51ST TURBOMACHINERY & 38TH PUMP SYMPOSIA

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Integrally Geared Compressor Failure due to excessive pipe strain

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Biography

Marcela Lopez is a bp Rotating Equipment Engineer with Innovation and Engineering based in Houston, Texas. She provides excellence in technical rotating equipment support and recommendations to facilities within the US to improve production, life extension, risk management mitigation, increase reliability, and advancement of technology.

Marcela has over 9 years of experience in the industry and graduated from University of Florida at Gainesville with B.S. in Aerospace and Mechanical Engineering.

Robert C. Eisenmann, Jr.

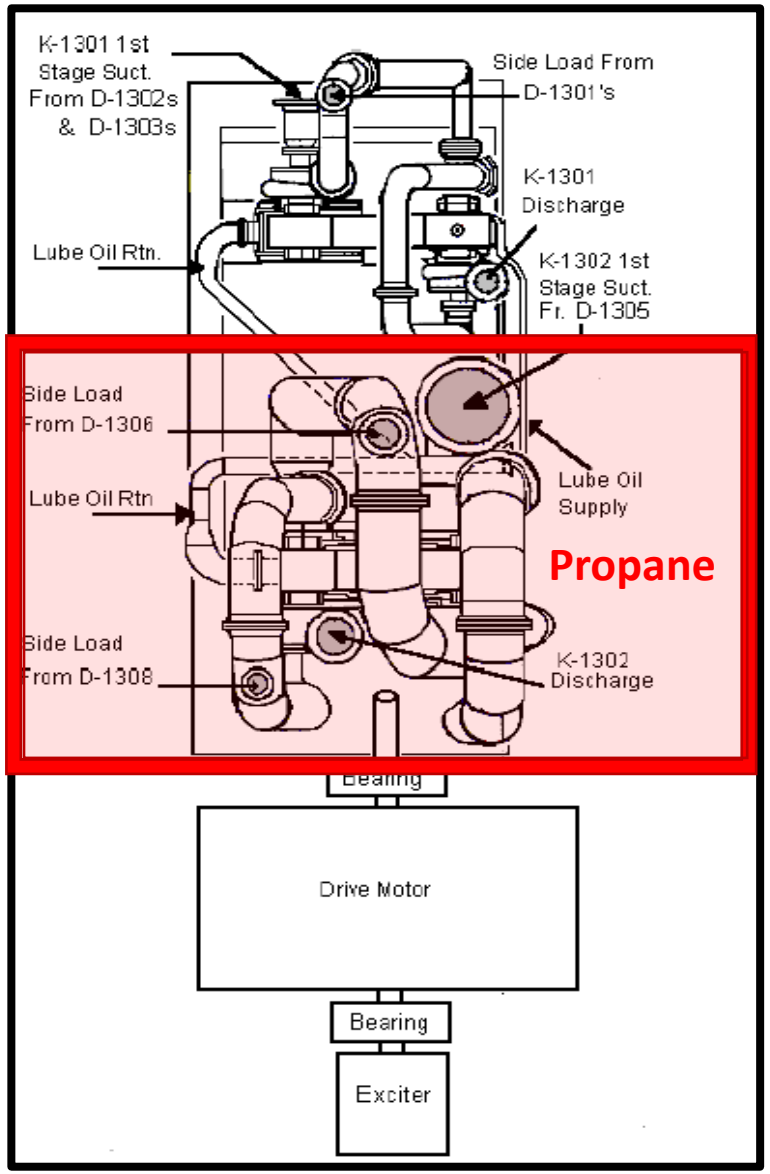
Robert C. Eisenmann, Jr. is the bp Rotating Systems Advisor with Innovation & Engineering based in Houston, Texas. He provides technical advice to the bp global portfolio to support business delivery, company strategy, industry direction, and technical assurance to support business decisions. He also promotes technology solutions and development and implementation of best practices across the bp. He is currently the API 618 Chairman, API 692 Chairman, API Committee for Refining Equipment (CRE) Chairman serves as a SME for BP's Engineering Technical Practices and has been a member of the Texas A&M Turbomachinery Advisory Committee since 2012. Bob has over 30 years of experience in the industry. Bob graduated from Texas A&M University at Galveston in 1992 with a B.S. in Marine Engineering.

Abstract

• Following a complete overhaul of an integrally geared compressor, the compressor failed upon startup. The compressor ran for 7 seconds before the machinery protection system tripped the machine. During disassembly, it was discovered that three of the four impellers rubbed severely against the impeller eye labyrinth seals and the accompanying dry gas seals were destroyed from excessive pipe strain.

• This case study highlights the failure data, corrective actions taken in investigation and reassembly of the machine.

