# Refurbishment of NASA's Johnson Space Center Liquid Nitrogen Bulk Storage Tanks in preparation for Thermal Vacuum Optical Testing of the James Webb Space Telescope (JWST)

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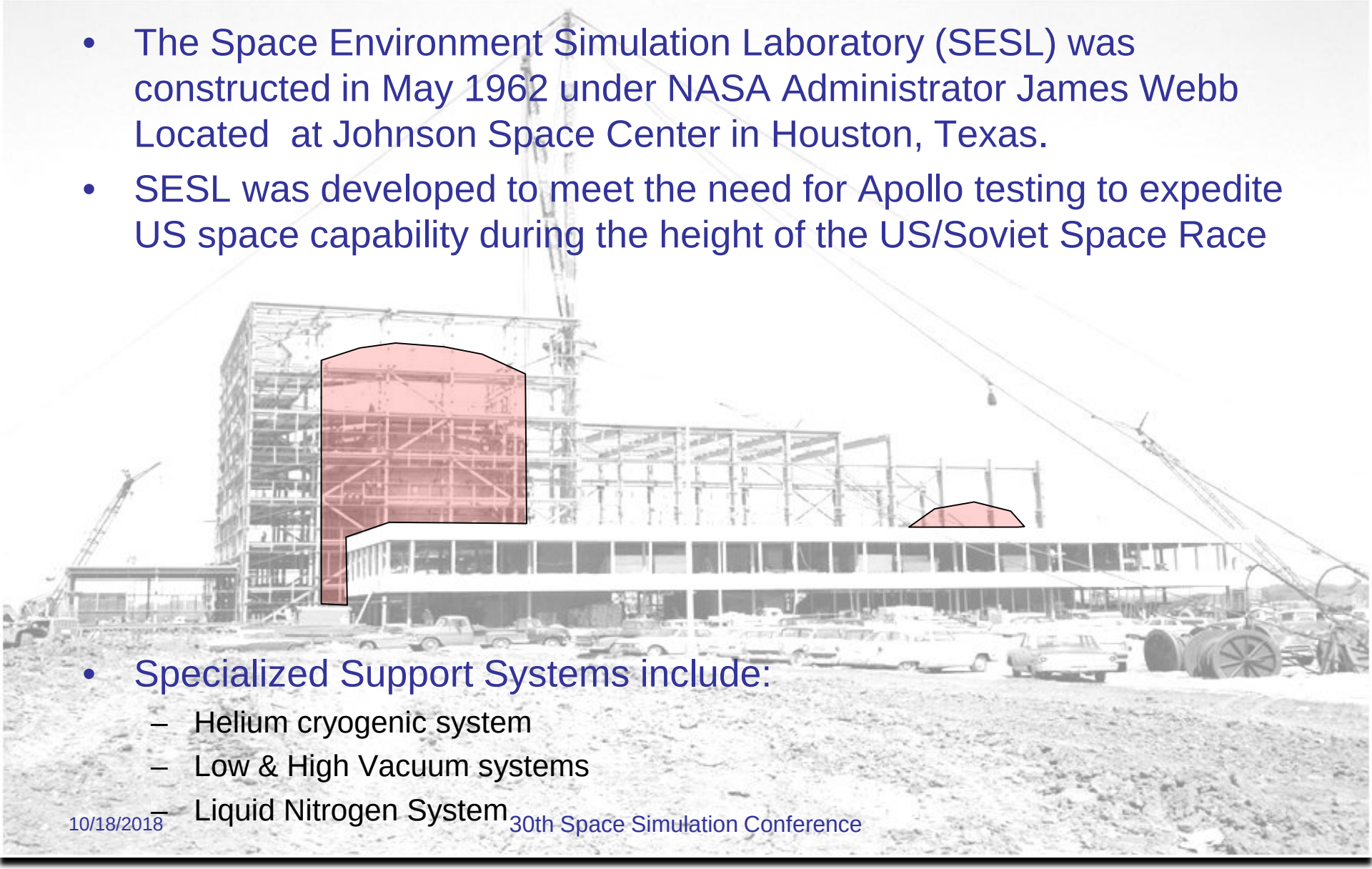
# Space Environmental Simulations Laboratory

- The Space Environment Simulation Laboratory (SESL) was constructed in May 1962 under NASA Administrator James Webb Located  at Johnson Space Center in Houston, Texas.
- SESL was developed to meet the need for Apollo testing to expedite US space capability during the height of the US/Soviet Space Race



- Specialized Support Systems include:
  - Helium cryogenic system
  - Low & High Vacuum systems
  - Liquid Nitrogen System

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

- Primary use of Liquid Nitrogen for this facility is for Environmental Cooling in Chamber B and a Thermal Shield in Chamber A.
- The liquid nitrogen bulk storage(tank farm) is comprised of six tanks with the following capacities.

