Safety Challenges and Solutions
LANSCE
DTL Cracked Weld Repair

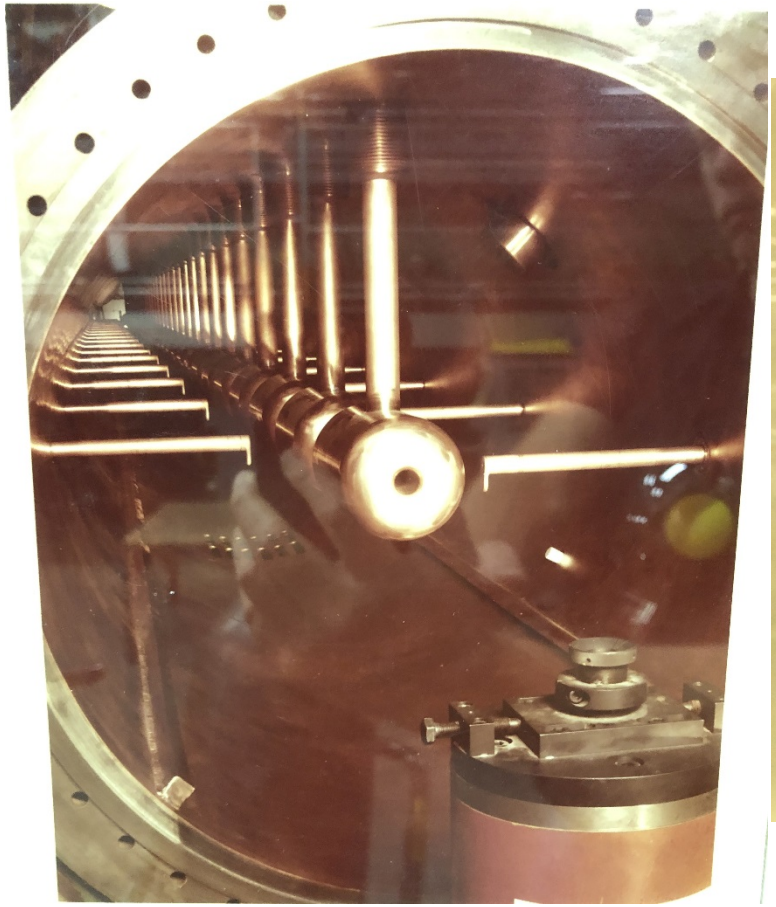
Michael Borden (+57 other people)

LANL AOT-MDE GL

9-11-2019

LANSCE is a unique national user facility running five experimental facilities

Photos from Original Build



Inside of tank - drift tubes and post couplers

Drift tube installation

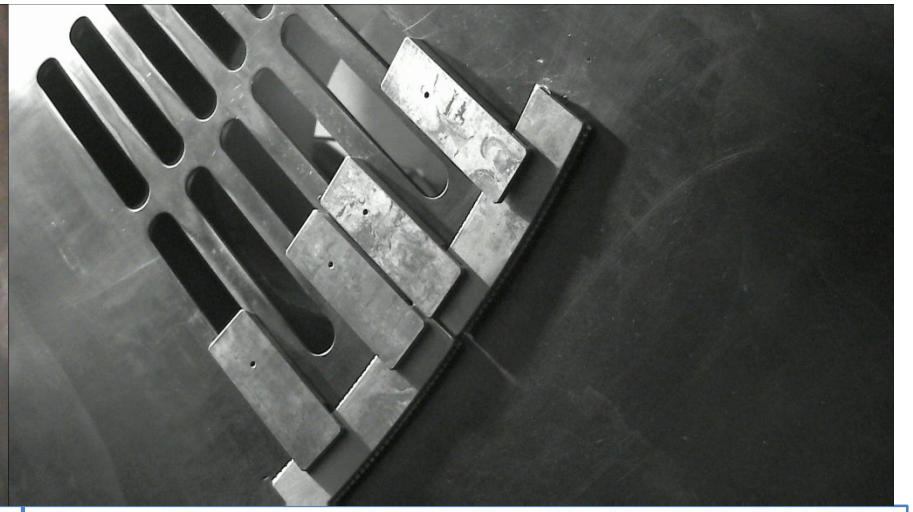
Recent Module 3 Operating Parameters Indicates Degradation with Time

