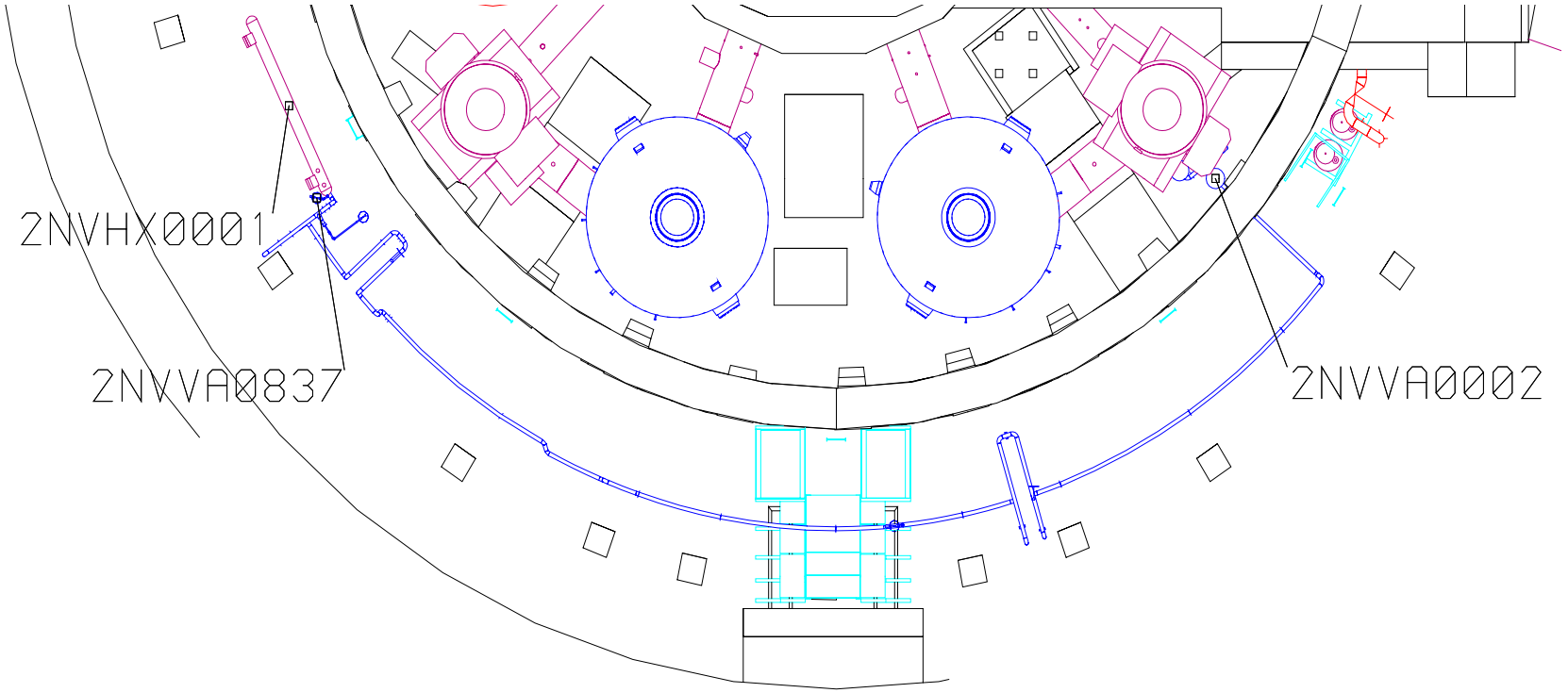
OLD SUMP STRUCTURE (ECCS)
(~240 sq/ft of strainer surface)



NEW ECCS STRUCTURE
(~2400 sq/ft of surface strainer)



Overhead View of Unit 2 Letdown Line



Challenges and Solutions

Challenges

The ALARA team was challenged with creating innovative dose saving initiatives for all phases of the sump replacement.

The planning process included;

- Demolition and removal of the old ECCS sump
- Interference removal for new ECCS sump structure
- Modification and re-routing of installed system piping and electrical systems
- Preparation and leveling of the pipe chase floor for new sump structure base plates

Solutions for Lowering Dose Rates

- Lead shielding?
- Increase letdown flow prior to shut down?
- Drain letdown (primary system water) and fill with de-mineralized water?
- Minimization of work crews and mock-up training?

Letdown Line Over Old ECCS Sump Structure

Tight Places

Struts, Concrete pads, Cable Trays and Other Interferences

Historical approach to lowering Dose Rates on the Letdown Line

- We typically increase the letdown flow rate prior to shut down in an effort to flush the line and then clean up with filters and Ion exchange.
- We isolate the Letdown Line prior to peroxide injection so that crud burst source term is not deposited in the Letdown Line.
- Operations drains, vents and re-fills the Letdown Line with de-mineralized water.
- We routinely install mass shielding on the letdown line during outages to provide more favorable dose rates in the pipe chase for routine valve work.

ALARA PLANNING

- We wrote detailed ALARA plans to minimize as much unnecessary work in the pipe chase as possible.

- We planned extensive mock-ups, including, building a replica of the pipe chase on our turbine floor where the entire sump was assembled, numbered and boxed sequentially.