| Vessel Name | ASME Serial # | Size (Gal) | Manufacturer | MAWP (PSIG) | Year Built | Type |
|---|---|---|---|---|---|---|
| **TK-LN2-101** | C-3793 | 28,000 | Horton Tank | 165 | 1958 | I |
| **TK-LN2-102** | C-3787 | 28,000 | Horton Tank | 165 | 1958 | I |
| **TK-LN2-103** | C-3796 | 28,000 | Horton Tank | 165 | 1958 | I |
| **TK-LN2-104** | C-3786 | 28,000 | Horton Tank | 165 | 1958 | I |
| **TK-LN2-201** | T-201-19 | 26,500 | LOX Equipment | 100 | 1960 | II |
| **TK-LN2-202** | 59G0244-1 | 24,000 | Strutners-Wells | 165 | 1960 | II |

- 162,500 Water volume
- 146,250 Gallon Capacity adjusted for ullage

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks


OGSE 2 PATHFINDER THERMAL VACUUM TEST

12/1/15 PHASE 1 8/23/16
FY16

THERMAL PATHFINDER THERMAL VACUUM TEST

11/15/16 PHASE 2 8/25/17
FY17

OTIS FLIGHT THERMAL VACUUM TEST

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

- Challenges
  - The bulk storage vessels(Tank Farm) also supplies Liquid Nitrogen to the entire JSC center so one vessel had to remain in service at all times.
  - One overall drawing with limited information exists for only TYPE I vessels
  - No vessel fabrication drawing existed for the TYPE II tanks.
  - Warming the tanks took 30 days.
  - One tank had to remain in operation to support JWST concurrent test build up and provide Liquid Nitrogen to
  - Weather considerations were monitored to coordinate field welds and installation prevent rain water intrusion into the annuls
  - Work stretched between December to August. Snow, rain and the continuous humidity could have fouled the annulus and extended the project schedule.
  - Concurrent James Webb Thermal Pathfinder and Flight unit integration support.
  - Testing Schedule limited how much work could be done to meet test schedule so a two year plan was developed to perform between tests.

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

- All tanks have 304 S.S. inner vessel with carbon steel outer shell.
- All tanks are pearlite insulated with active full time vacuum pumping.
- Each vessel had the original annulus safety devices with associated piping, valves and method of measuring vacuum annulus pressure. All items attached to the annulus were carbon steel and we at the end of their life service.
- In 2015 degradation of vacuum performance was identified on half of the vessel inventory. This was cause for concern for reliability and longevity for JWST testing.
- One tank was deemed unserviceable and was placed inactive due to a high vacuum pressure in the annulus.
- Corrosion and weathering of components- major impacts

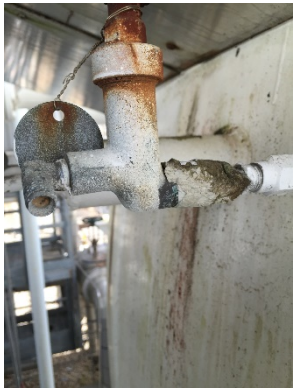
# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

- Phase I
  - Remove and Replace the Annulus Safety Devices on the -200 Type II Vessels. 2 vessels only.
  - Remove and Replace the carbon steel vacuum piping with 304 S.S. piping
  - Replace all vacuum isolation valves.
  - Install new thermocouple vacuum tubes with isolation valves.
  - Connect one thermocouple vacuum tube to facility data acquisition & monitoring system.
  - Perform a helium leak check on all six vessels and rate of rise.
  - Paint all new carbon to stainless steel transition welds.

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

## PHASE 1 –PREXISTING

SAFETY DEVICE TK-201



VACUUM GAUGE ISOLATION VALVES

SAFETY DEVICE TK-202

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

## PHASE 1 –PREXISTING

CAPPED ANNULUS SAFETY DEVICES -LEAKING-

VACUUM ISOLATION VALVES -LEAKING-

VACUUM ISOLATION SOLENOID VALVES -NOT WORKING-

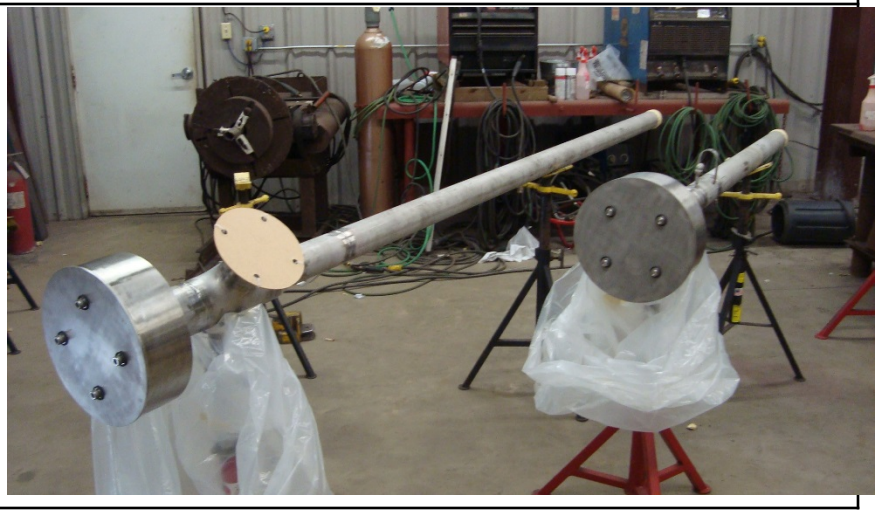
VACUUM PIPING WITH VALVE AND SAFETY DEVICE