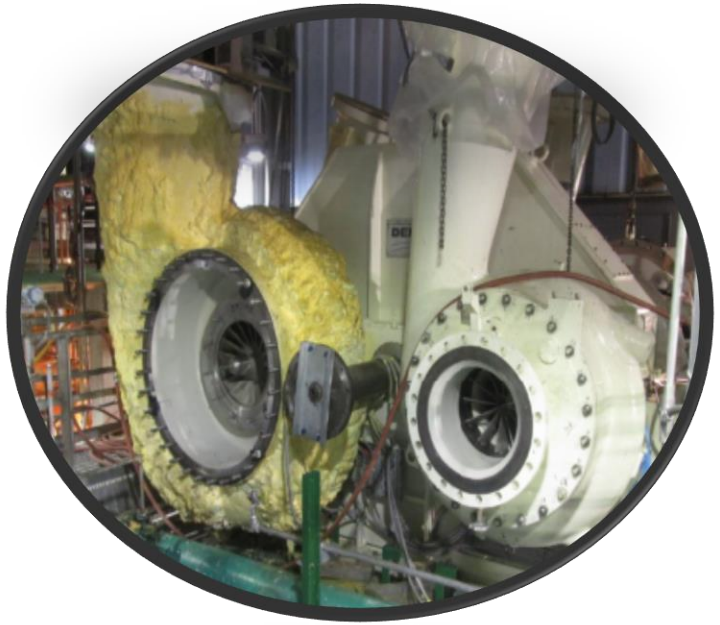
Integrally Geared Compressor



- 2 compressors coupled together
- Integrally Geared Compressor
  - 4 stage compressor (Propane)
- Integrally Geared Compressor
  - 3 stage compressor (Ethylene)
- Motor
  - 15,000 HP
  - 1200 RPM

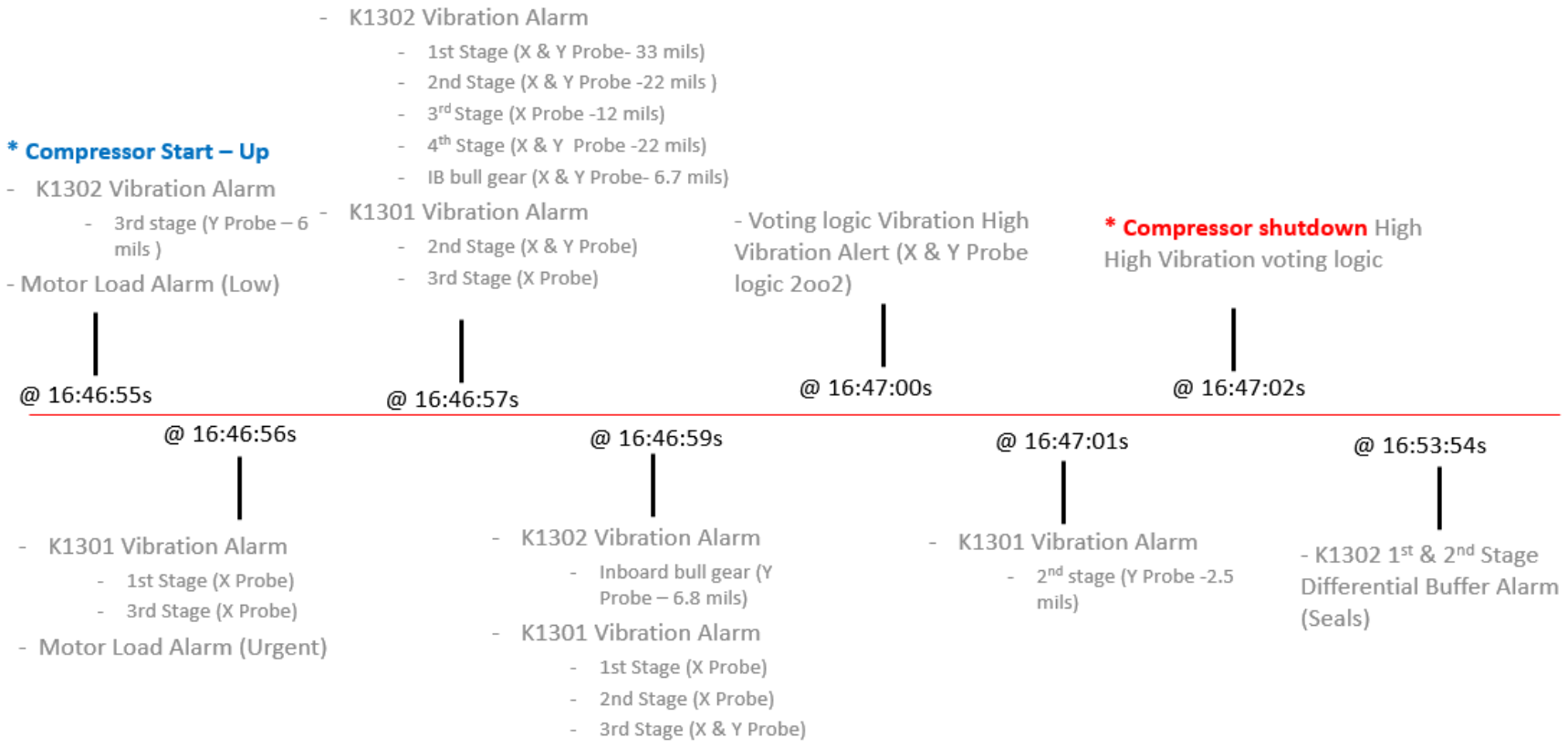
Turnaround Scope

- History
  - 1995 installation
    - No previous failure
  - Typically field OH's every 10 years
- 2018 shop overhaul
- Reinstallation
  - Piping Alignment – 7 up nozzle



Sequence of Events

- Propane compressor vibration trip after 7 seconds
  - No trip from Ethylene compressor
- Elected to not restart