- We then compiled all available information, applied the historical effective dose rate information of ~4.7 mr/hr to our projected ~15,000 man-hours, and we were still looking at a huge number! ~71 rem was simply not an acceptable number for the sump replacement.

Chemical Decontamination of the Chemical and Volume Control System Letdown Line

Chemical Decontamination in Nuclear Reactors

- 1950s-1960s: concentrated chemical solutions were developed for application in military reactors
- Late 1970s: dilute solutions developed (i.e. NP, LOMI) due to fear of corrosion of plant systems by harsher concentrated solutions
- 1979: first U.S. commercial application of dilute process at Vermont Yankee
- Early 1980s: decontamination of PWRs during first phase of steam generator replacements
- 1983: first use of dilute process in operational PWR (Ginna steam generator replacement)
- 1984: first U.S. application of LOMI process (Monticello)
- 1989 and 1995: Westinghouse acquired LN Technologies and PN Services to become only U.S. based vendor for nuclear plants

EPRI Decontamination Handbook, July 1999, TR-112352

Westinghouse Chemical Decontamination Process

- Contracted Westinghouse (Richland, WA) to perform chemical decontamination of piping
- Catawba Chose the NP-NP-LOMI process for decontamination
  - NP = Nitric Permanganate
  - LOMI = Low Oxidation state Metal Ion
  - Uses dilute chemical solutions that are essentially non-corrosive to plant piping
  - Applied at ~200 ^{0}F
- Set decontamination factor goal of 5-10

NP Chemistry

- Chemicals used: potassium permanganate ($KMnO_4$) and nitric acid (HNO_3) for NP step, oxalic acid (HO_2CCO_2H) for post-NP rinse
- Solution applied at 200 ^oF and pH ~ 2.5
- Cr "leached" from oxide film—insoluble Cr(III) oxide in film oxidized to soluble Cr(VI) and was removed by ion exchange

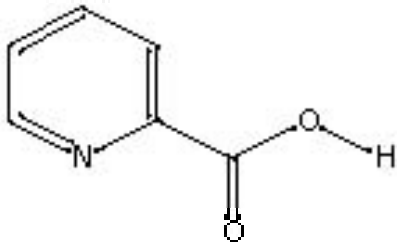
$$Cr_2O_3 + 2MnO_4^- + H_2O \rightarrow 2HCrO_4^- + 2MnO_2$$

- At completion of NP step, oxalic acid rinse was used to destroy excess MnO_4^- and residual MnO_2 for removal of resulting Mn(II) ions by ion exchange

$$11H^+ + 5HO_2CCO_2^- + 2MnO_4^- \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$$

LOMI Chemistry

- Chemicals used: vanadous formate ($(HCOO)_2V$) and picolinic acid (Pic = picolinate ion)



picolinic acid

- Solution applied at 200 ^{0}F and pH ~ 2

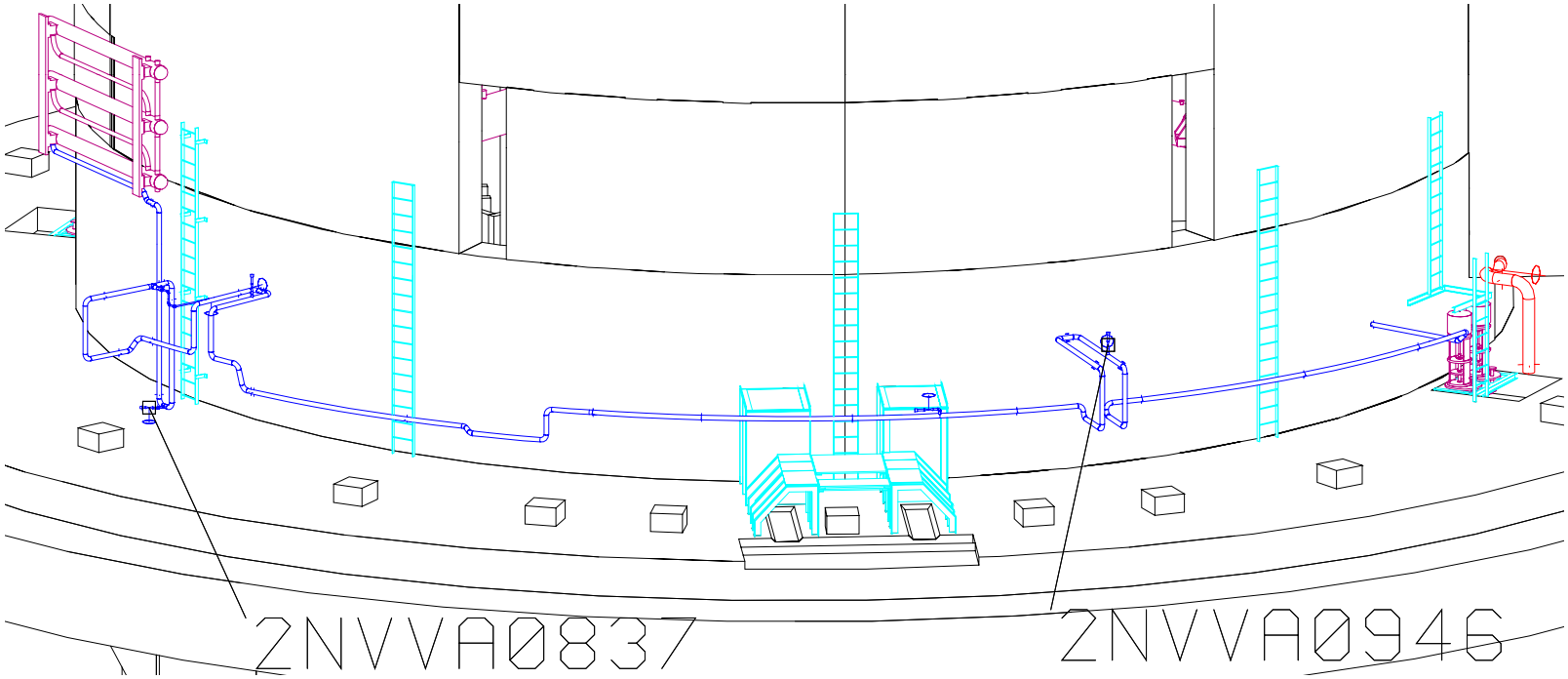
- $NiOFe_2O_3$ dissolved and Ni(III) and Fe(II) ions stabilized in solution by picolinate for removal by ion exchange