VACUUM PIPING WITH VALVE

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

## PHASE 1 –PREXISTING

SHOP FABRICATION OF VACUUM PIPE SPOOLS WITH ANNULUS SAFETY DEVICES



# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

## PHASE 1 – NEW

INSTALLATION OF VACUUM ANNULUS SAFETY DEVICES

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

## PHASE 1 – NEW

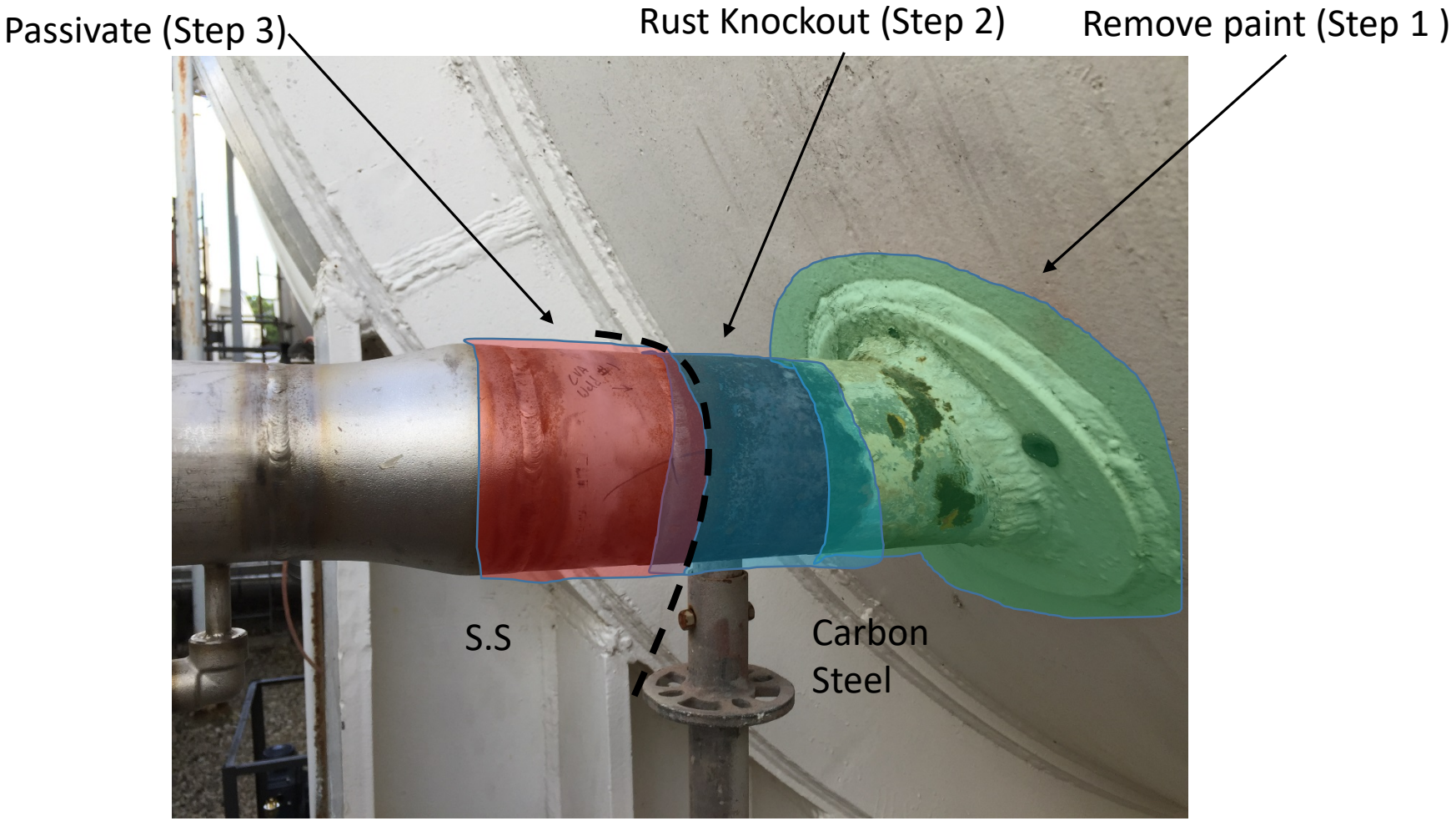
NEW INSTALLED VACUUM PIPING

THERMOCOUPLE VACUUM TUBE

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

**PHASE 1 – NEW**

Typical Process on all tanks
Surface Preparations(Emphasis on the S.S. to Carbon Steel)



# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

## PHASE 1 – NEW

Top Coat Process -Typical on all Tanks Paint 4” beyond the S.S side weld seam

NEW INSTALLED PIPING WITH COATING

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

## PHASE 1 – SUMMARY OF WORK – August 2016

| | TK-101 Before | TK-102 Before | TK-103 Before | TK-104 Before | TK-201 Before | TK-202 |
|---|---|---|---|---|---|---|
| | FY16 Mod | FY16 Mod | FY16 Mod | FY16 Mod | FY16 Mod | FY16 Mod |
| MODIFICATION COMPLETE | √ | √ | √ | √ | √ | √ |
| Helium Leak Checked | FAILED (3) | FAILED (3) | FAILED (3) | FAILED (3) | √ | √/PASS (3) |
| NDE | √ | √ | √ | √ | √ | √/PASS |
| PSMO BUY OFF | √ | √ | √ | √ | √ | √ |
| Rate of Rise | √/166 microns | √/Out of Range | √/Out of Range | √/331 microns | √/Out of Range | √/18 microns |
| Blank off Vacuum Pressure (Warm Tank) (Microns) | 150 Before/37 After | 255 Before/123 After | 364 Before mod 1/ 116 after mod 1 | 120 Before/75 After | 250 – 450 w/out heat, Out of Range with Heat (1) (2) | 22 microns |
| Vessel Helium Leak heck | √/Fail | √/Fail | √/Fail | √/Fail | √/PASS | √/PASS |
| Process Tank Purge (Dew point< -50 C) | √ | √ | √ | √ | √ | √ |

**(1) Placed tank out of service for JWST Thermal-Pathfinder suspect high water content in annulus**
**(2) Heated inner vessel and pumped annulus for +50 days thru cold trap to remove water/moisture from annulus.**
**(3) Placed back into service for test. Tanks that failed helium leak check were fixed after Thermal Pathfinder Test**

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

- Phase I Post modification Findings
  - Helium leak check on vessels revealed annulus safety devices were all leaking on the -100 Type I tanks. 4 total tanks.
  - Tank -201 after replacement of both annulus safety devices could not be successfully pumped down.
    - Two mechanical pumps were fouled in the process of vacuum pumping.
    - Culprit-Previous annulus safety device had allowed water to intrude through the corrosion.
  - Tank -202 successfully reached < 35 microns and success full three day rate of rise.
  - Performed exploratory engineering evaluation on one Type I Tank flange to aid in the design to remove and replace the leaking safety devices.
  - Tank -201 coldtrap water vapor collection. Trap was Changed every 4-6 hours for +50 days during JWST Thermal pathfinder test.

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

## PHASE 1 –Exploratory Engineering– August 2016

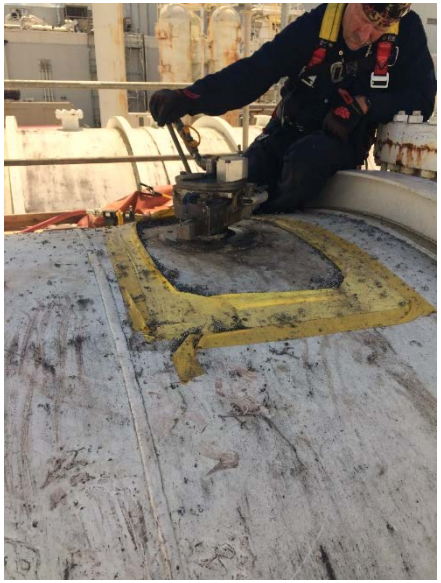
**Pearlite Fill Flange, Carbon Steel**

**O-ring groove on blank flange.**
**Note: A gasket was used with an unknown sealant.**

**Pearlite flange with carbon steel flange.**

**Major corrosion on studs**

**During helium leak checks all Type 1 tank annulus safety devices failed helium leak checks. An effort was made to identify if the pearlite fill Flanges could be used to accommodate new safety device.**



**In place 32 RMS machining**

**32 RMS finis with 316 S.S Studs and blank flange with O-ring groove and Viton O-ring(AS568)**

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

- Phase II
  - Remove and Replace the Annulus Safety Devices on the -100 Type I tanks. 4 vessels only.  This would eliminate vacuum leaks on these tanks
  - Remove and Replace all ancillary process valves.
  - Replace the liquid level high and low process isolation valves and tubing to liquid level instrument.
  - Perform a helium leak check and rate of rise on all modified vessels.
  - Paint all new carbon to stainless steel transition welds.