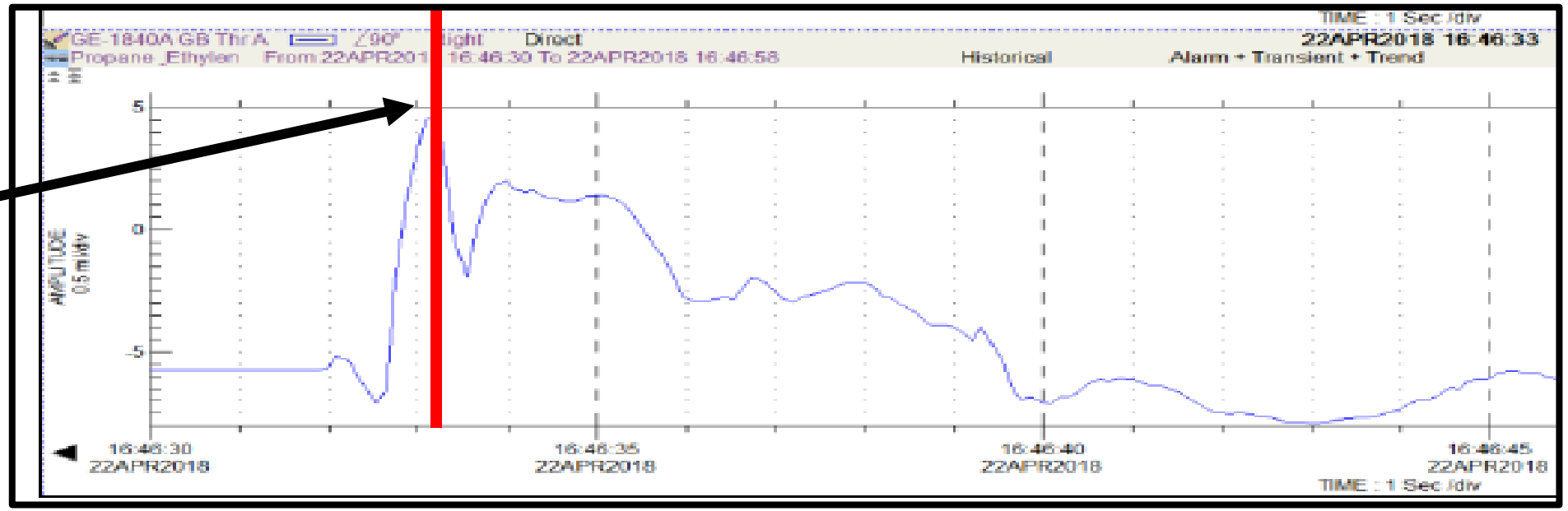


Propane Compressor Radial Vibration

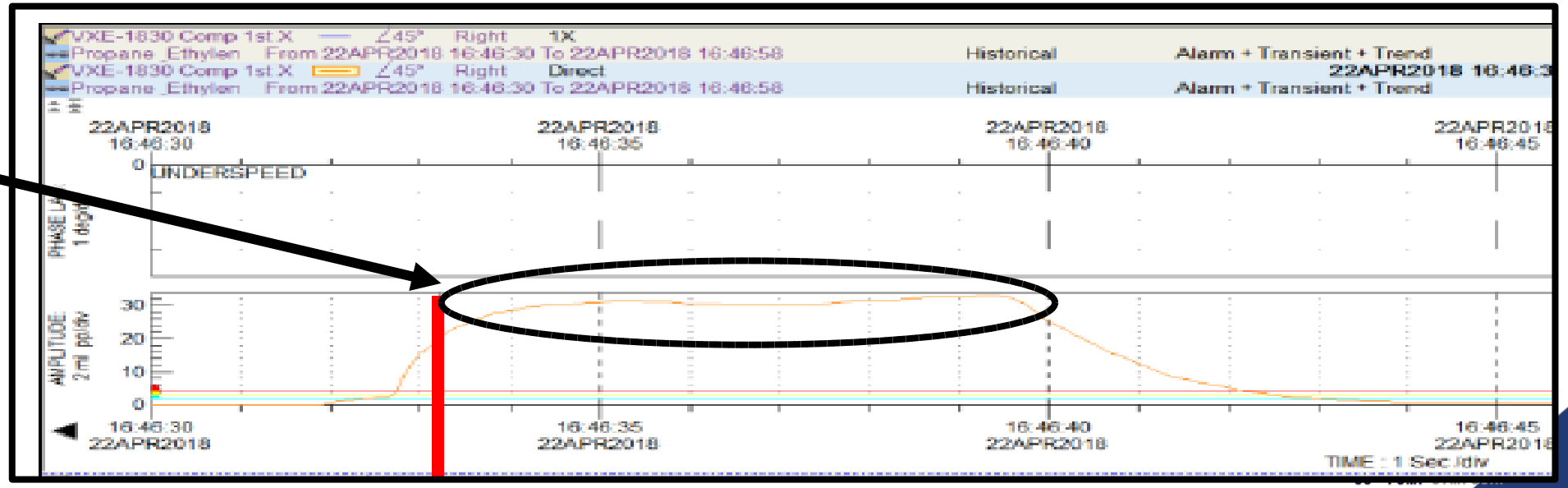
High Vibration across all stages

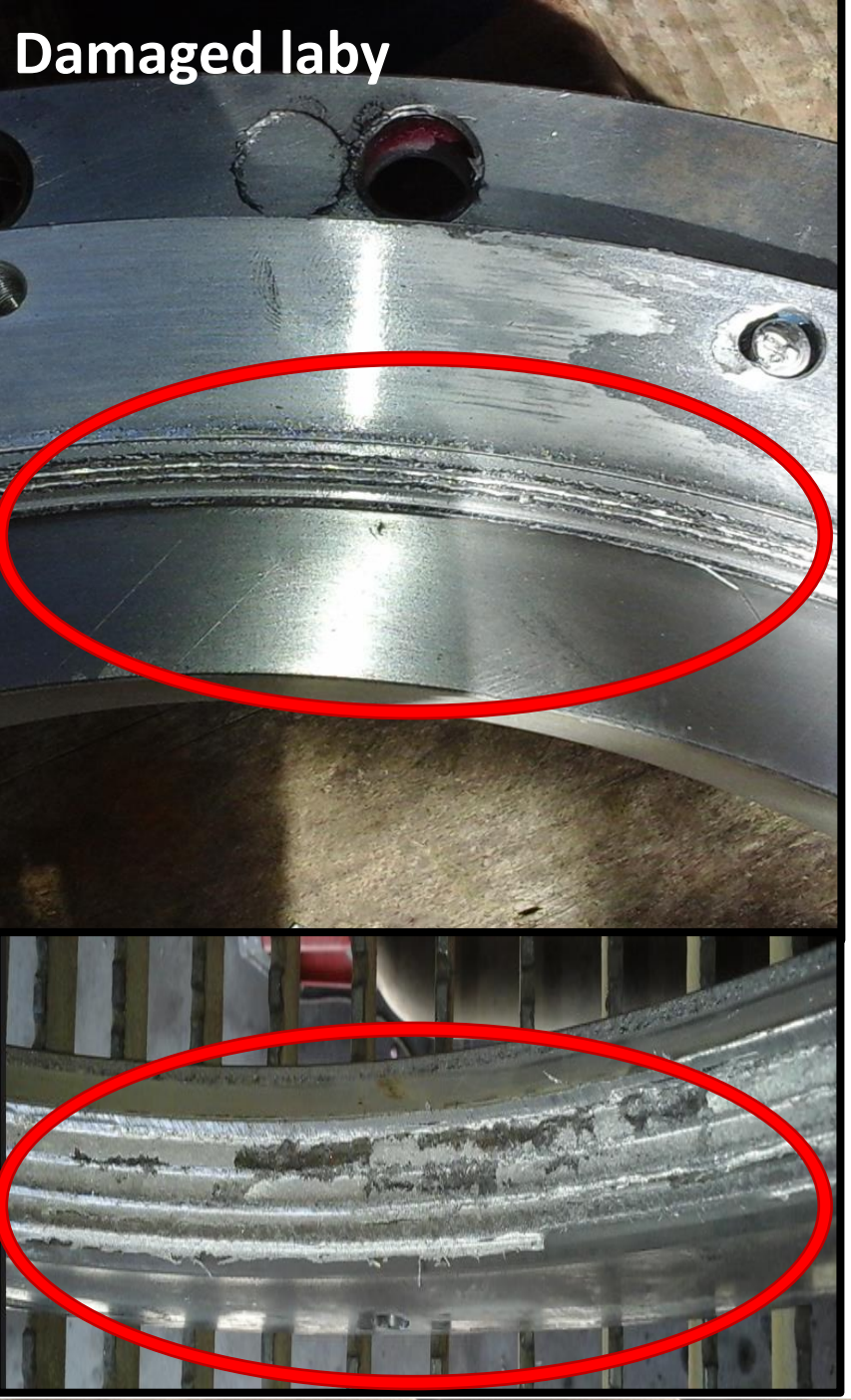
Propane Compressor Coastdown

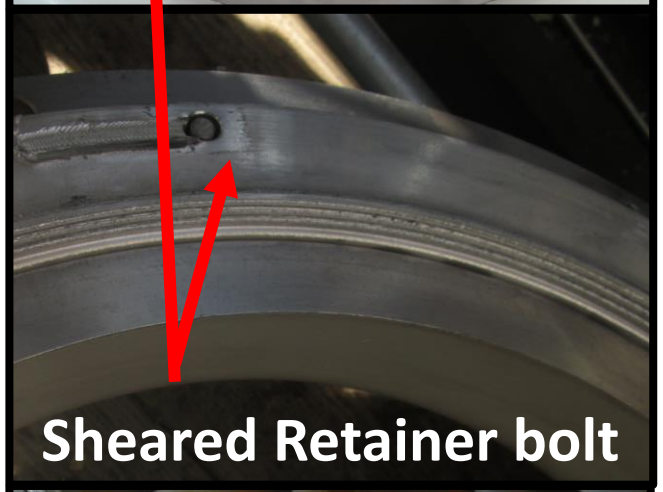
Peak axial movement



