



# PLYMOUTH PLANT INCIDENT INVESTIGATION





Outer Tank Wall Penetration  
Gas Vapor Leak

Damaged Boil Off Piping  
Small Fire

First Responder  
Gathering Point

Damaged 1/2" Fitting  
LNG Leak

Damaged 1" Pipe  
Gas Leak

Damaged 10" Pipe  
Gas Leak

# Incident Command Post



# LNG I Area Pre-Incident



# LNG I Area Post Incident



# Reconstructed LNG I Area



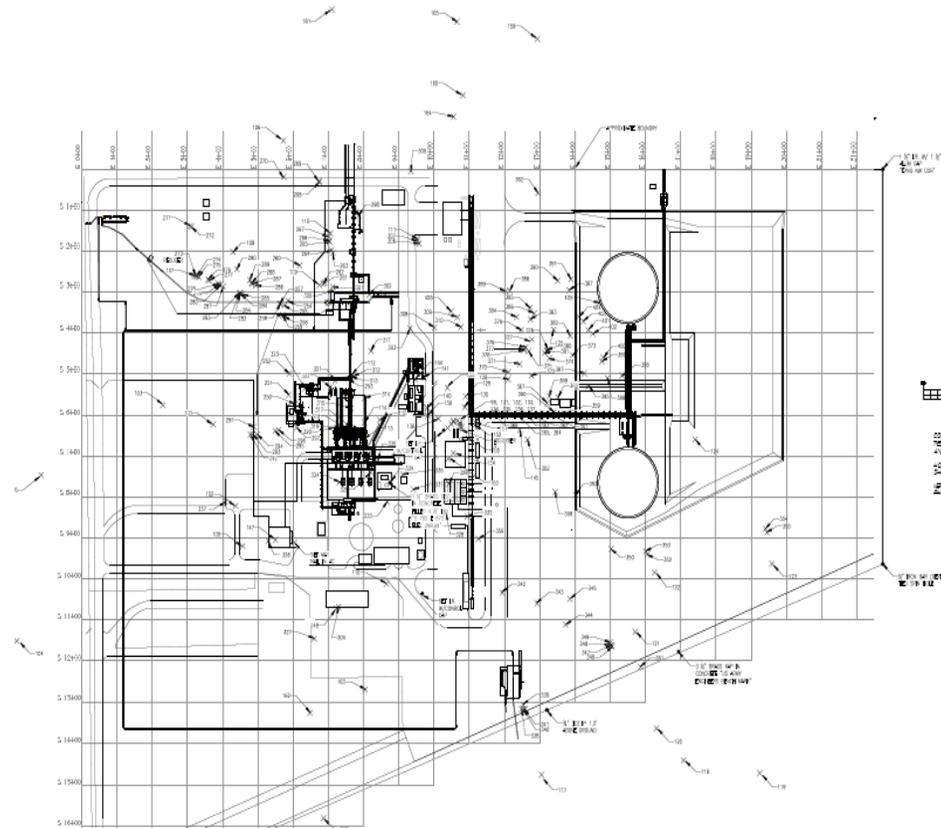
# Overview

- Evidence Preservation
- Incident Investigation Overview
- Metallurgical Evidence
- Procedure Review
- Blast Modeling
- Auto-Ignition Testing
- Root Cause
- Tank Mechanical Integrity Inspections
- External Communication
- Questions/Discussion



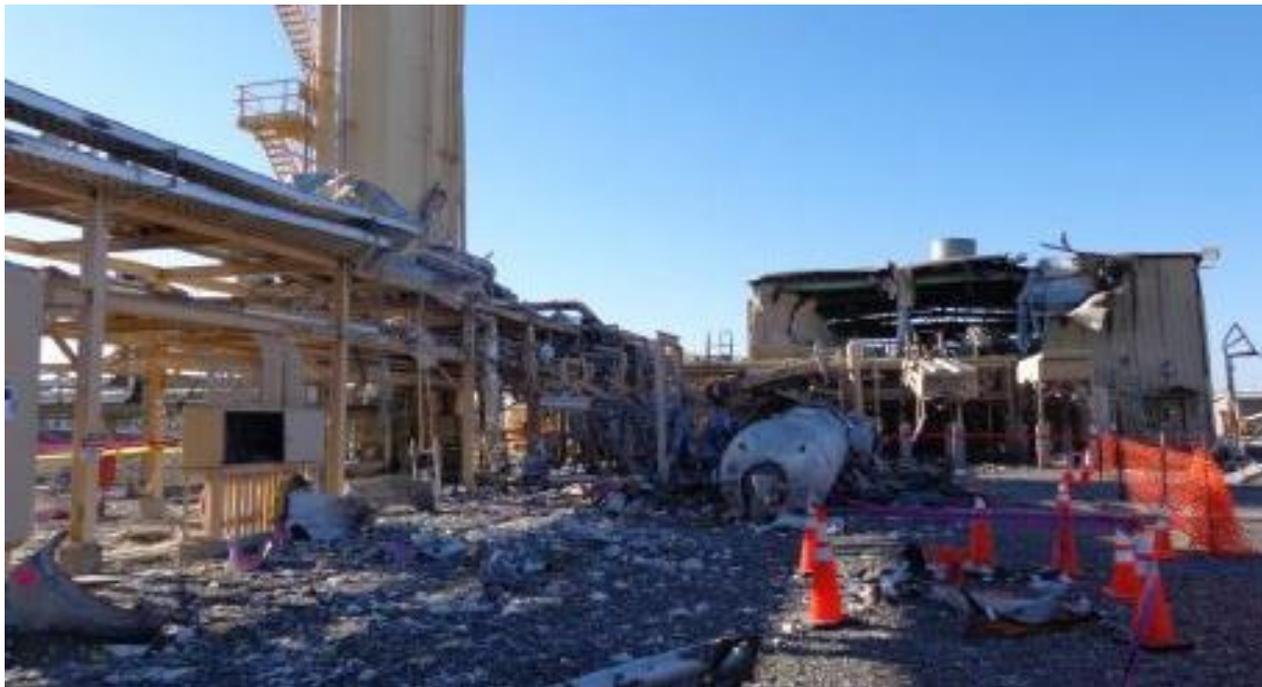
# Evidence Preservation – *ABS Consulting*

- In order to maintain the integrity of the investigation, all evidence was photographed, catalogued, collected and controlled by a third party
- All evidence was under secure supervision 24/7 immediately following the incident