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

## PHASE II

ANNULUS
SAFETY
DEVICES
-LEAKING-

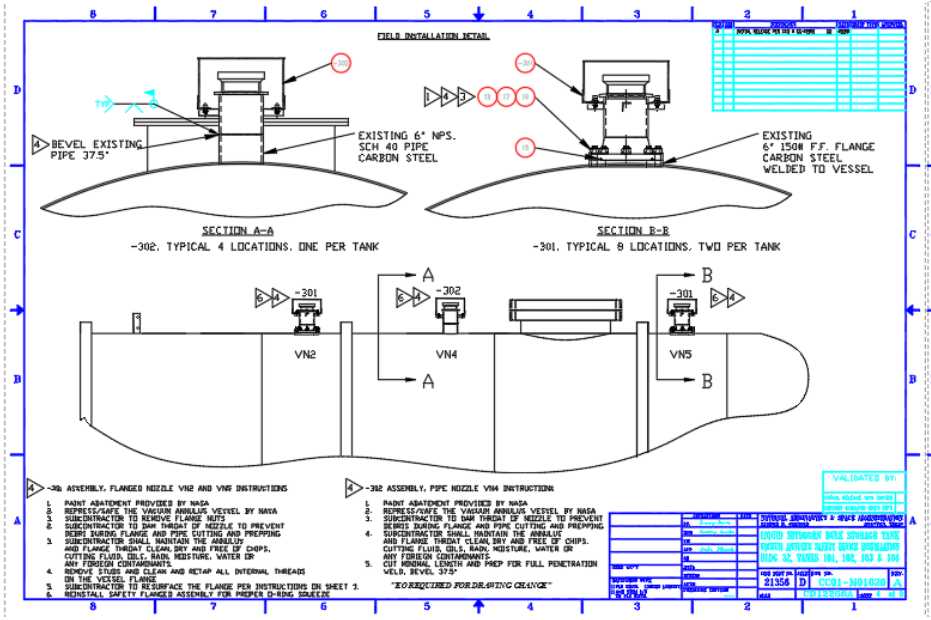
SIZED NEW REQUIRED DISCHARGE AREA FOR EACH TANK PER CGA 341-6.4.2

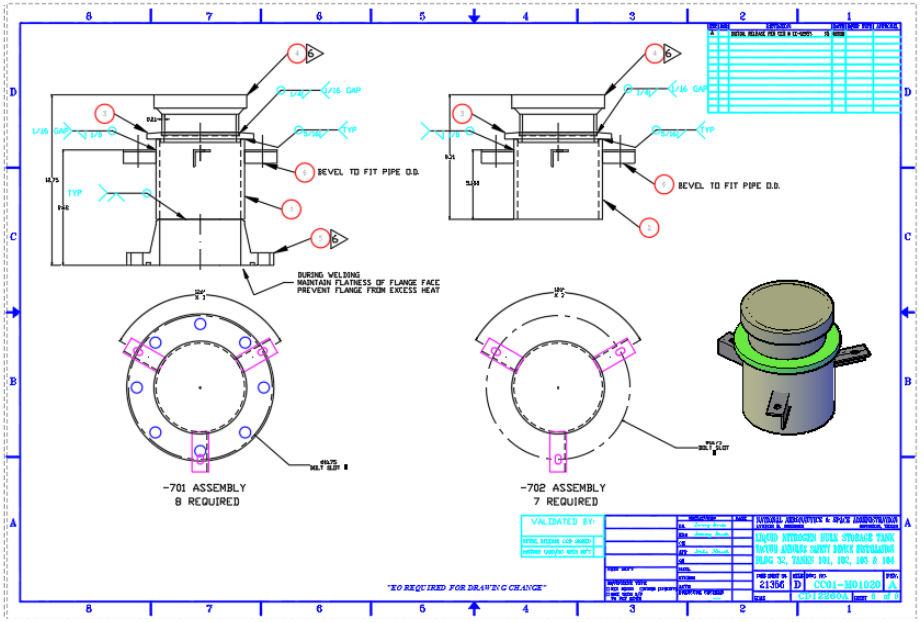
56 in^2 WAS REQUIRED PER TANK

THE EXISTING PORT PLUS TWO PEARLITE FILL PORT FLANGE WOULD HAVE TO ACCOMMODATE THE NEW SAFETY DEVICES.