Radial vibration continued to increase





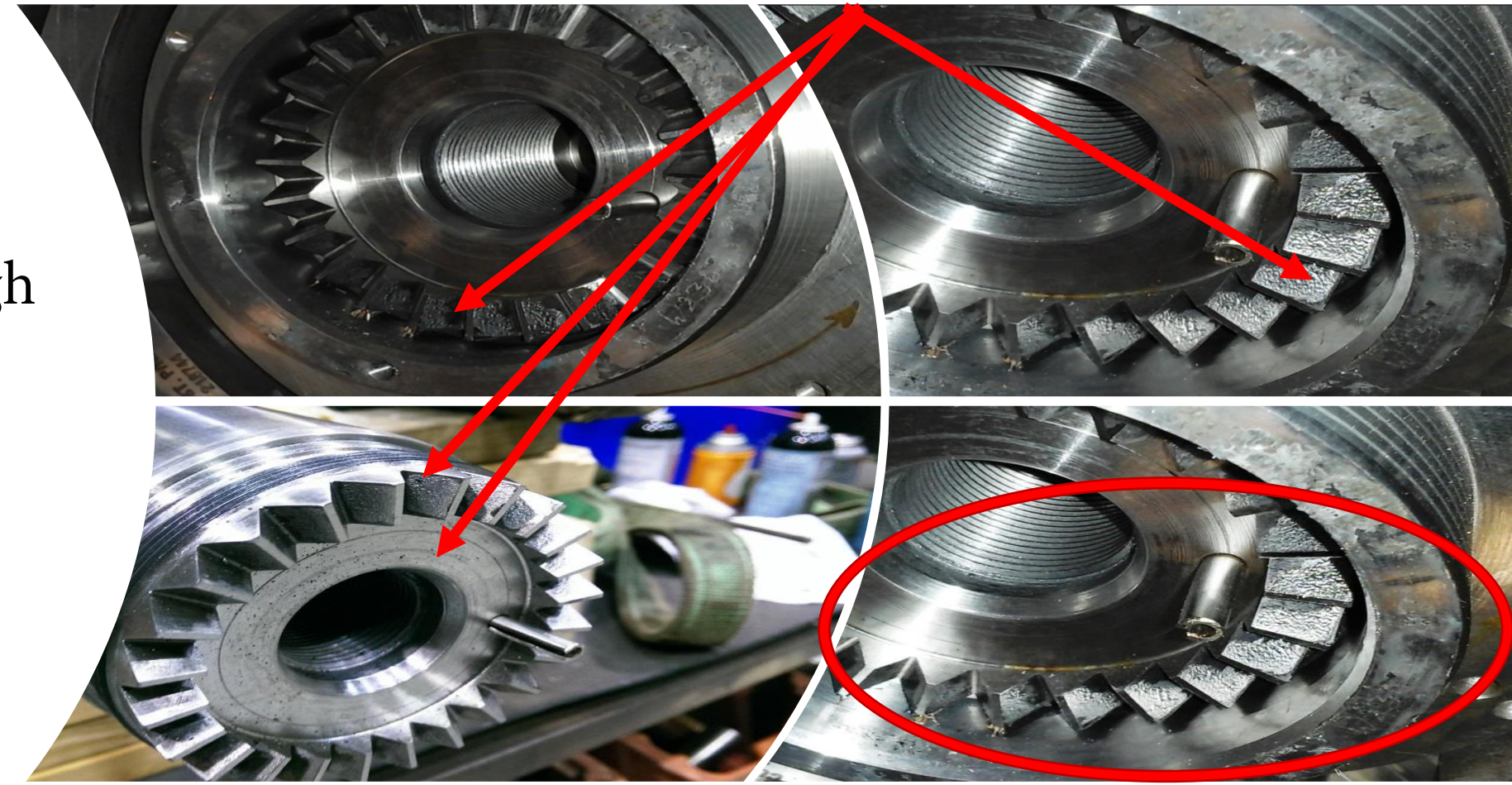


Findings – Laby & DGS seals

- Labyrinth seal damage on 1st, 3rd and 4th stages
- Dry gas seals
  - 1st stage primary seal leak
  - 2nd stage seal failed - primary and secondary leak