$$NiOFe_2O_3 + 2V(Pic)_2 + 8HPic \rightarrow 2V(Pic)_3 + Ni(Pic)_2 + 2Fe(Pic)_2 + 4H_2O$$

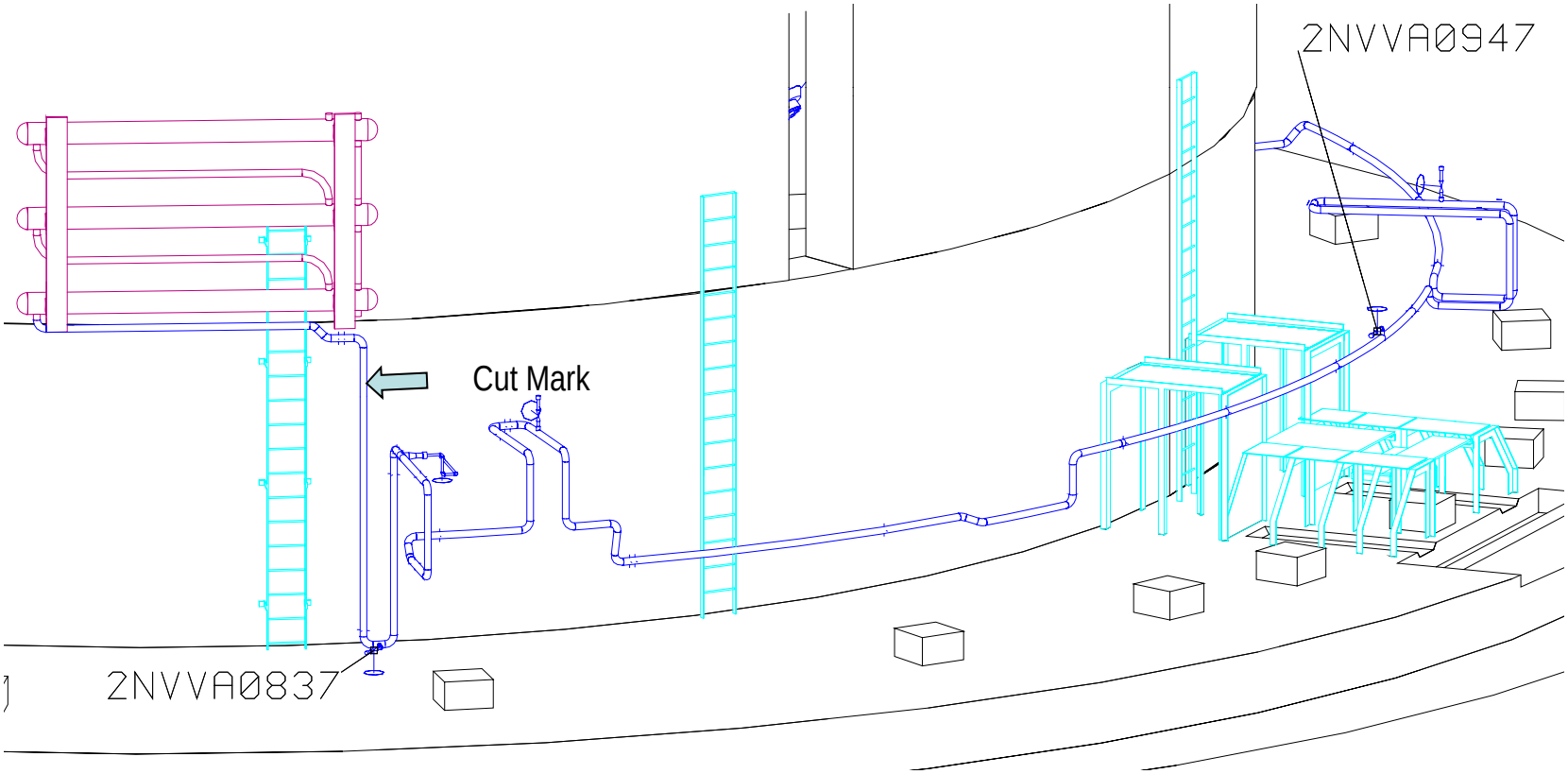
- Process also works for Fe_2O_3

$$Fe_2O_3 + 2V(Pic)_2 + 6HPic \rightarrow 2V(Pic)_3 + 2Fe(Pic)_2 + 3H_2O$$