## Evidence Preservation – *ABS Consulting*

- A 3-D scan was completed prior to initiation of any disassembly or clean up of debris in the incident area
- Evidence preservation was methodically slow, but necessary in an investigation of this magnitude



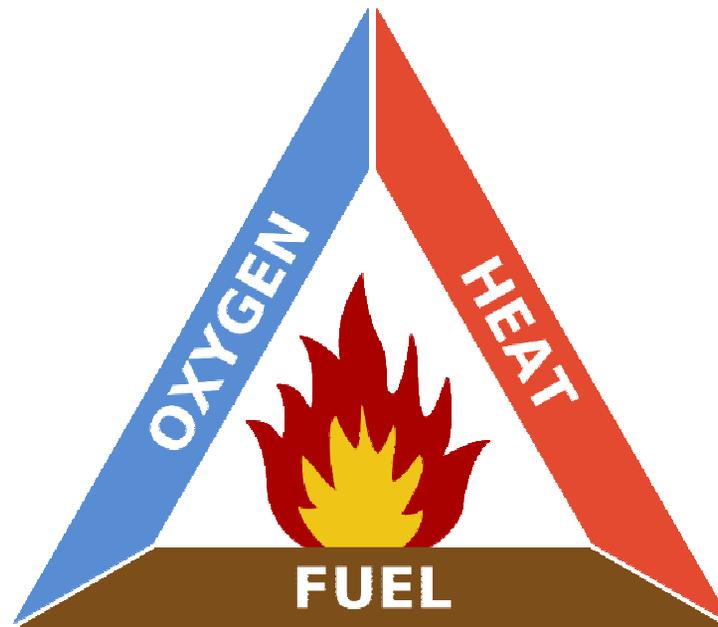
# Incident Investigation Overview

- Investigation was completed in full compliance and cooperation with regulating agencies including the Pipeline and Hazardous Materials Safety Administration, Washington Utilities and Transportation Commission, Federal Energy Regulatory Commission, and others.

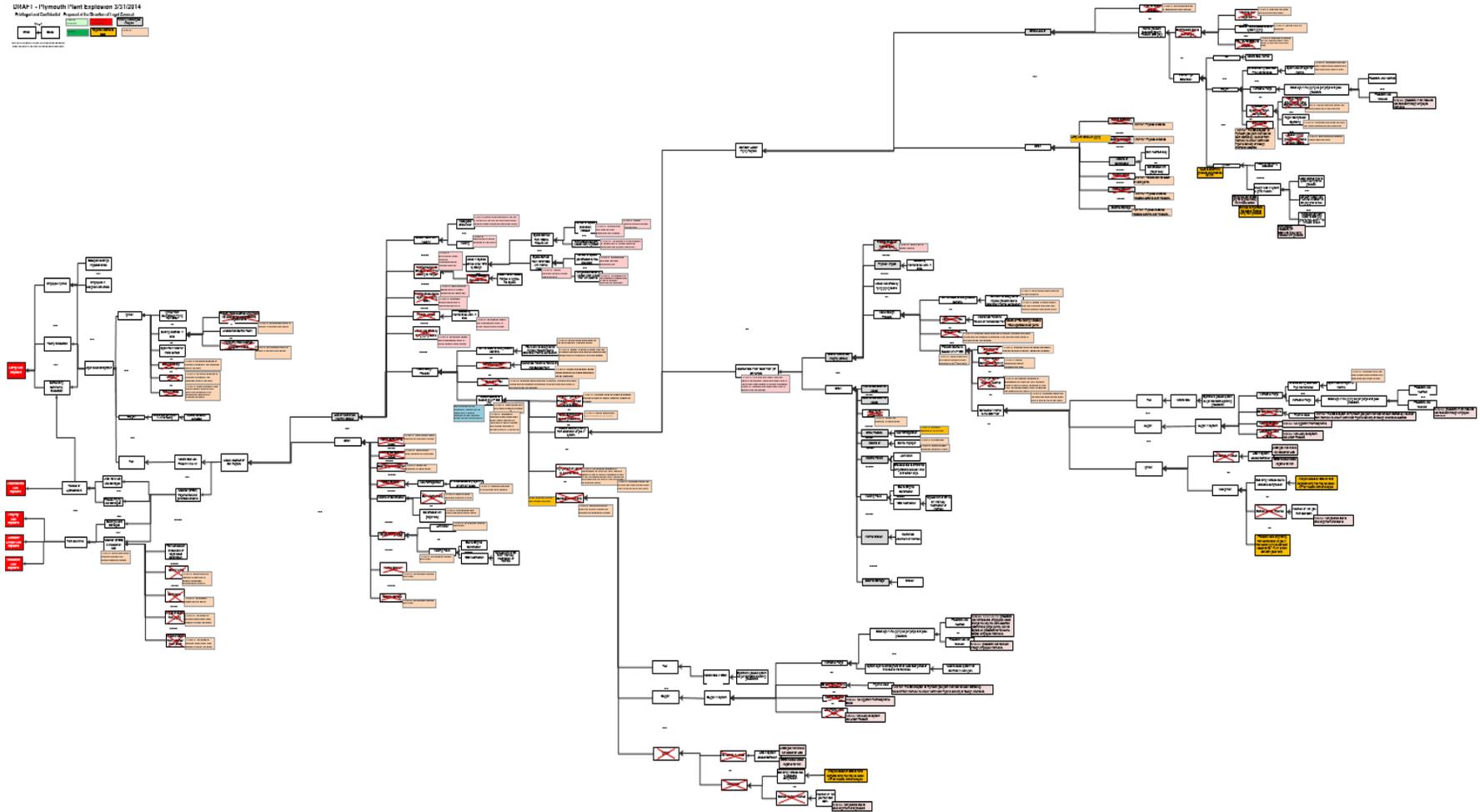


# Incident Investigation Overview

- In an event that has fire or explosion the incident investigation seeks all components of the “Fire Triangle”