Date	PRF	RF Gate Length	Beam Pulse	Average RF Power
	Hz	usec	usec	kW
7/16/2017	120	1010	625	153.75
11/16/2017	120	810	475	116.85
11/17/2017	120	830	525	129.15
11/27/2017	120	830	565	138.99
6/28/2018	120	880	625	153.75
9/18/2018	120	760	520	127.92
9/20/2018	120	700	400	98.4
9/24/2018	60	1010	625	76.875
9/24/2018	60	1060	625	76.875
9/26/2018	60	1060	725	89.175
10/9/2018	60	1040	725	89.175

LANSCE Alvarez Drift Tube LINAC (DTL)

- 201 MHz DTL is upstream of all experimental areas – all areas were offline (Module 3 ~ 60’ long)
- Crack near ion pump grate in Module 3 prohibits RF induced longitudinal currents from flowing continuously in the copper cladding causing high-voltage breakdown
- Crack was approximately 12 inches long at the grate to copper cladding weld joint (is not a structural tank weld)

Non-Intrusive Low Risk Options were Installed Through the Ion Pump Grate



Copper tape applied to crack –

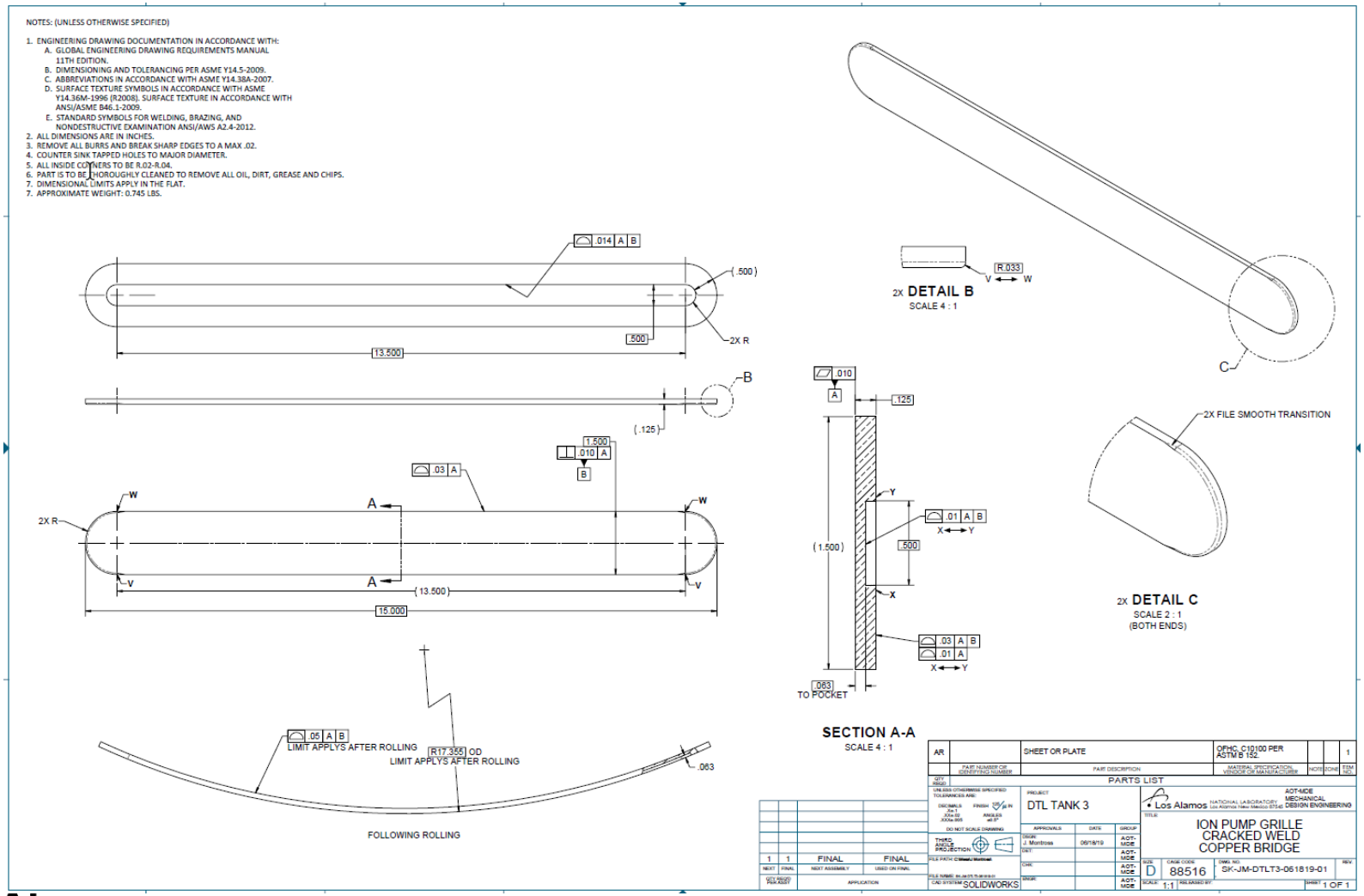
Was tried first and conclusively proved that the source of the breakdown was indeed the crack. Tape blistered after a few hours at full power.