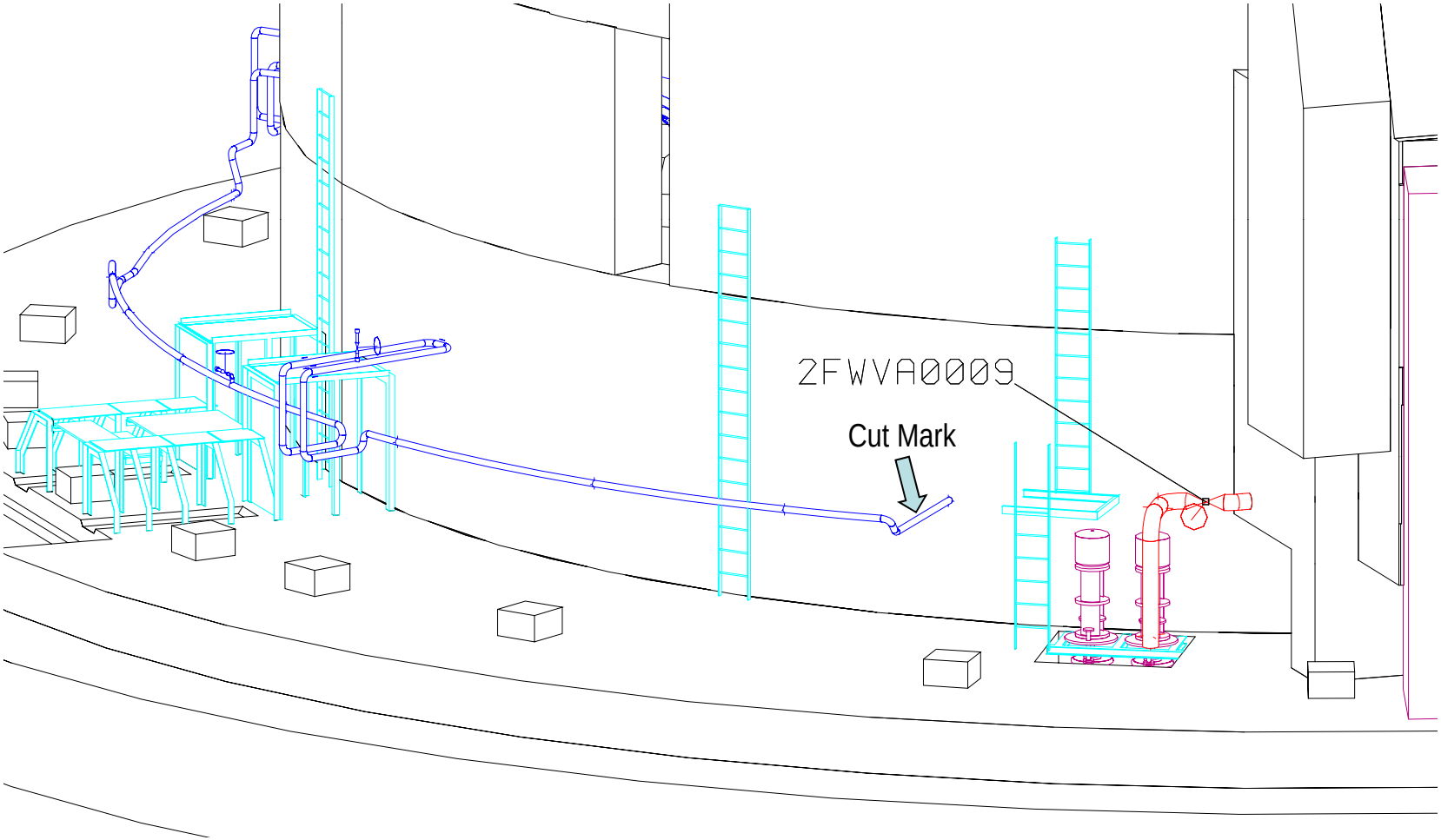
Perspective View of NV Letdown Line



Perspective of NV Letdown Line-West End

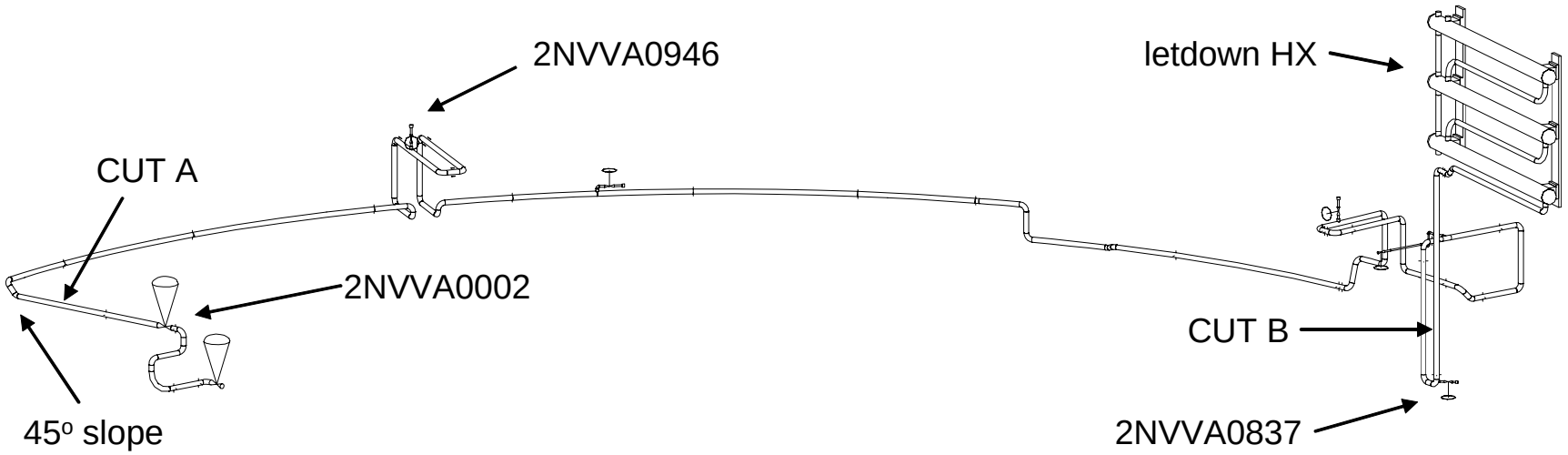


Perspective of NV Letdown Line-East End



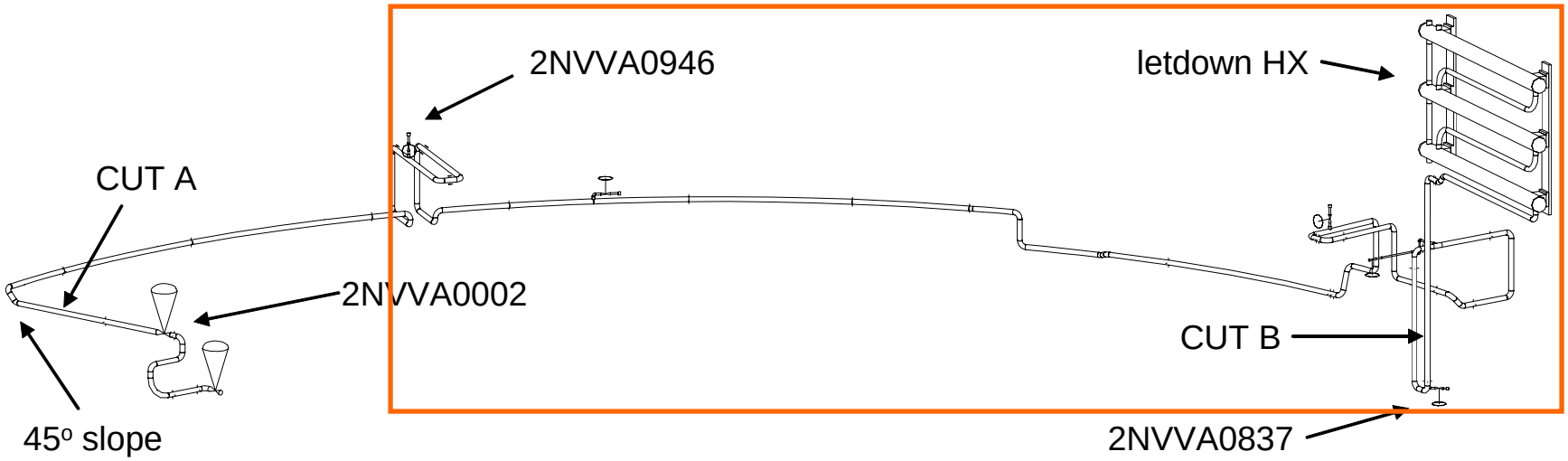
Orientation of Piping

- ~ 200 ft of piping with a volume of ~ 70 gal. was decontaminated.
- Duke Major Projects personnel made cuts and installed flanges compatible with Westinghouse equipment.
- Prior to cutting, dissolved hydrogen in water was a concern due to possible flammability.