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

## PHASE II




- Design would weld one safety device and weld another to exiting safety device pipe stub

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

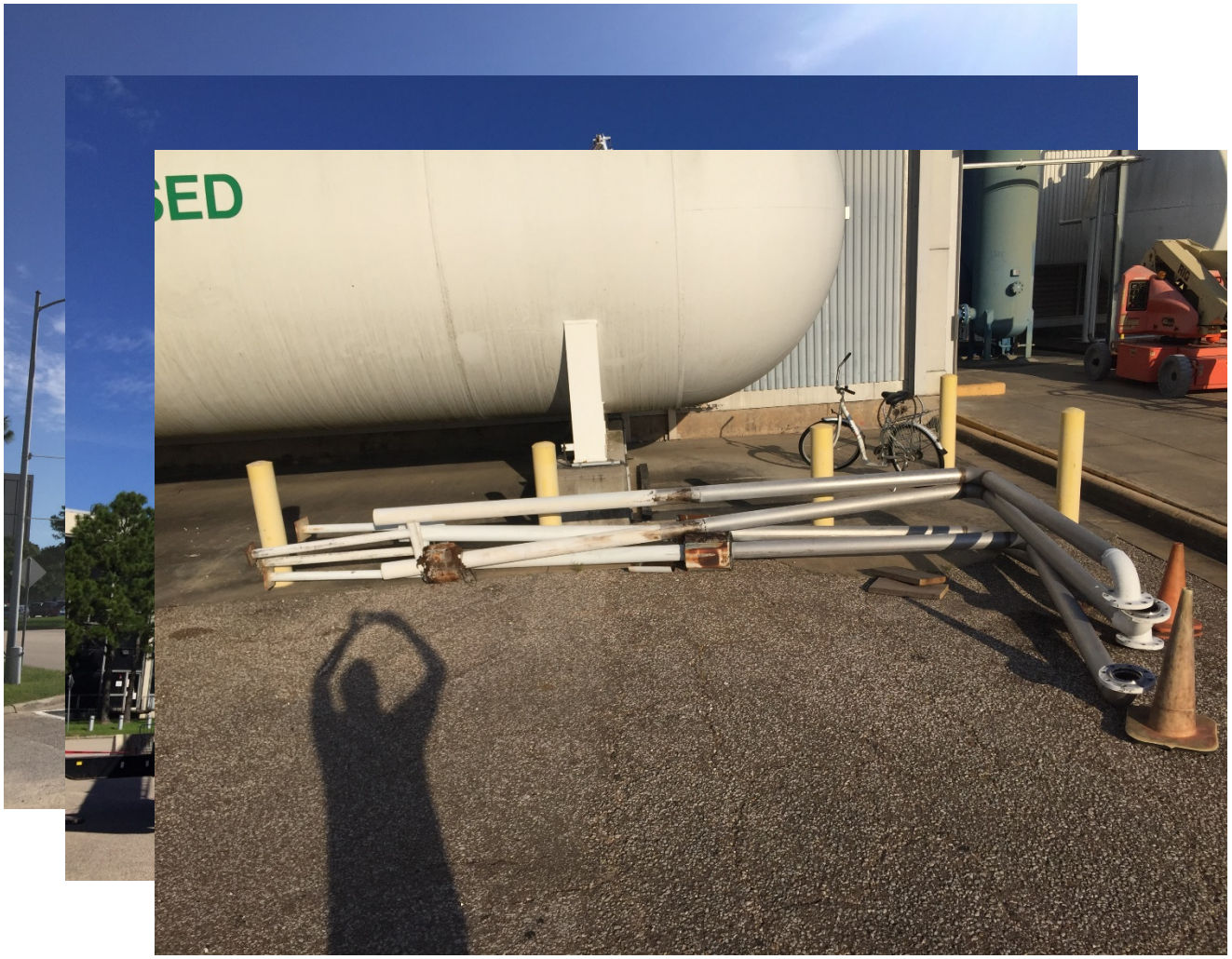
## PHASE II



SCAFFOLDING DAY

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

**PHASE II**




DEMO DAY

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

Tank 201 Modification

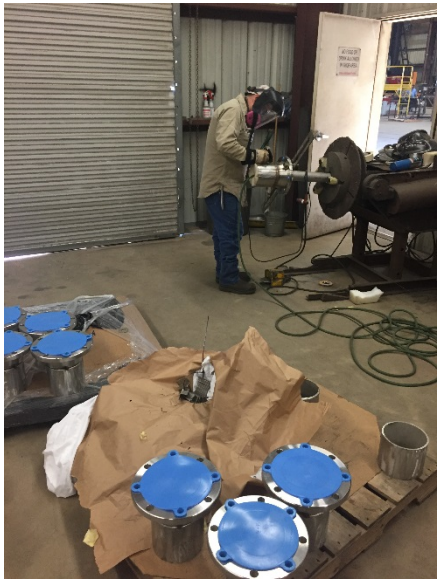
Tank 201 Before

Tank 201 After

Material Delivery for LN2 tank annulus safety components

Flanges

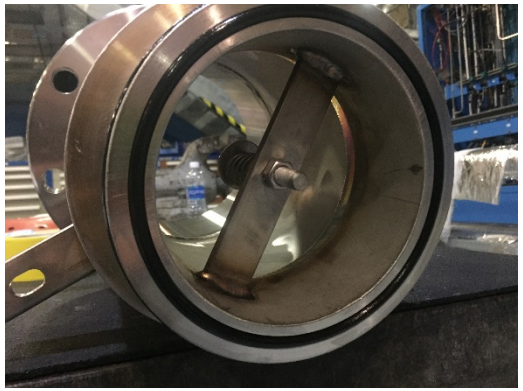
Safeties

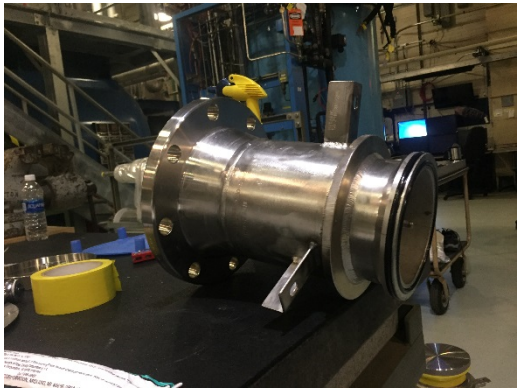


Shop Welding Freeport Welding
5% X-ray, 100% Dye Penetrant

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

← Vacuum Annulus Safety Devices Bench Checking →





Helium Leak Checking by JACOBS Techs.

← Tank Preparation for safety devices retrofit →