Copper bridge with RF fingerstock bridging the crack -

Two versions were installed and tried, but were not successful in preventing high voltage breakdown

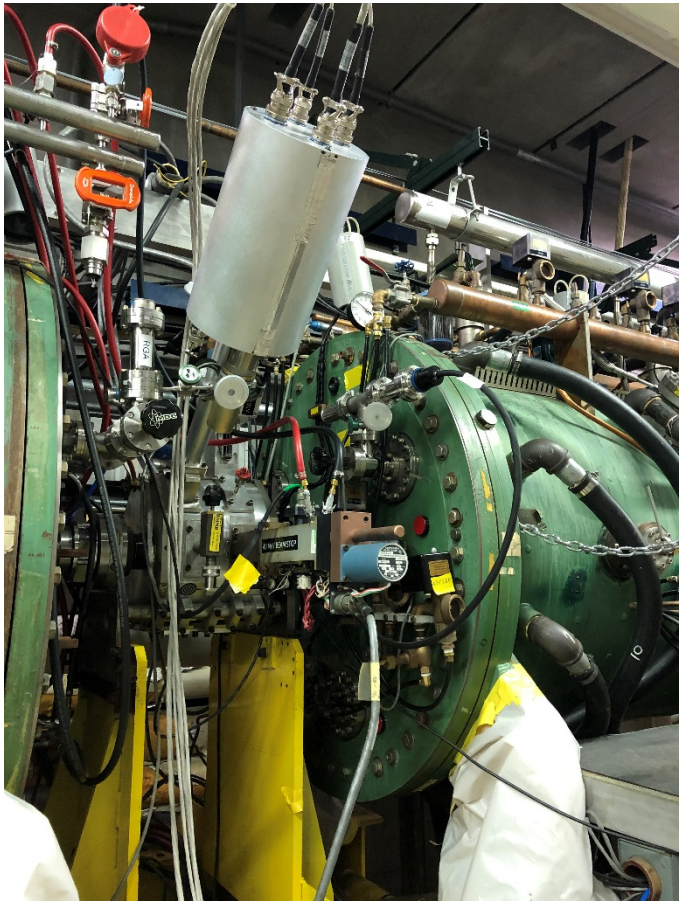
Decision is made must enter the tank and repair the crack