Cut B Section

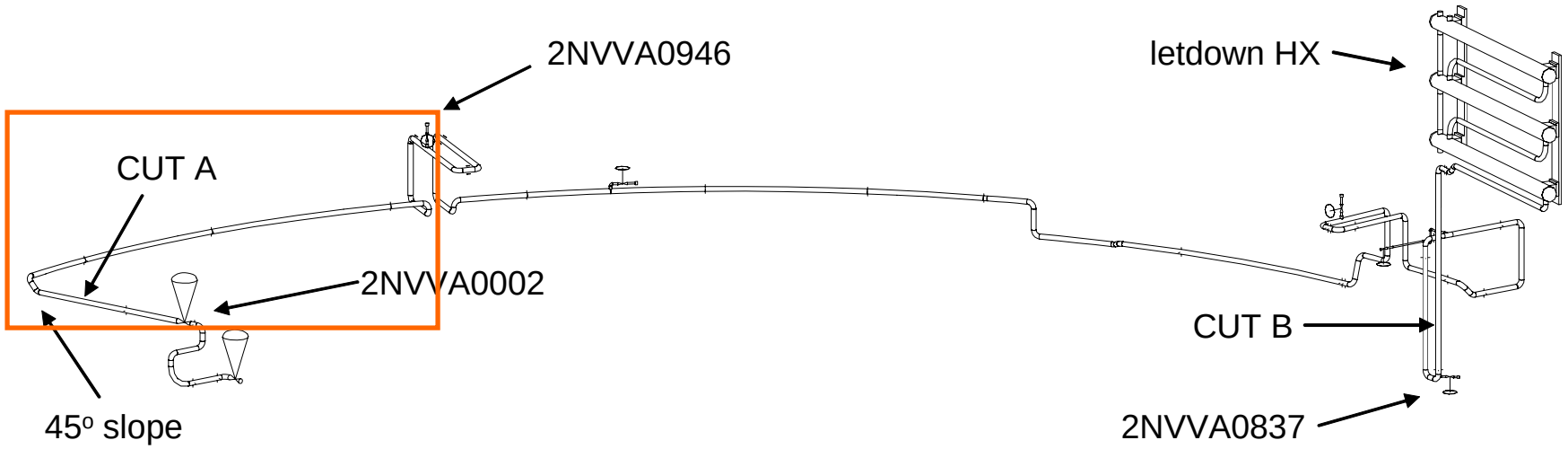
- We Drained letdown water through 2NVVA0837.
- We back flushed de-mineralized water through 2NVVA0946 to purge remaining letdown water and residual hydrogen.
- The remaining water was drained through 2NVVA0837 to ensure dry cut with no hydrogen



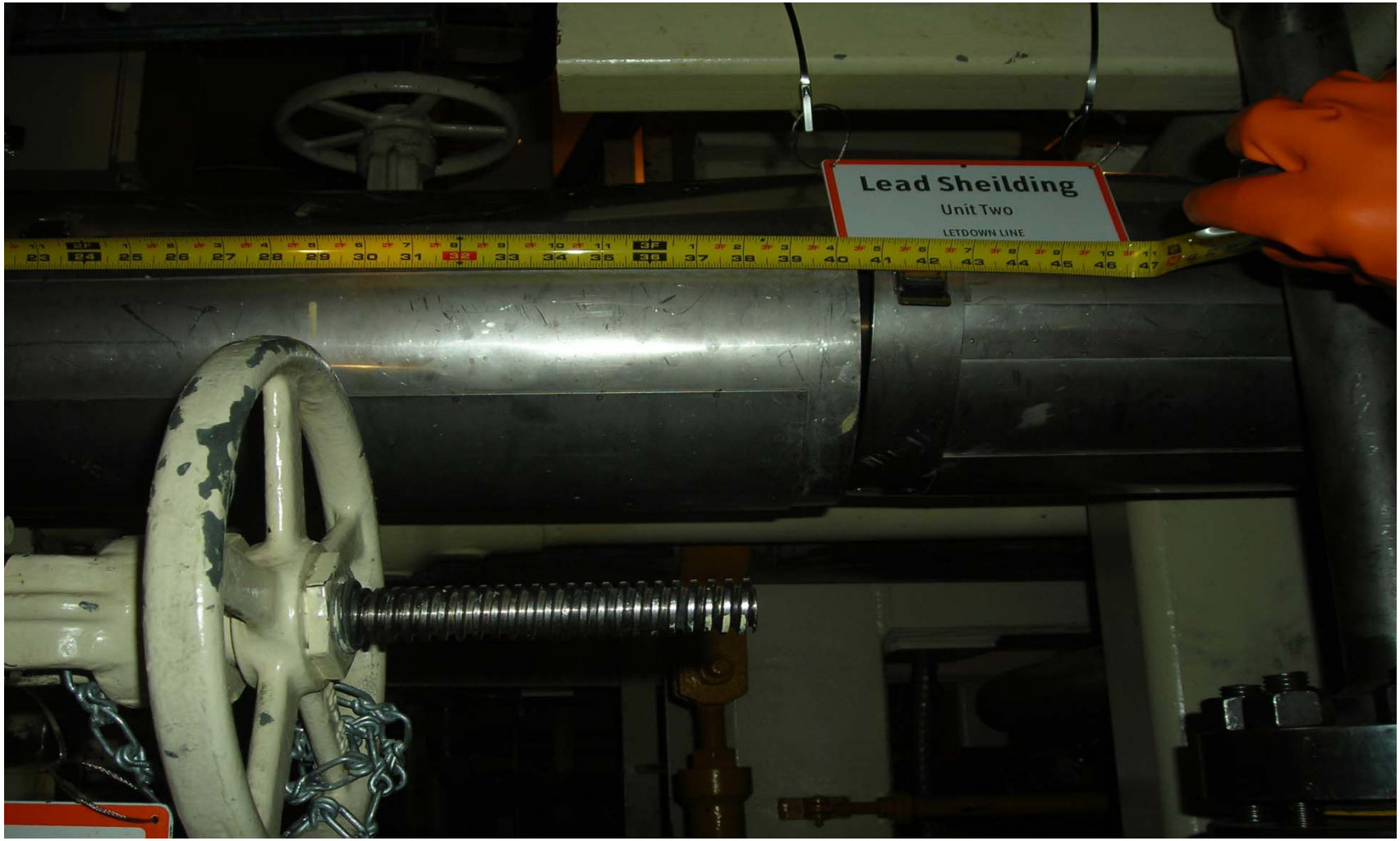
Letdown Line at ~ 126 deg. “Horse shoe”