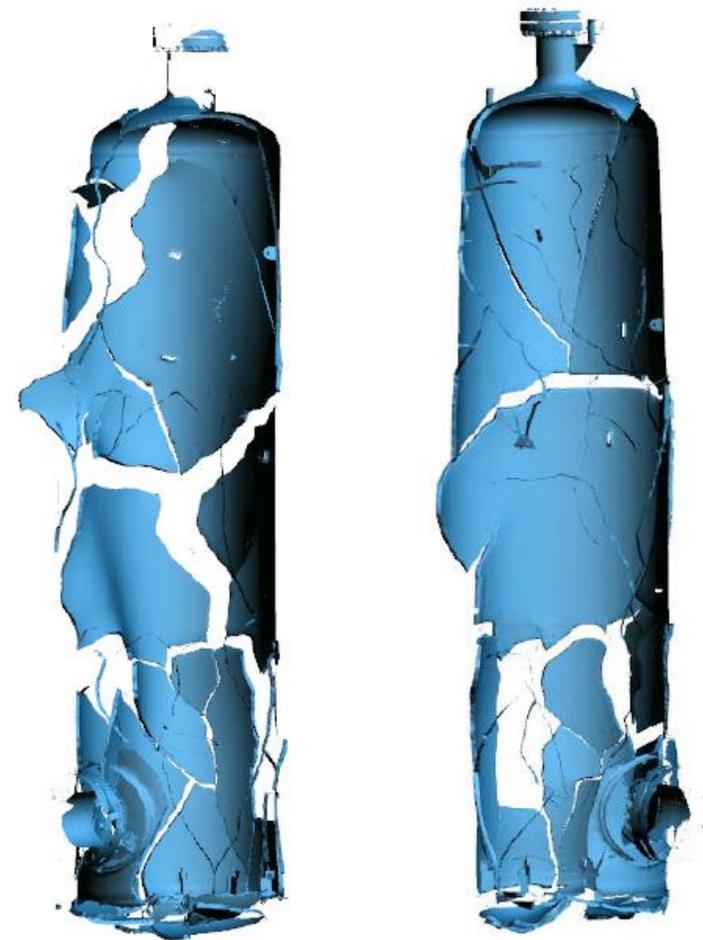


# Incident Investigation Overview



# Metallurgical Evidence – *Stress Engineering Services*

- Adsorber D-20A weighing ~50,000 lbs
- Debris generated from the failed adsorber caused significant collateral damage
- Mechanical failure of the adsorber was the initial focus of the investigation
- Stress Engineering Services (SES) was contracted and mobilized to the site to evaluate vessel fragments
- SES performed high resolution scans of all available vessel fragments
- Scanned fragments were weighed and re-assembled in a 3-D model to ensure all pieces were accounted for



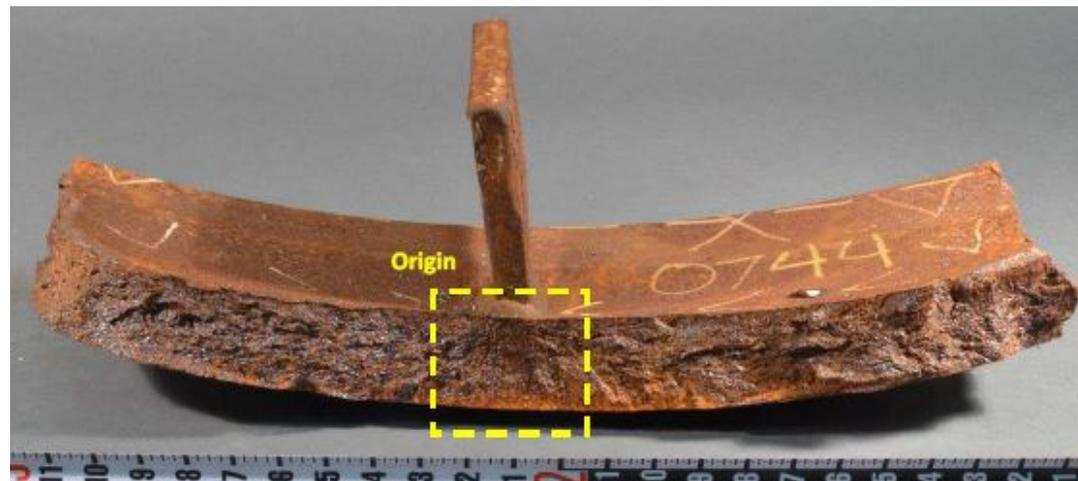
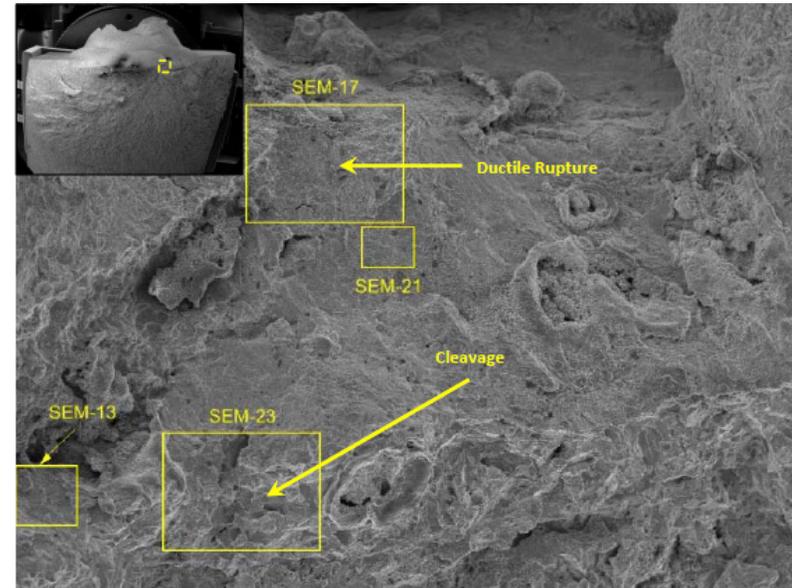
# Metallurgical Evidence – *Stress Engineering Services*

- Chevron markings point towards fracture ‘initiation sites’
- Fragments containing points of interest were shipped to SES facilities in Houston for detailed examination



# Metallurgical Evidence – Stress Engineering Services

- SES also performed testing to confirm proper materials of construction
  - Found no cause for concern
  - Found no evidence of soot/combustion materials on vessel walls