Copper Bridge To Be Welded Over The Crack



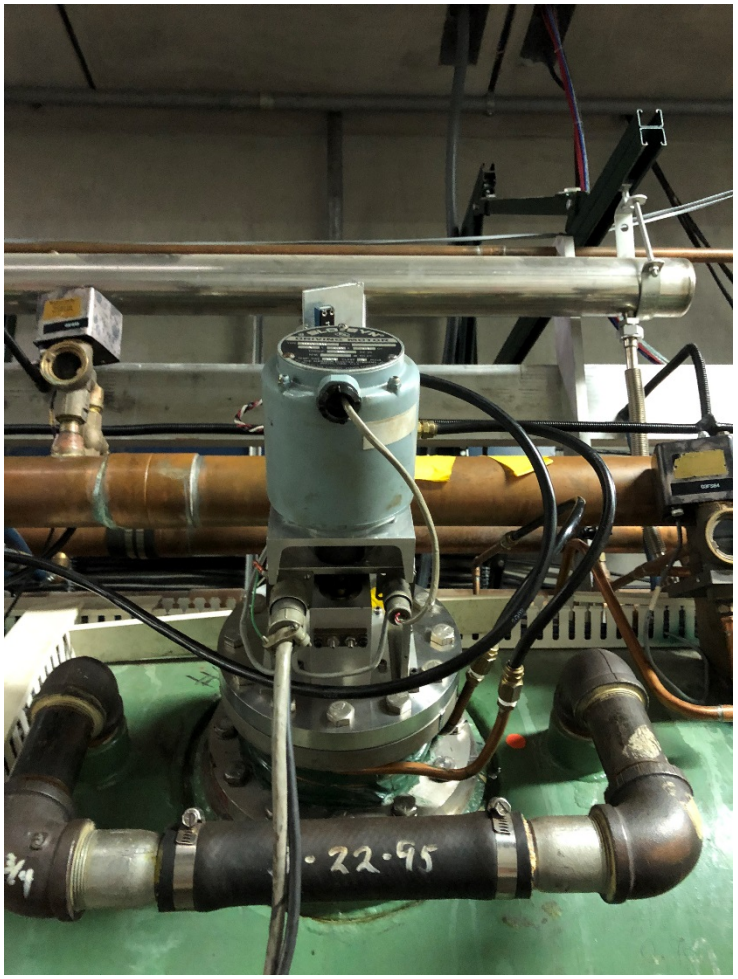
Preparing to Enter Tank 3 Through End to Weld Bridge over Cracked Weld

- Tank head had to removed to allow welder to enter and perform the repair (Spider Crane)
- Frequency tuners and post couplers on the aisle side and #116 at the repair area are removed
- Alignment data was acquired for post couplers and drift tubes for 14 of 18 drift tubes
- Performed mock up of tank and practiced welding to simulate actual conditions
- Full PPE dress was used while welding in Mock-up
- Multiple check lists were developed and walked down and refined during Mock-up