Cut A Section

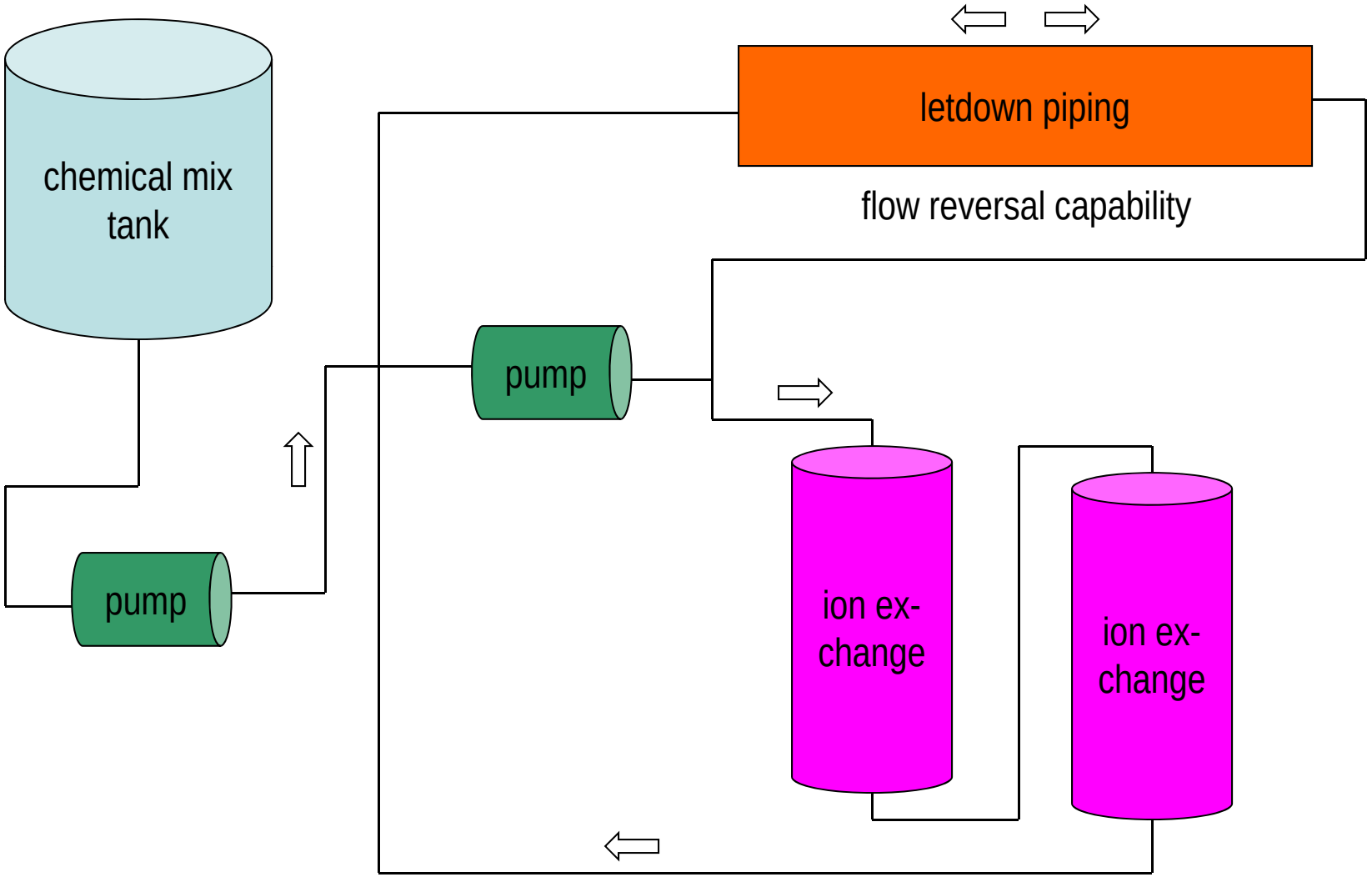
- Dead leg (between 2NVVA0002 and 2NVVA0946) contained letdown water and dissolved hydrogen.
- A wet cut made was made in the bottom of pipe to allow water to drain
  - Dead leg volume = 18.6 gal



Horizontal Letdown Piping at ~229 deg.