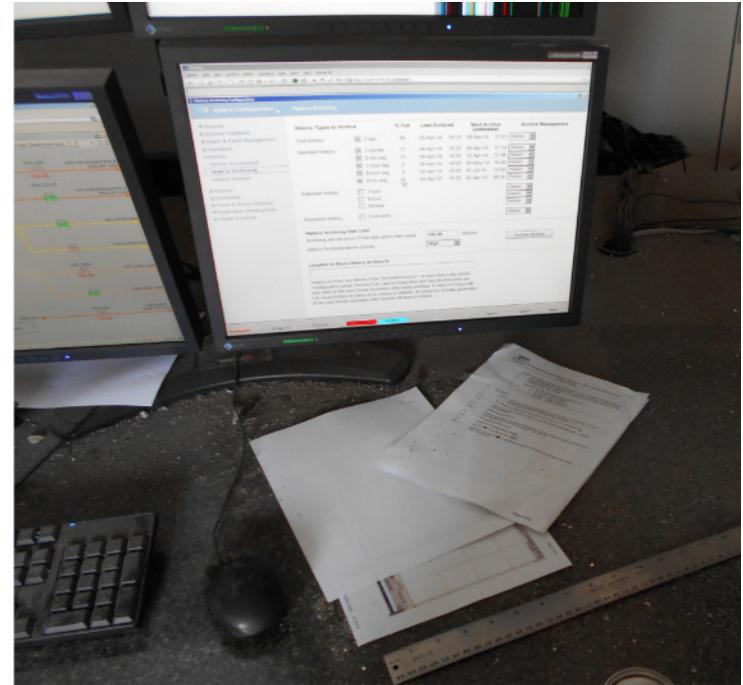


## Metallurgical Evidence – *Stress Engineering Services*

- Concluded that vessel was overloaded (overpressure) due to events elsewhere in the process area
  - Plymouth’s alarm log charted one DP reading of -1089 PSID immediately prior to the facility shut-down
    - $DP = \text{Upstream Pressure} - \text{Downstream Pressure (D-20A Outlet)}$
    - $-1089 = 685 - \text{Downstream Pressure}$
    - Therefore the Pressure on the bottom side of D-20A = 1774 psi

# Procedure Review

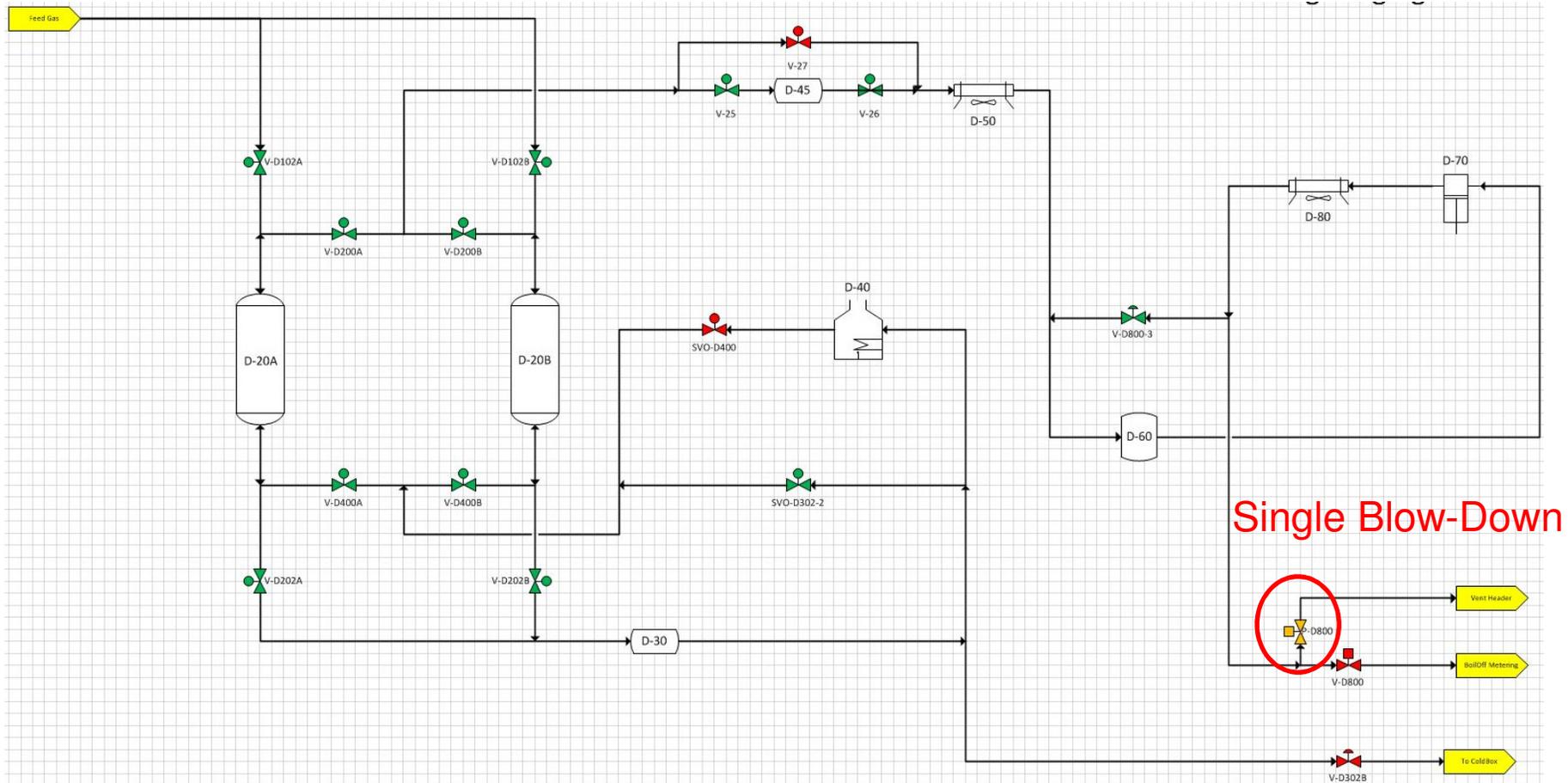
- The investigation team reviewed current and past revisions of Plymouth operating procedures
- Paired with operator interviews this provided the best understanding of how the Plymouth facility is operated
- Determined that current procedure was used and followed