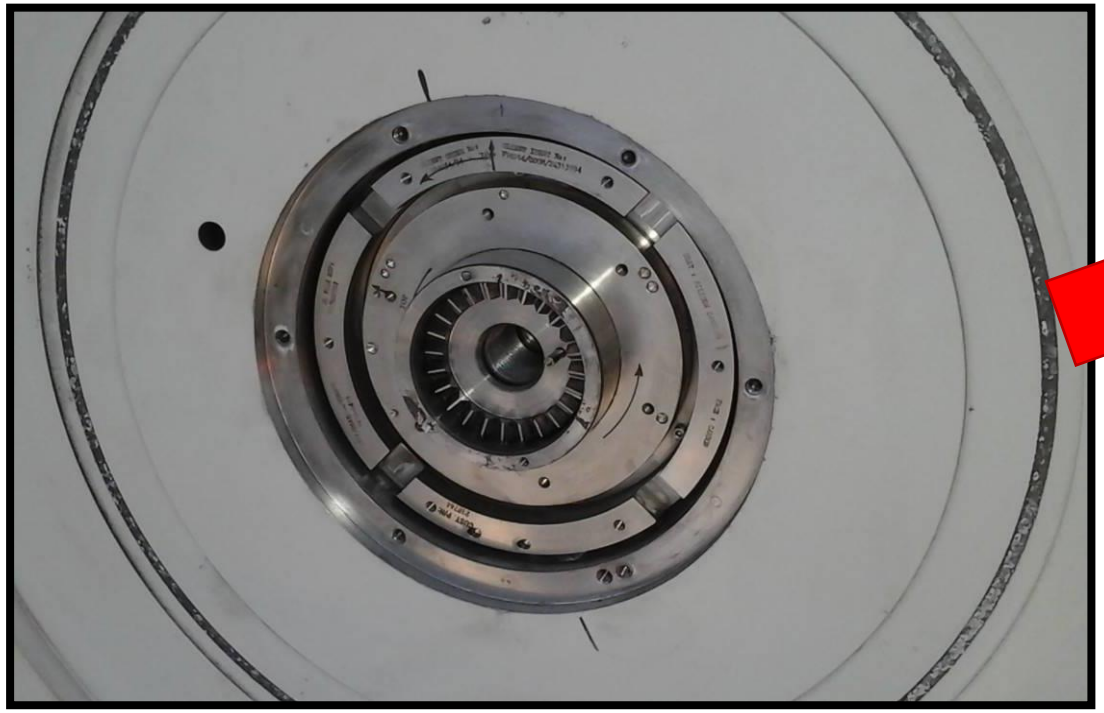
Findings - Hirth Tooth Coupling Damage

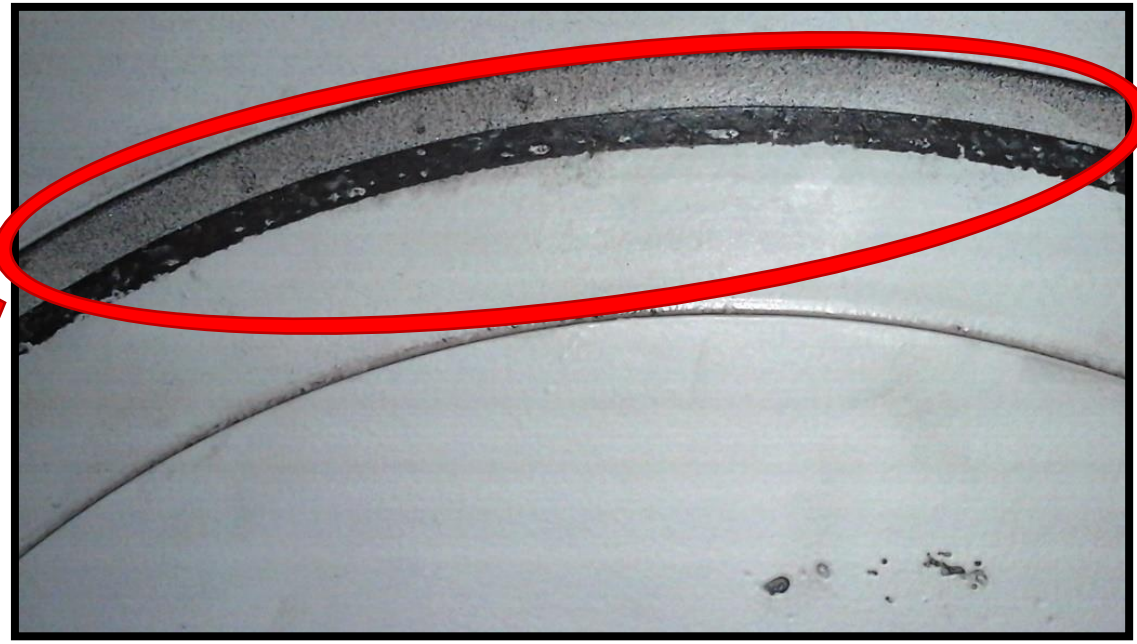
- Surface damage - high loads in 7 sec run



Findings - Volute & Back of Impeller Rub

- Rubbing contact on back side of impeller





Potential Causes

- **Process Slug** – No Evidence
  - Potential water in propane trucks – analysis certification on spec
  - Rain water entrainment – borescope showed system was dry

- **Volute not aligned with respect to gearcase assembly** – No Evidence

- **Impeller rubbed on volute** – No Evidence