Scaffolding

Demolition

End of Service Life Safeties

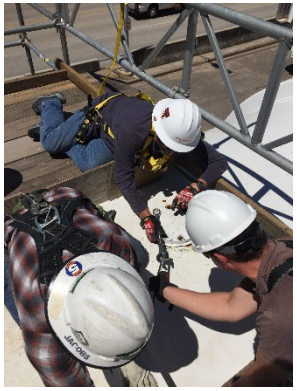
Abate Paint

← Removal of old safeties and piping by JACOBS Techs and NASA Rigging →

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

## Installation of Flanged Safeties

Removing Existing Flanges



Existing Flange Condition

Mobile Machining Flanges

After Machining

Final with New S.S. Studs

New Safeties Installed

## Field Installation of Welded Safeties

Cutting flanges

Welding

100 % Dye Penetrant

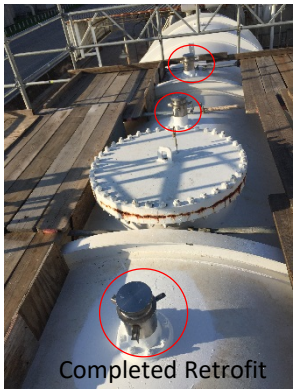
Completed Welded Assy

Primer Coat

Primer Coat

Primer Coat

Top Coat



Completed Retrofit

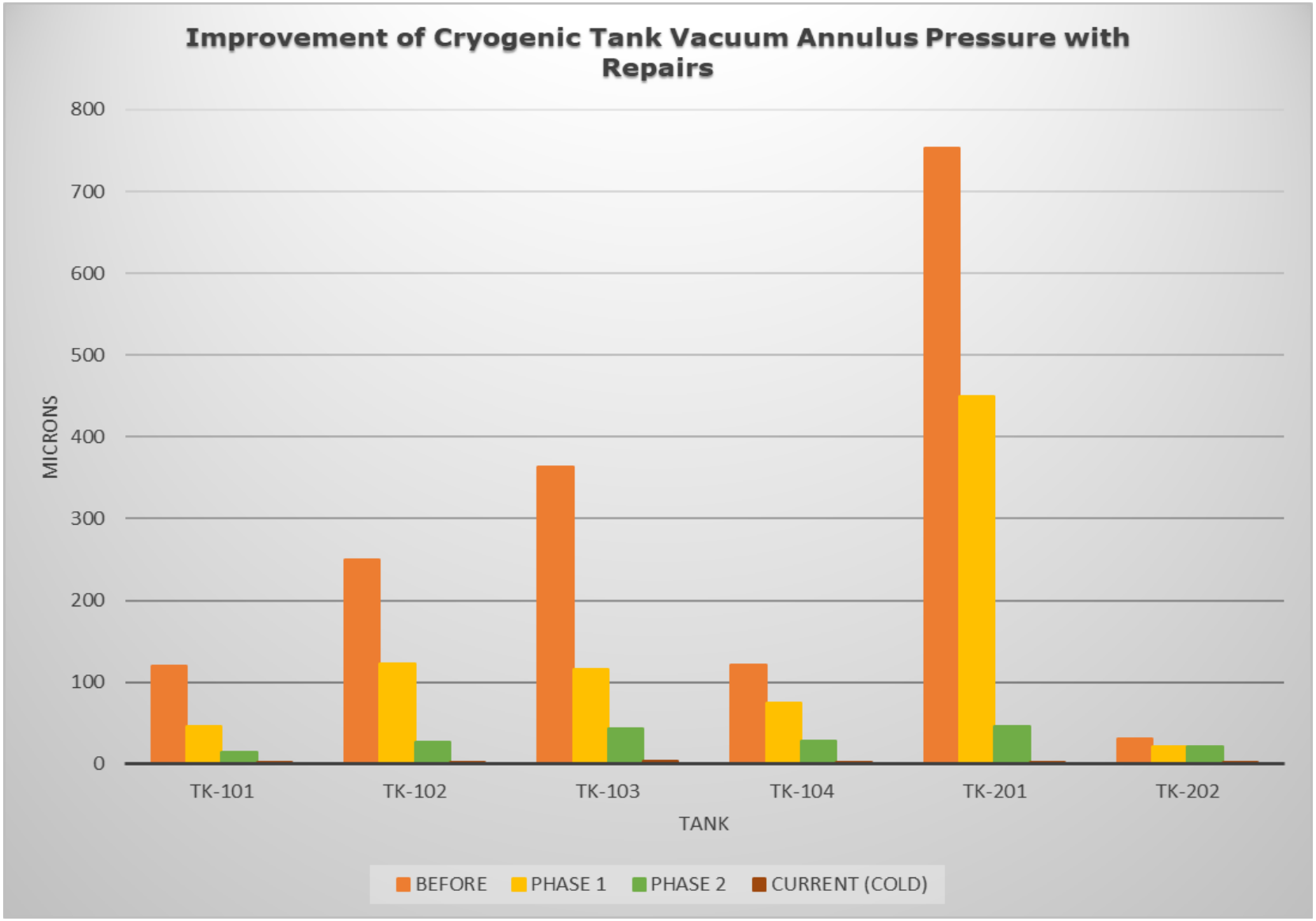
- **Successful Mobile Machining**
- **Successful Field Welding**
- **Successful Helium Leak Checks**
- **Successful Vacuum Rate of Rise**
- **Successful Pressure System Weld Inspection**
- **Zero Accidents**