# Procedure Review

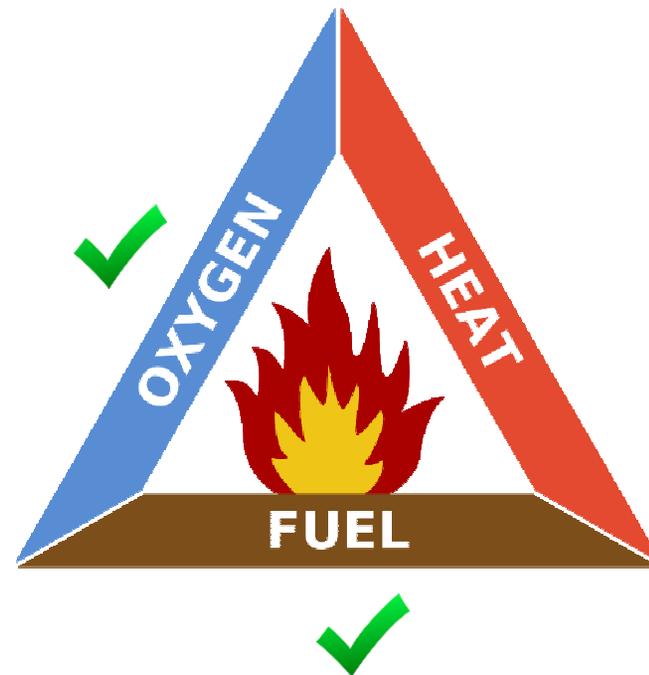
- In the start-up section of the Purification System Procedure it calls for a specific valve alignment and a **“Pack and Purge to 100 PSIG 3 times”**
- Before purification system is started each season purging was performed to remove oxygen that could have been introduced to the system during maintenance activities
- Equipment maintenance files demonstrated that (3) manual valves had been removed from the system for several months and were re-installed just prior to the March 31<sup>st</sup> start-up

# Procedure Review



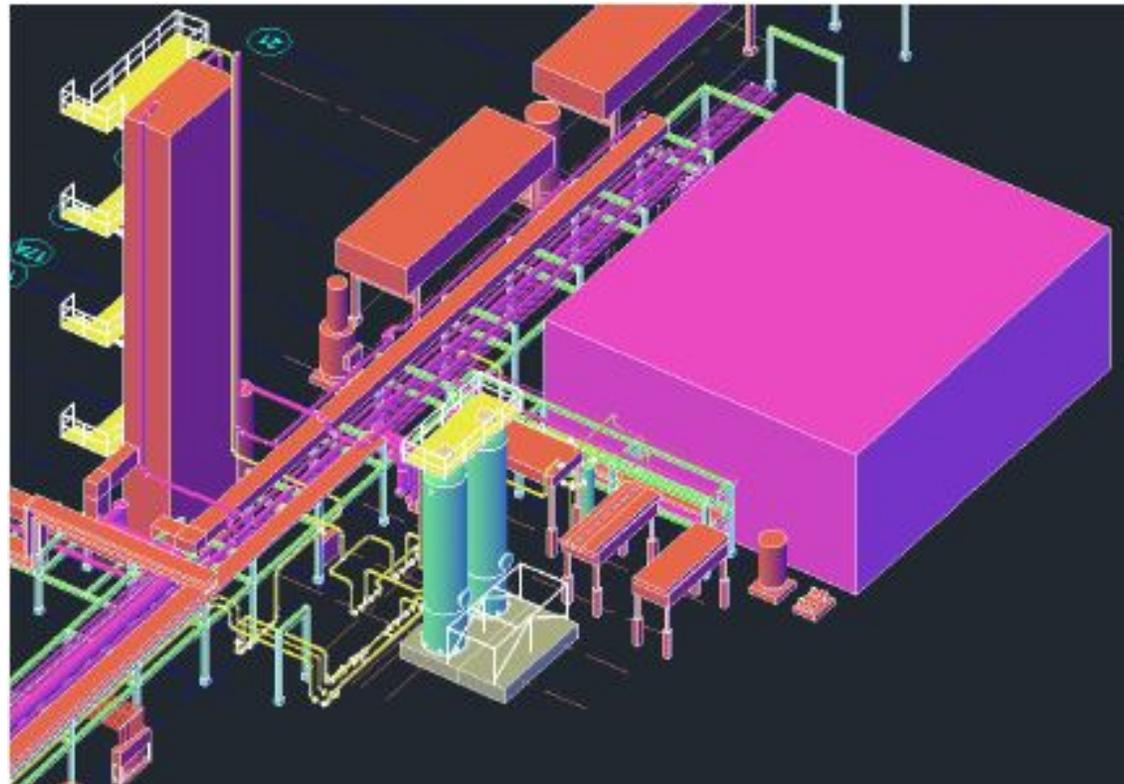
# Procedure Review

- “Pack and Purge to 100 PSIG 3 times”
  - Valve Alignment allowed for “spring effect” if not blown down to 0 psig
  - AGA: Purging Principles and Practice provides purging guidelines, however it doesn’t prescribe methodology for purging molecular sieve adsorbers.



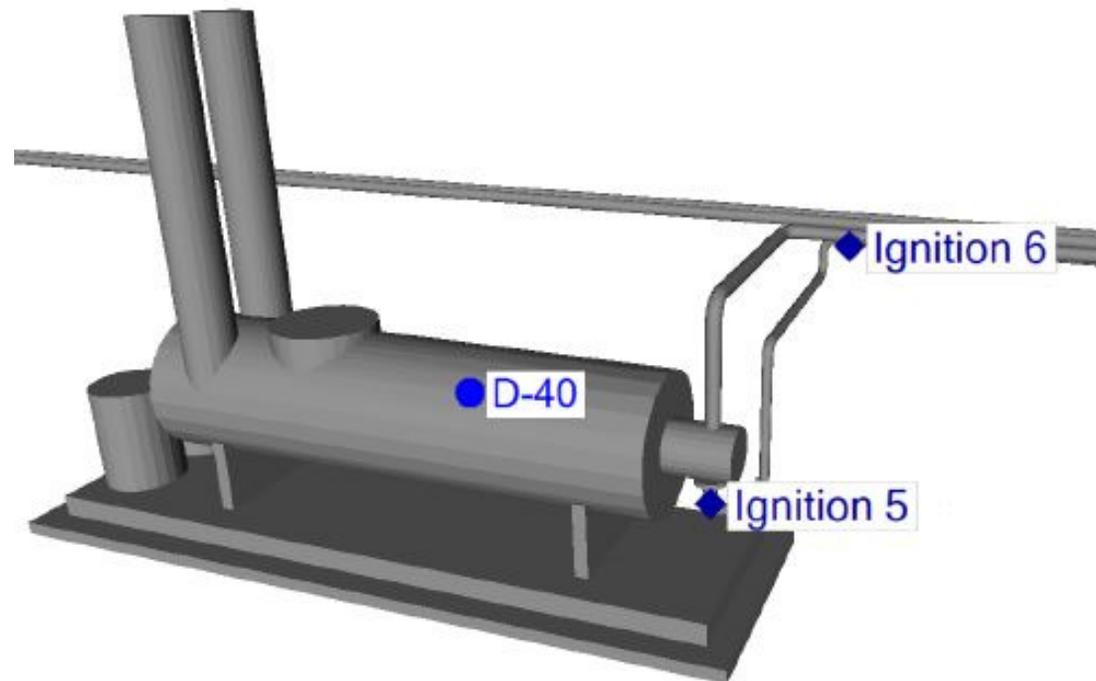
## Blast Modeling – *ABS Consulting*

- With evidence that combustion was not internal to Adsorber D-20A the investigation team hired ABS to perform blast modeling in order to determine potential ignition locations