  - Excessive coating of volute - clearance behind impeller confirmed to be within spec
  - Excessive axial float – no damage on thrust bearing/collars & clearance within spec

Potential Causes

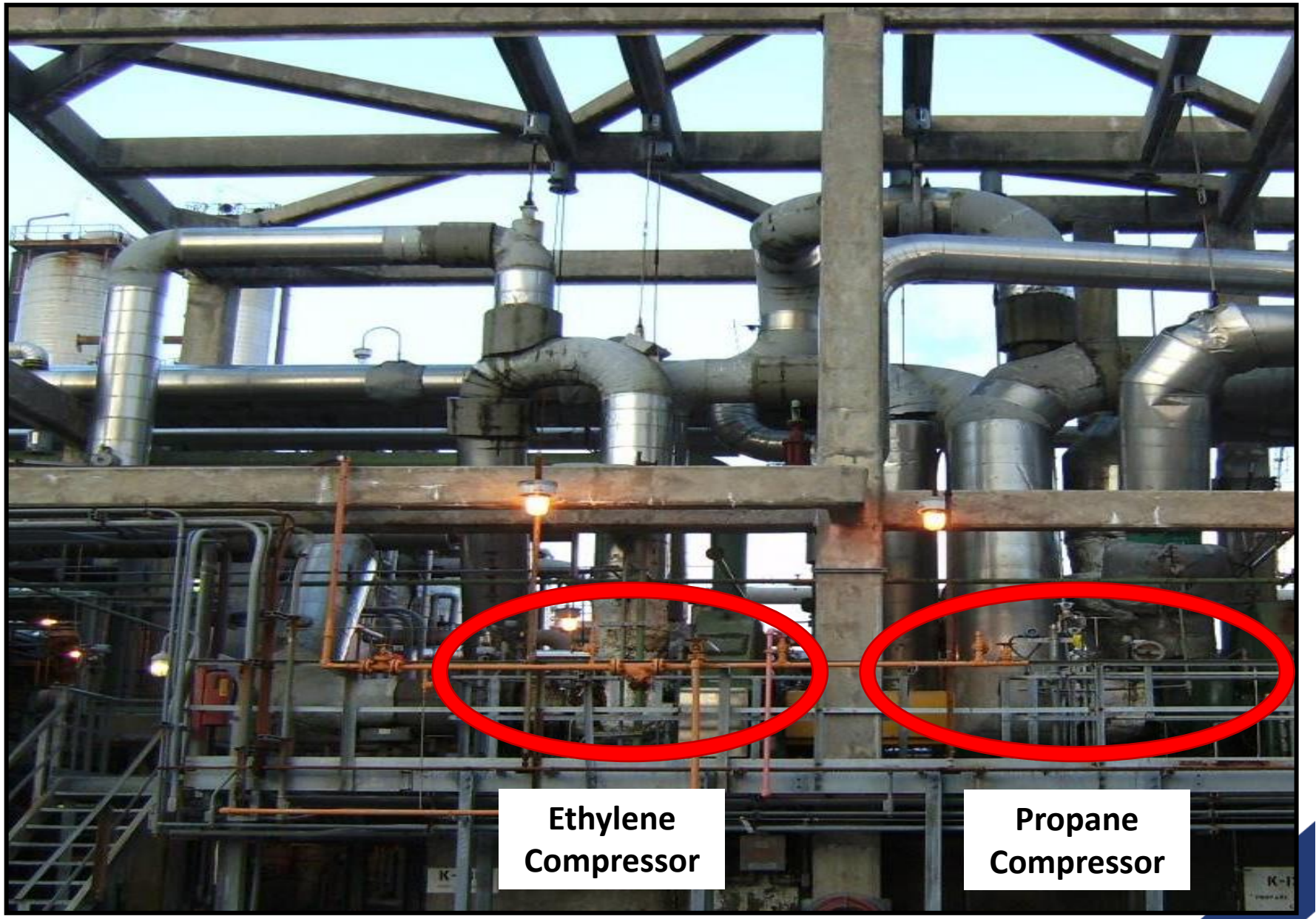
- **Deficiency of overhaul and assembly** – Contributing cause
  - Labyrinth seal installation deficiency
    - Volute insert installation blocks not in correct position and fully seated in volute fit
  - Rotor Assembly - Inadequate bolt tension of impeller hirth coupling
    - Tension bolt installed 3rd 30% below and found 4th stage at 30% of target (vibrations)
      - Utilized faulty tooling