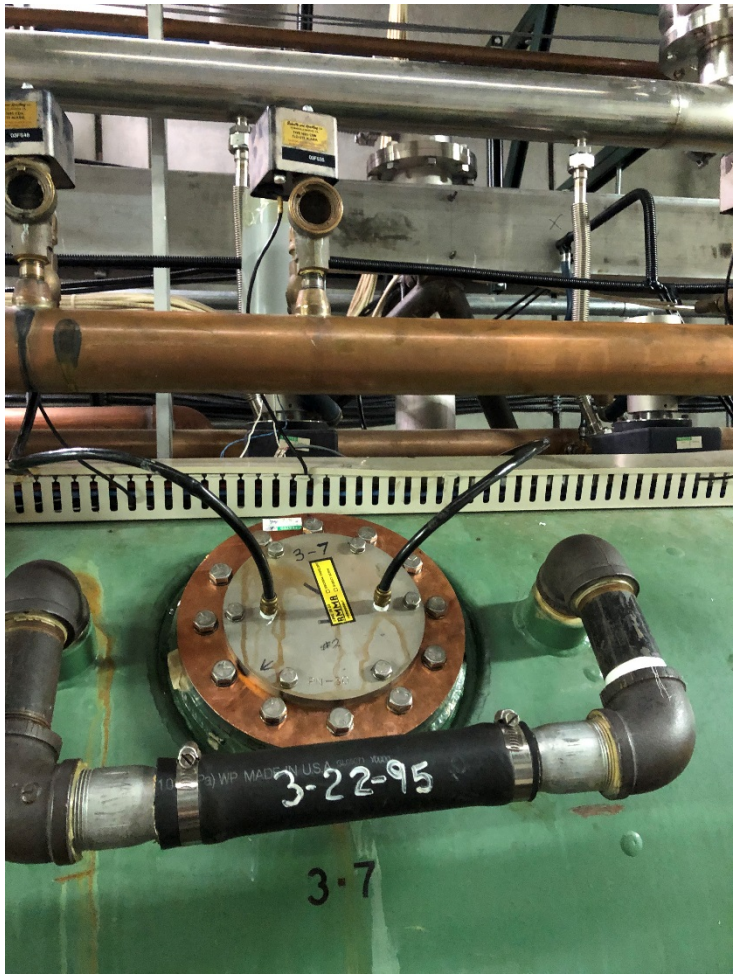


Upstream End Wall of Tank 3

Frequency Tuners – port size 5.75 inches



Active frequency tuner



Passive frequency tuner

Integrated Work Document IWD – Hazard ID

- Confined Space
  - person will enter a confined space, a 35 inch diameter pipe, to a location near the second ion pump grate, about 23 feet from the only entry and exit point
  - there is limited mobility in the confined space especially with regard to maneuvering:– must shimmy in and out on torso to clear drift tubes
- Welding
  - copper vapor exposure limits
  - welding in the prone (face down) position affects ability to see and guide the welding gun
  - radioactive base metal (1/8” copper cladding)
  - Protection from hot surfaces
  - Tig welding plasma is an ignition source

Integrated Work Document IWD – Hazard ID

- Breathing
  - available oxygen is displaced by CO_2 exhaled, Helium welding cover gas
- Communication
  - affected by the wearing of a respirator
  - affected by the limited number and size of ports to external personnel

Industrial Hygiene estimates and measurements

- Module 3 Ventilation High Points
- Airborne copper fume. Permissible Exposure Level (PEL) = 0.1 mg/m^3 (8 hour exposure)
- Volume of space 250 cubic feet
- Air supply 1,000 CFM
- Calculated maximum copper fume = 0.45 mg/m^3
- Dependent on 2.5 FPS (150 FPM – 1,000 CFM) air flow. Measure this flowrate in real time using calibrated anemometer and adjust calculated value accordingly.
- Sample results on mock-up were 0.43 mg/m3

Radiation Protection Assessment

- **Hazard assessment**
  - Work history (present and past) on the interior surface of the module 3 tank and associated beamline components were less than 1000 dpm/100 cm^2 (majority NDA).
  - Highest dose rate in the module 3 tank is 50 mrem/hr on contact at the tank entry (open) area; dose rate at the location of the weld 1 mrem/hr on contact.
  - Estimate of airborne radioactivity from welding: 0.8 DAC
    - MicroShield estimate of airborne radioactivity based on a dose rate of 2 mrem/hr on contact (actual dose rate 1 mrem/h).
    - Gamma spectroscopy of tank identified radionuclides: Zn65 and Co60
  - Test weld Mock- Up
    - Activated copper sample – radiological characteristics
      - Fixed contamination: 1900 dpm/100cm^2 beta/gamma
      - Dose rate : 0.1 mrem/h on contact
    - Air samples collected from the worker's breathing zone and LEV.
      - Gamma spectroscopy: NDA
      - Gross alpha/beta: NDA
    - No work area or personnel contamination detected.
    - Sample radiological characteristics unchanged following the test weld.