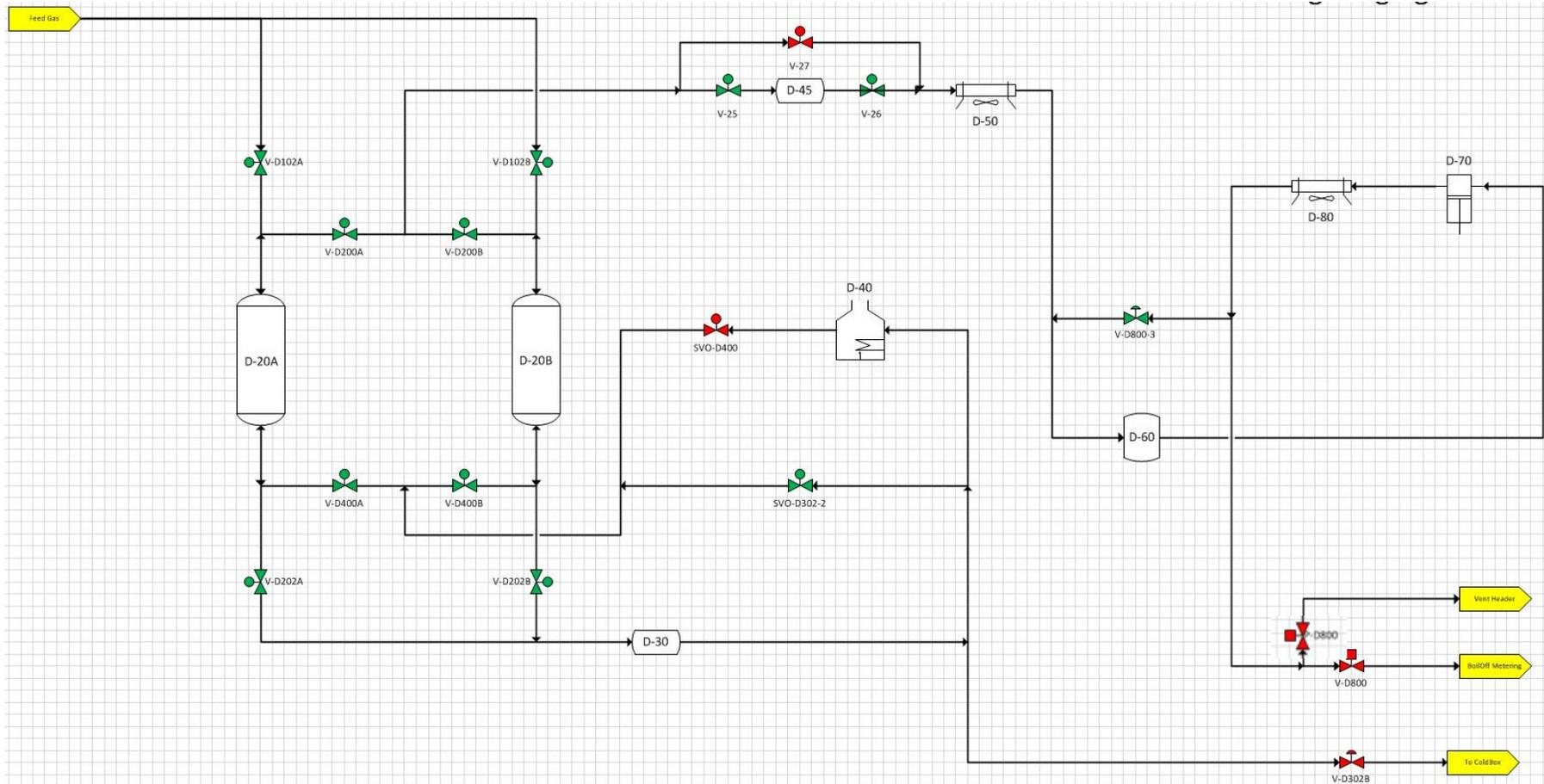


## Blast Modeling – *ABS Consulting*

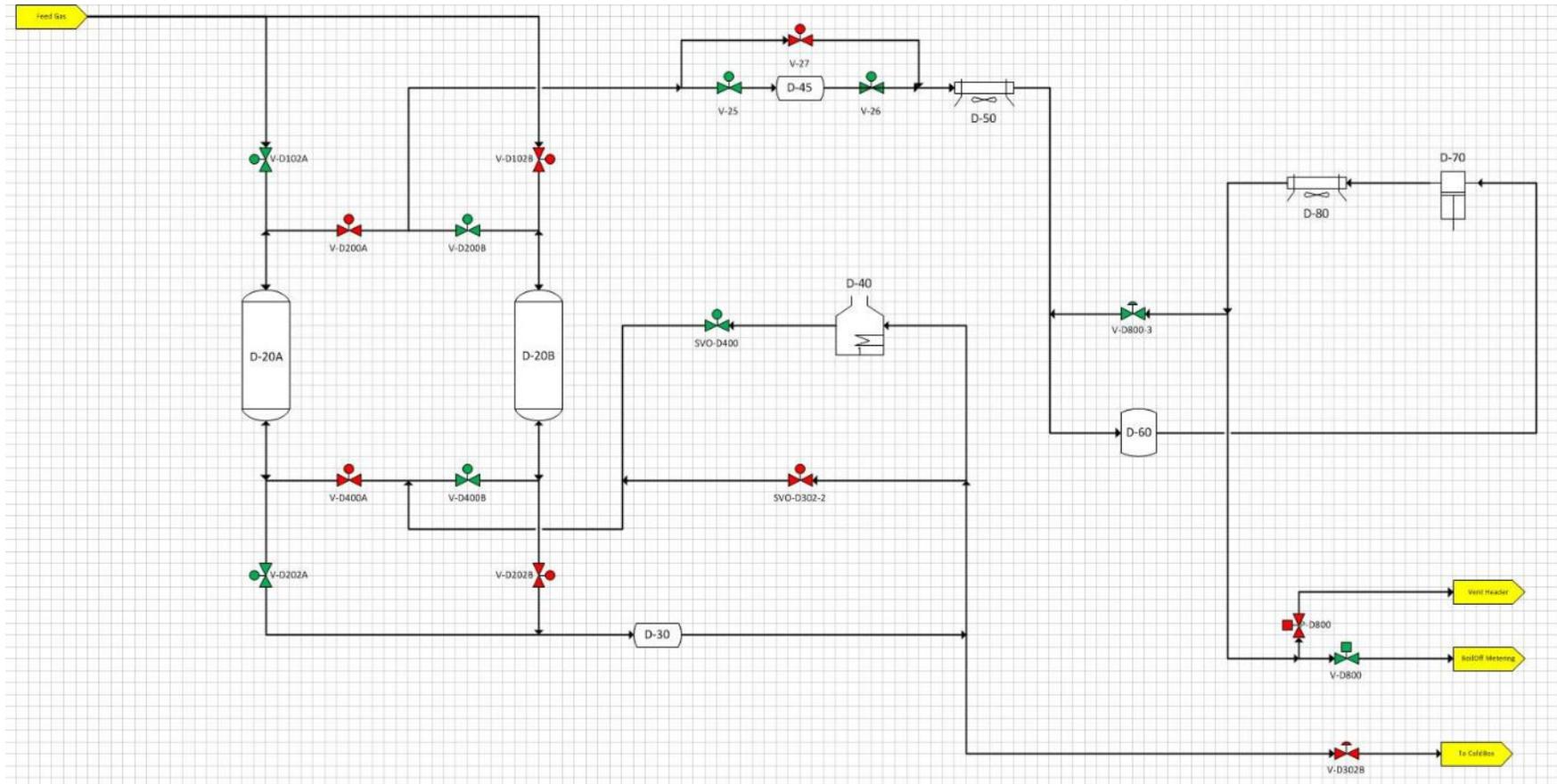
- Results identified the Salt Bath Heater inlet nozzle as the initial ignition location (identified as ignition location 5)



# Valve Alignment

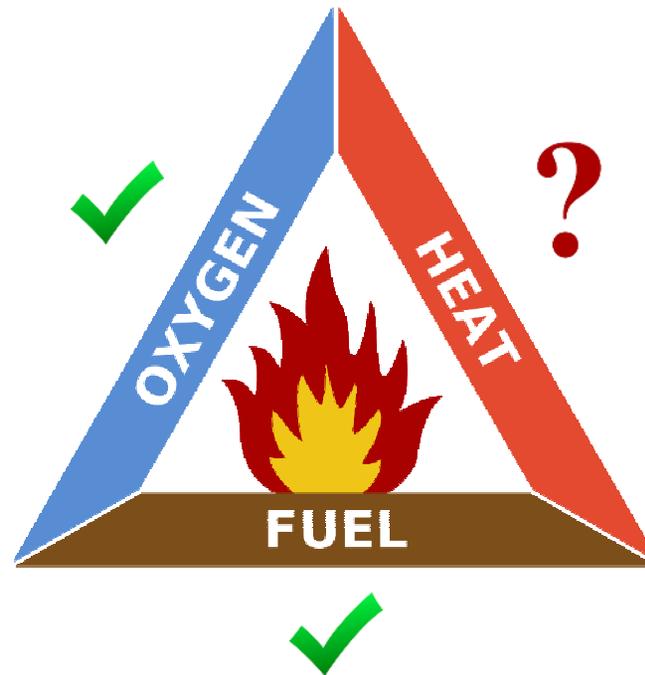