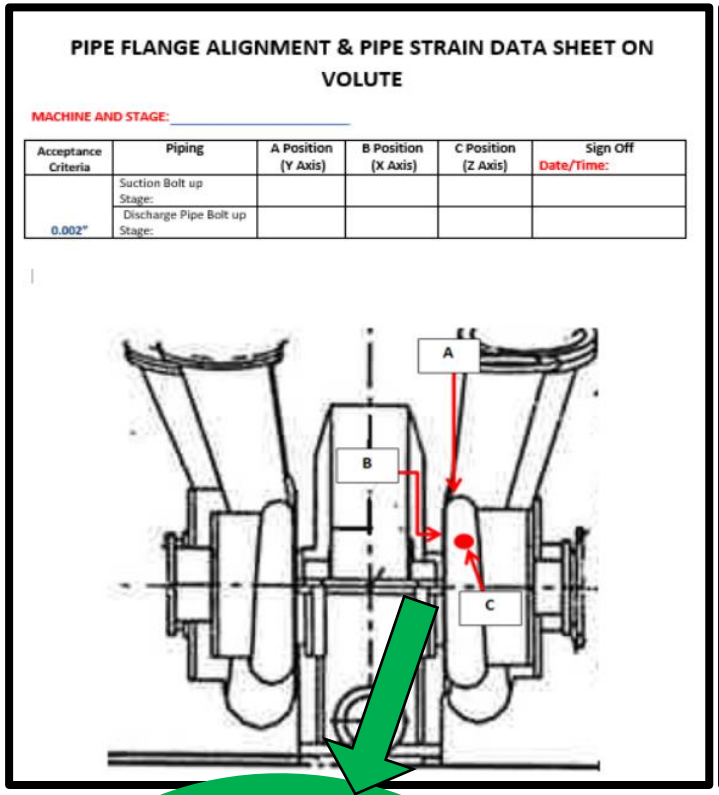
Primary Cause

- **Pipe Strain** – Primary Cause
  - **Piping Alignment**
    - Step by step piping alignment not followed in sequential order
  - **Spring Cans**
    - Piping installed with spring cans locked and unlocked only after installation of all piping to compressor case was completed
    - Spring cans final position unknown + not documented
      - Only verbal communication that deflections on the machine were monitored

Piping System

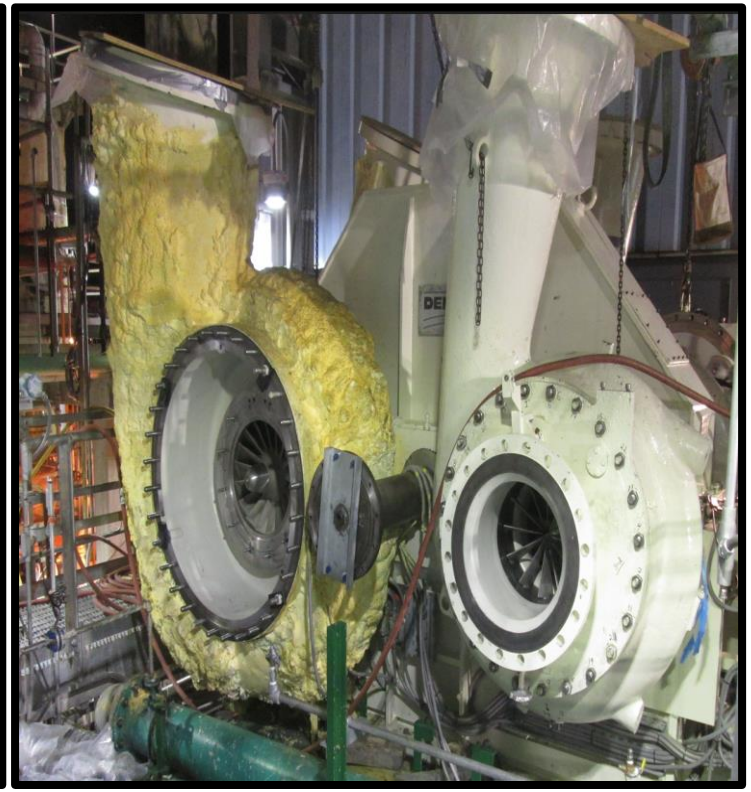
- Complex piping arrangement
- Piping supported by spring cans
- Vertically supported