Decontamination Equipment Setup



RESULTS

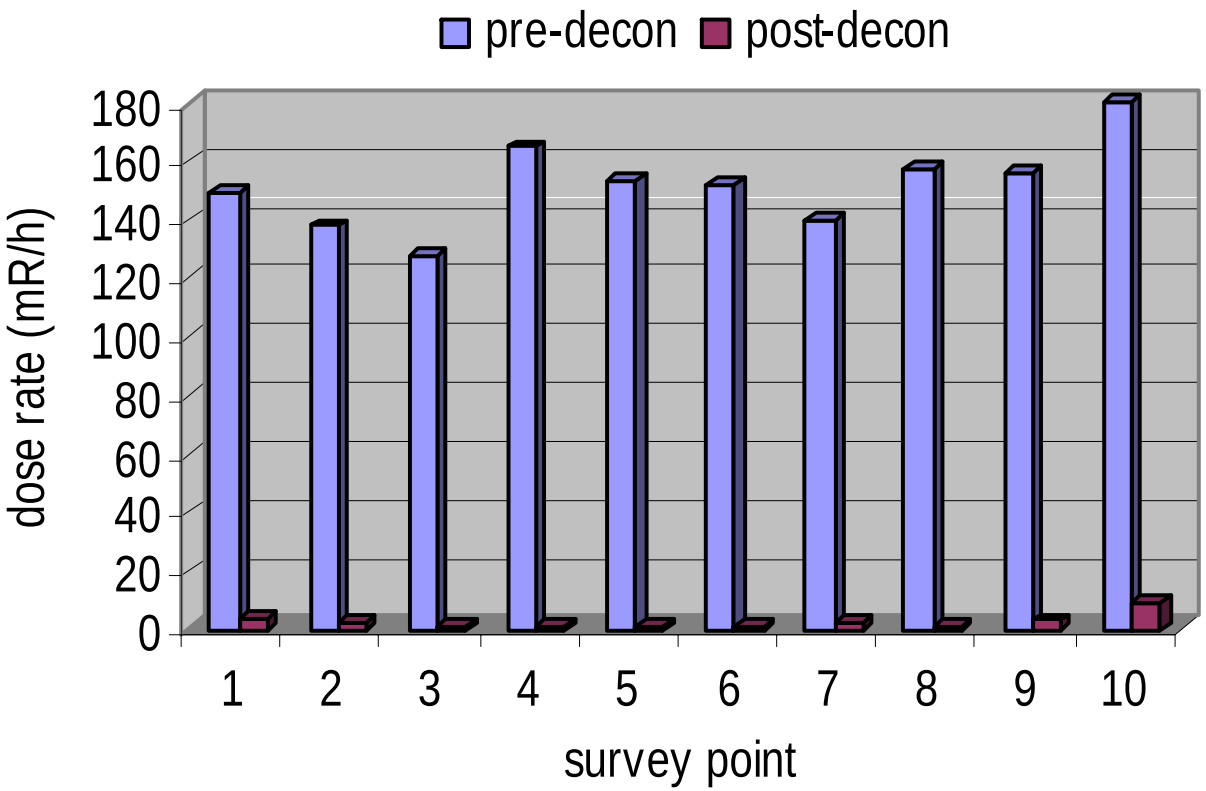
Activity and Radionuclide Removal

step	duration (h)	activity removed (Ci)
NP 1	3.75	0.1
Oxalic acid rinse 1	4.25	3.2
NP 2	3.25	0.1
Oxalic acid rinse 2	4	0.1

radionuclide removed	percentage of total (%)
^{58}Co	75.4
^{60}Co	15.6
^{51}Cr	6.1
^{54}Mn	2.1
^{59}Fe	0.5
^{65}Zn	0.3

- 3.5 total Ci activity removed after above steps → A decontamination factor of nearly 100 was achieved.
- LOMI step deemed unnecessary as a result

Dose Rates at Various Survey Points



survey point	pre-decon mR/h	post-decon mR/h
1	149	4
2	138	2
3	128	1
4	165	1
5	153	1
6	152	1
7	140	2
8	158	1
9	156	3
10	180	9

Summary

- NP-NP chemical decontamination
  - Outage schedule time allocated for chemical decontamination was 36 hrs
  - Actual schedule time used was ~ 18 hrs
  - Chemical process duration = 15 hrs with a 3 hr demobilization time.
- Achieved decontamination factor of nearly 100 (99% activity removed) without requiring LOMI step
- Total radioactive waste = 10 ft^3 ion exchange resin
- Effective Dose Rate declined from ~4.7 mr/hr to ~1.4 mr/hr.
- Actual Dose received for the entire sump replacement was ~24 rem.
- The ~24 rem actual includes; ~ 4 days of project duration overrun. When calculating the man-hour overrun into our original estimate w/o Chemical Decontamination it would raise the original dose estimate to ~78 rem.
- When considering actual Vs. estimated man-hours, our dose savings can be considered close to 54 rem.
- After our success in U2, Chemical Decontamination was performed for our U1 sump replacement project and an additional 30 rem was saved, bringing the total dose savings to >80 rem for the two units.