Sample Configuration for Radioactive Welding

- *HEPA Vacuum ventilation in cone*
- *Sampling unit in cone*
- *Sampling unit in work area*
- *Welder full anti-C PPE and full face respirator*

Radiation Protection Assessment

- **Hazard Controls**
- Respiratory protection – none required
  - DAC less than 1
  - Air monitoring is not required (HI < 2), however, low volume samplers were placed in the module 3 tank tuner slug port opening and general work area (post repair all nda).
- Anti-contamination clothing
  - Coveralls with rubber booties selected for the industrial hazard (spark & flame resistant) rated and approved – Level I anti-C.
  - Skull cap/hood required
  - Gloves – Leather welding gloves
- Job coverage
  - RWP - Continuous RCT coverage

Integrated Work Document IWD – Controls

- Confined Space
  - confined space permit
  - Attendant IH continuous
  - rescue plan, rescue attachments: ankles and upper arm over welding and Rad PPE - rescue team -ROCO
  - rescue equipment includes personnel attachment points and ropes to engineered tie off point–ROCO
- Welding
  - calculations show that the copper vapor exposure is manageable when adequately ventilated
  - special TIP-TIG welder purchased to feed wire automatically and allow the weld to be done with one hand (following slides)
  - PPE –Respirator ½ or full-face (1/2 face was used)
  - Helium gas to minimize weld contamination and conduct heat (critical to success)
  - Leather PPE-jacket, arm sleeves, gloves, mask, goggles, flame resistant coveralls and hood, multiple leather welding blankets, high heat guards on guide arm
  - Hand trigger for welder and operator to adjust welder current and wire feed
  - radioactive surveys to determine rad levels prior to entry and during operation
  - chance of fire – minimum, fire watch on-hand with fire extinguisher

Integrated Work Document IWD – Controls

- Breathing
  - Respirator two possibilities
  - ventilation to be suppled to generate a minimum of 1000 cfm at welder– use of blower to suck air through the tank
  - Communication -throat activated microphone to communicate to external personnel and Weld attendant operator (extensively used proven with mock-up and full dress rehearsal)
  - Multiple access points for equipment insertion, viewing and communication (frequency tuner ports upstream and downstream and post coupler ports at every drift tube centerline, ion pump; grate), lights, camera, sampling, small tools (extensively used previous 6 months)

Miller Tip-Tig Welding Unit

- One Handed Operation
- Wire filler feed integral Tig Torch combination
- Ramped start and stop functions
- Full Current control
- Start and stop on hand control with welder

Half Face Respirator and Miller Goggles and Hood Protection factor 10-Particulate and up to 13-UV

Electromagnetic Arc Sensor

DuPont Proshield 6 SFR rating

DuPont™ Tempro® for added protection

Designed to be worn over primary flame-resistant apparel, such as DuPont™ Nomex® or DuPont™ Protera®, DuPont™ Tempro® is a lightweight, disposable overgarment for use by workers in potentially flammable or electric arc environments.

DuPont™ Tempro® provides a barrier against the non-hazardous dirt, grease, grime and aerosols that these workers encounter every day, helping to protect and keep clean the primary flame-resistant garments that they wear.

In the event of an industrial fire or electric arc, DuPont™ Tempro® garments will not contribute to potential burn injury. They will not ignite and continue to burn when the flame source is removed.

UniTech Service Group 4AFR (Anti-C and Flame Resistant)

UniTech Flame-Resistant Coveralls
Created by applying a chemically reacted finish to an 88% cotton/12% nylon blend material. The result is soft and comfortable coveralls with excellent flame resistance that is retained for the life of the garment. The coveralls feature a brass zipper front, a breast pocket and a dosimeter tab. The 7.4 oz/yd2 material has an 8 ATPV or greater value, which exceeds NFPA 70E requirements for class 2, electrical safety in the workplace.