# Valve Alignment



# Auto-Ignition Testing – *Fauske & Associates*

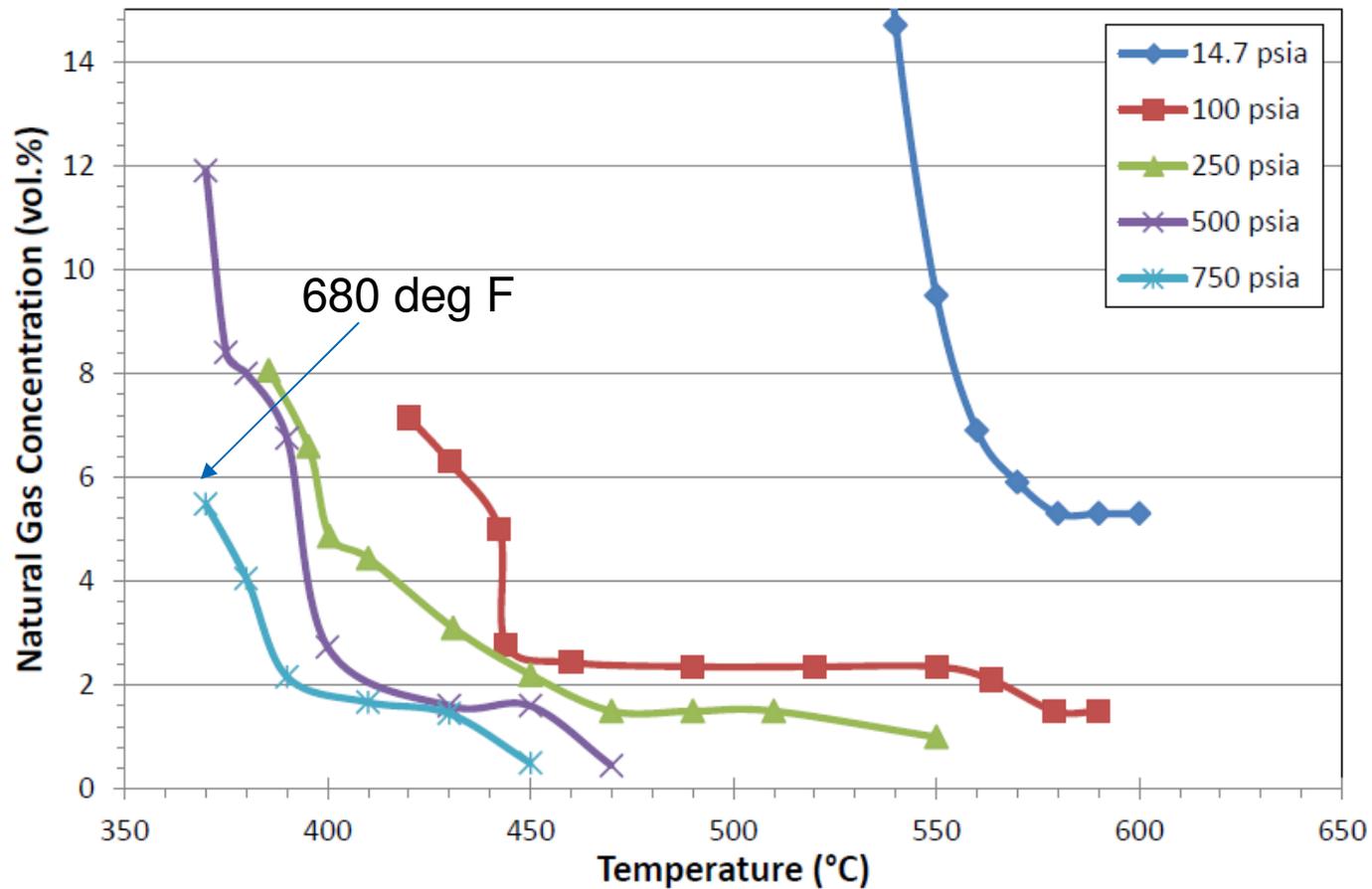
- Published values of the auto-ignition temperature of Methane is currently documented as ~1000-1100 deg F
- Salt Bath Heater set-point = 550 deg F