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

## PHASE II – SUMMARY OF WORK – August 2017

| | TK-101 Before | TK-101 After | TK-102 Before | TK-102 After | TK-103 Before | TK-103 After | TK-104 Before | TK-104 After | TK-201 Before | TK-201 After | TK-202 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | FY16 Mod | FY17 Mod | FY16 Mod | FY17 Mod | FY16 Mod | FY17 Mod | FY16 Mod | FY17 Mod | FY16 Mod | FY17 Mod | FY16 Mod |
| MODIFICATION COMPLETE | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| Helium Leak Checked | FAILED | √/PASS | FAILED | √/PASS | FAILED | √/PASS | FAILED | √/PASS | √ | √/PASS | √/PASS |
| NDE | √ | √/PASS | √ | √/PASS | √ | √/PASS | √ | √/PASS | √ | √/PASS | √/PASS |
| PSMO BUY OFF | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| Rate of Rise | √/166 microns | 5.4 microns @ 3 Days | √/Out of Range | 8.4 microns @ 3 Days | √/Out of Range | 37.2 microns @ 3 Days | √/331 microns | 5 microns @ 3 Days | √/Out of Range | 10.7 microns @ 3 Days | √/18 microns |
| Blank off Vacuum Pressure (Warm Tank) (Microns) | 150 Before/37 After | 15 | 255 Before/123 After | 27 | 364 Before mod 1/ 116 after mod 1 | 44 | 120 Before/75 After | 27 | 250 – 450 w/out heat, Out of Range with Heat | 46 microns | 22 microns |
| Vessel Helium Leak heck | √/Fail | √/PASS | √/Fail | √/PASS | √/Fail | √/PASS | √/Fail | √/PASS | √/PASS | √/PASS | √/PASS |
| Process Tank Purge (Dew point< -50 C) | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ | √ |
| Current Status to Return to Service | N/A | Cold, Full, | N/A | Cold, Full, | N/A | Cold, Full, | N/A | Cold, Full, | - | Cold, Full, | 5/16/16 Returned to Service |

# Refurbishment of Liquid Nitrogen Bulk Storage Tanks



# Refurbishment of Liquid Nitrogen Bulk Storage Tanks

- SUMMARY
  - After almost 60 years of service the LN2 tanks have served well with original equipment.
    - Certain key components had reached their end of life service.
    - Continual exposure to the elements had taken their toll on key components.
  - Key components were commercially available for us to do the design and the majority of the work in house.
  - Qualified local shop fabricators and field welding contractors was key.
  - Cost for Phase I and II project was equivalent to the price of one new vessel with less capacity not including the cost of retrofitting.
  - A corrosion control program is critical to identify and mitigate problem areas and components on the annulus shell.
  - The tanks are projected to operate for the next three decades without major maintenance on the annulus shell.

# QUESTIONS