Miller welding goggles with ½ face respirator and full face welding mask and respirator

Rescue Techniques Practiced In Mock-UP

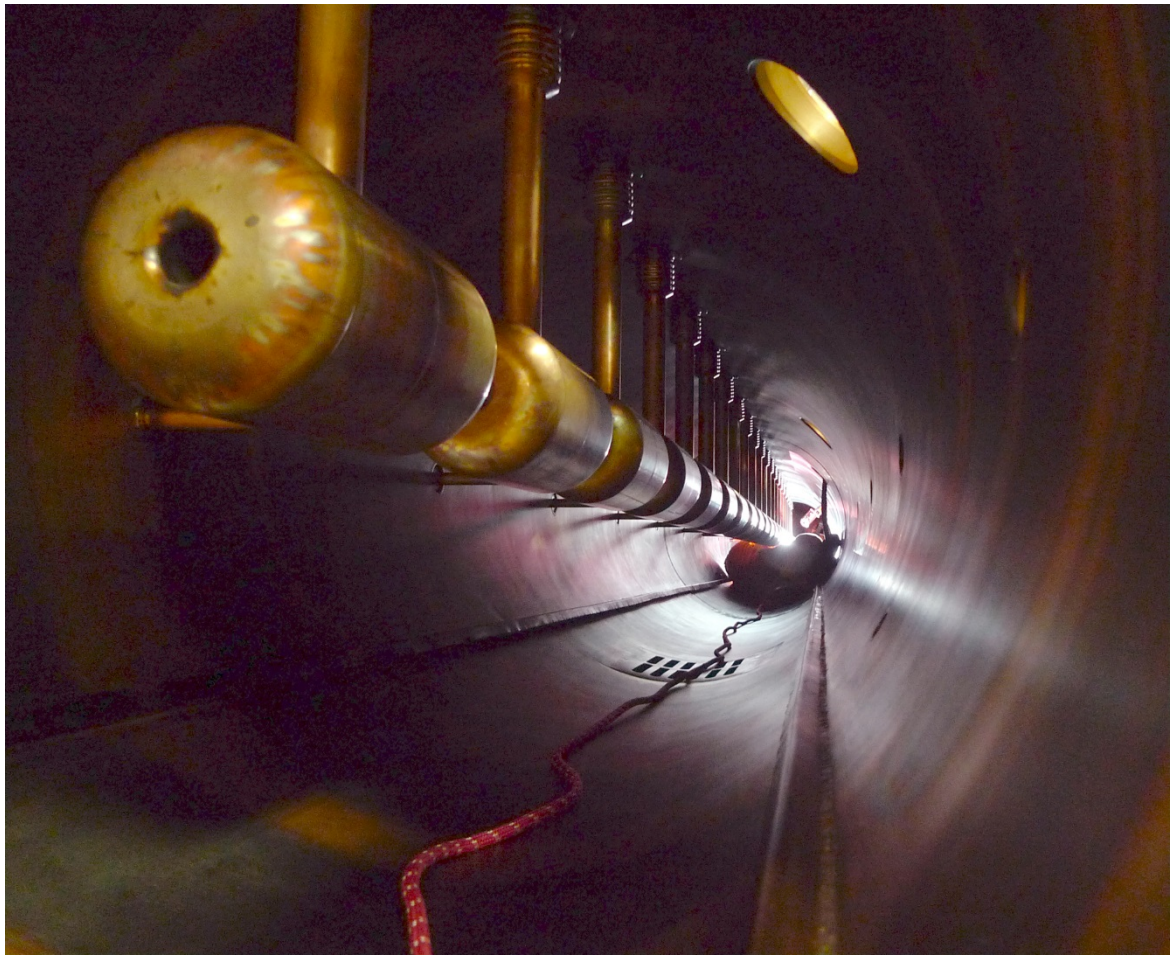
- Several Standard Harnesses were tried but collided with Drift Tubes and were not ideal retrieval points
- Upper Arm and Ankle Retrieval were the most effective and allowed the welder movement to be successful welding
- Full Dress Rehearsal in Tank