## Auto-Ignition Testing – *Fauske & Associates*

- Most published values of the auto-ignition temperatures (AIT) of methane are measured at or near atmospheric pressure
  - Published documentation of AIT under increased pressures is sparse and certainly not available for the gas mixture assumed to be present at the time of the incident
- Because of the lack of available industry documentation, the investigation team enlisted the services of Fauske & Associates to perform AIT testing under varying pressures
  - Fauske used a composite natural gas mixture generated from Plymouth's most recent chromatograph readings
  - Performed testing starting at atmospheric pressure at a variety of concentration levels Once experimental setup validity was confirmed they began increasing pressures

# Auto-Ignition Testing – Fauske & Associates



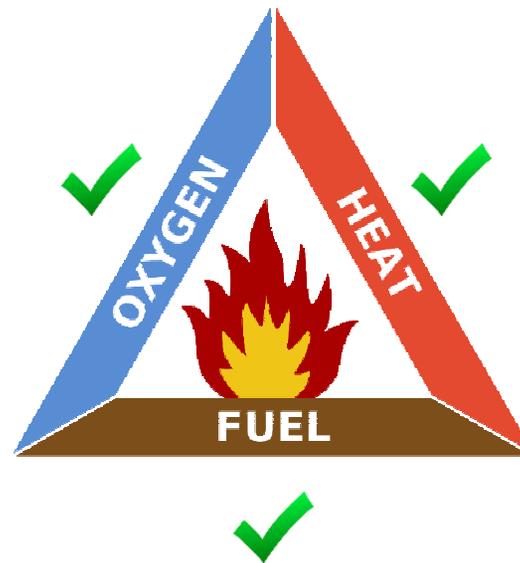
## Auto-Ignition Testing – *Fauske & Associates*

- Concluded that auto-ignition of Plymouth inlet gas at ~700 psig could fall as low as 680 deg F.
- The plant heater was running @ 550 deg F
- Calculated additional heat was provided during pressure up from 53 psig to 685 psig (adiabatic compression) 15 minutes prior to the incident



# Root Cause

- The lack of a complete purge left an air and natural gas mixture in plant piping downstream of the adsorber towers. During startup the flammable mixture was pulled into the salt bath purification heater where it then ignited, creating a rolling detonation back through the purification piping until it reached adsorber D-20A which then failed, dissipating the energy of the rolling detonation.



# LNG I Tank Integrity Inspection

- API 653 inspections of the inner and outer tanks
- 4 full height quadrant inspections using penetrant (PT) and visual methods
- 100% shell to floor weld vacuum box inspection and sample penetrant and vacuum box inspections on the floor plates



# LNG I Tank Internal Inspection



- Dent indication on east quadrant was characterized using electromagnetic residual stress sensors and laser scanning. Fitness for service was performed by Stress Engineering. The dent was repaired by blend grinding and was made safe for continued operation
- External foundation inspection
- Roof support bolts inspected by Chicago Bridge and Iron

# External Communications

- **April 8, 2014 Community Meeting** Informed community of incident status and plans for incident investigation.
- **Jan, 15, 2015** Door-to-door visits to all Plymouth residents related to partial re-start of a new gas purification system and the LNG 2 process.
- **Jan, 29, 2015** Letters mailed to all Plymouth residents about partial re-start.



# External Communications

- **May 1, 2015** Williams held dinner for the town of Plymouth to share our progress of the rebuild, answer questions of what we knew to date of the incident cause.
- **June 2, 2015** Annual LNG Consortium in Las Vegas. Reviewed information to date of incident investigation. Attendees were employees of lower 48 peak shaving LNG companies.
- **Sept 28, 2015** Discussed incident and emergency response activities with industry regulatory affairs group members in Pittsburgh, Pa.
- **Oct 14, 2015** Attended local Fire District 6 Emergency planning meeting. Williams provided a discussion around our current plant status and in service plans.
- **Nov 20, 2015** Held a tour of our plant facility with 14 Cascade Natural Gas corporate employees. We discussed the incident event day along with our rebuild status.



## External Communications

- **Jan 20, 2016** Meeting with local Fire District 6 and other nearby businesses to discuss emergency services needs and confined space rescue services.
- **Jan 22, 2016** Hired city of Pasco WA, Fire Dept. to provide confined space rescue services for entry in one of our LNG process coldboxes (several of the fire district attendees responded to our March 31, 2014 incident). We provided an update of our facility repairs and discussed using our facility for their rescue retrieval training.
- **Feb 3, 2016** Meeting with local Fire District 6 and other nearby businesses to discuss setting up a contract to allow local industries to volunteer during emergency events.
- **Mar 4, 2016** Letters mailed to all Plymouth residents about LNG 1 commissioning and start-up activities lasting several weeks; expected to be completed during the month of March, 2016.



# QUESTIONS?