Weld Positions goggles and ½ and Full-face Days and Days of Practice, Including Rescue in Mock-Up and Full Dress Rehearsal in Tank

Welder and Rescue Team Just Prior to Entry

Welder In Position for Welding

- Tig Torch, lights, camera, sample monitoring are inserted through Slug Tuner and Post coupler Ports at the Repair Area



Good news

- The Copper Bridge Welded as Expected from the Many Practice Welds Conducted

Bad News-Good News!

- Crack Opened on Opposite Side
- We Welded Over to Top and Sealed it

Guiding Documents

- AOT-MDE-IWD-19-001, DTL Tank 3 Inspection, Clean Out and Repair
- AOT-MDE-IWD-19-011, SOW, Tank Welding Repair, Module 3
- 29 CFR 1926 Subpart J, Welding 1926.353(a)(2)
- ANSI Z49.1:2012 Safety in Welding Cutting and Allied Processes, Section 7.1 Ventilation in Confined Spaces
- Radiation Work Plan: RWP 19-XXXX
- LANL Policy P121, Radiation Protection
- LANL Policy P101-27, Confined Spaces
- LANL Policy P101-27, Confined Space Entry Permit
- LANL Policy P101-27, Confined Space Rescue Plan
- LANL Policy P101-25, Cranes, Hoists, Lifting Devices, and Rigging Equipment
- LANL Policy P101-26, Welding, Cutting, and Other Spark- or Flame-Producing Operations
- LANL Policy P101-26, Attachment A. Form 1563, Spark- Or Flame-Producing Operations Permit
- Air flow calculation email from Industrial Hygiene

Review and Preparation was Rigorous

- Most of these slides were presented at a Rehearsal of Concept (ROC) meeting
- Audience included safety professionals from all of LANL
  - Welding experts
  - Industrial Hygiene experts
  - Radiation protection experts
  - Rescue Experts
  - DOE Site Office Participation
  - Every Manager under the sun, but the local management owned it

Weld Repair Was a Complete Success

- Welder Received a total of 33 mrem of exposure for month of July
- Welder spent a total of just shy of 11 hours inside the tank, total welding time just short of 1 hour
- Contamination was nda for entire job for all workers and work area smears
- Full Beam Production at 120 Hz, Declared August 21 at 15:00
- LANSCE Man of the Year “Jason Burkhart” Welder

The (partial) Cast

Jason Burkhart	Michael Martinez	Nathan Garcia
Michael Borden	Buck Wilds	John Bernal
Stephen Milton	Dick Bingham	Sylvie Adam
Denise Gelston	Hargis James	Dennis Ortiz
Kevin Andrews	Brian Adkison	Brian Smith
Paul Martin	Samuel Bigger	David Bell
Mark Kirshner	Brian Moore	Alfred Maestas
John Chamberlin	Richard Pohl	Robert Moore
Walter Barkley	Terry Morrison	Danny Evans
Michael Lake	John Lyles	Tsuyoshi Tajima
Brandon Roller	Michael Duran	Ray Valicenti
Mark Gulley	Robert Brennecke	Anju Poudel
David Ballard	Josh Brito	James O'Hara
Francesca Pacheco	Nathan Kollarik	David Bingham
Mario Pacheco	Michael Romero	Kelly Bingham
Gus Sinnis	Aaron Adair	Rebecca Williams
Aaron Walker	Brandon Atencio	James Vigil
Matt Hardy	Peter Plowman	Kenneth Lucero
Stephen Porto	Manuel Soliz	