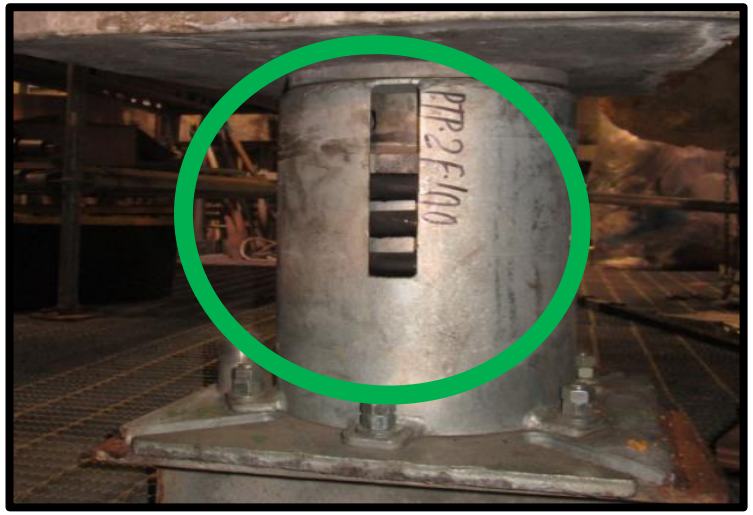



PIPE FLANGE ALIGNMENT & PIPE STRAIN DATA SHEET ON VOLUTE

MACHINE AND STAGE: _____

Acceptance Criteria	Piping	A Position (Y Axis)	B Position (X Axis)	C Position (Z Axis)	Sign Off Date/Time:
0.002"	Suction Bolt up Stage:				
	Discharge Pipe Bolt up Stage:				



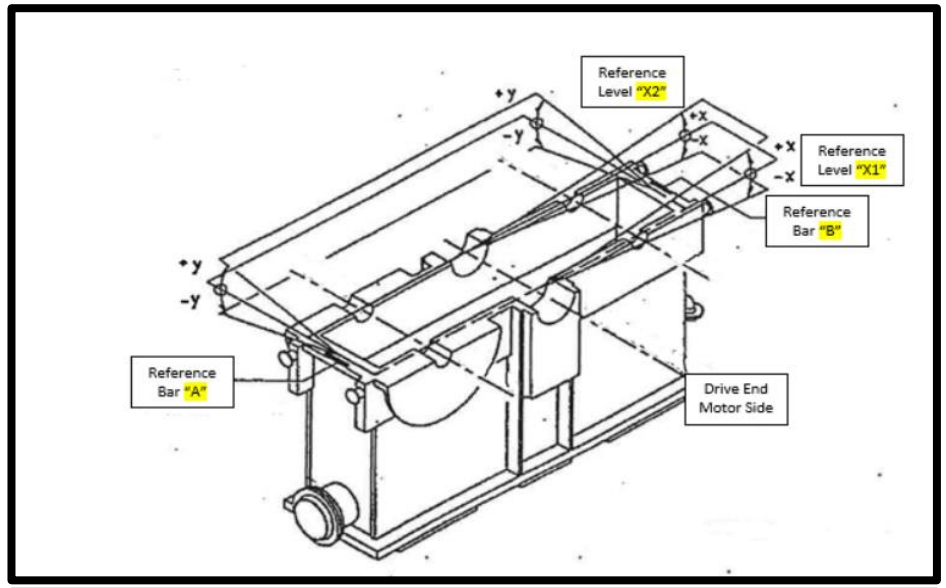


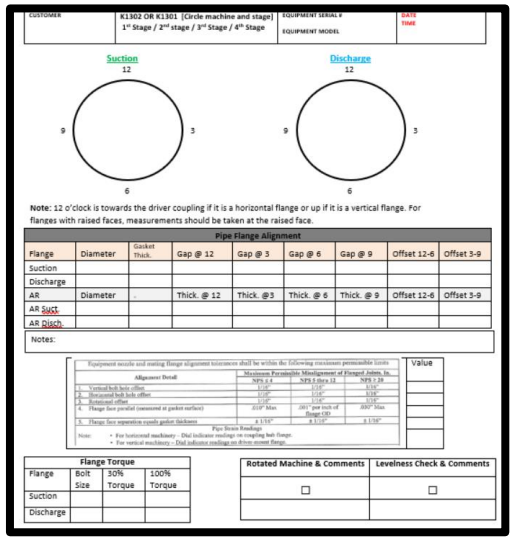
Reassembly after Failure

- Defined sequential order of piping connection/installation
- Defined communication plan onsite to ensure coordination of different discipline crews to achieve defined sequence
- Unchocked spring cans before installation and adjusted during installation to ensure adequate load setting
- Implemented QA/QC and check sheets
- Engineering witness points at all piping reassembly monitoring volute deflection
- Updated site procedures

Reassembly after Failure

- Gearcase levelness Checks performed
  - Determine deflection effect
  - Determine twist effect



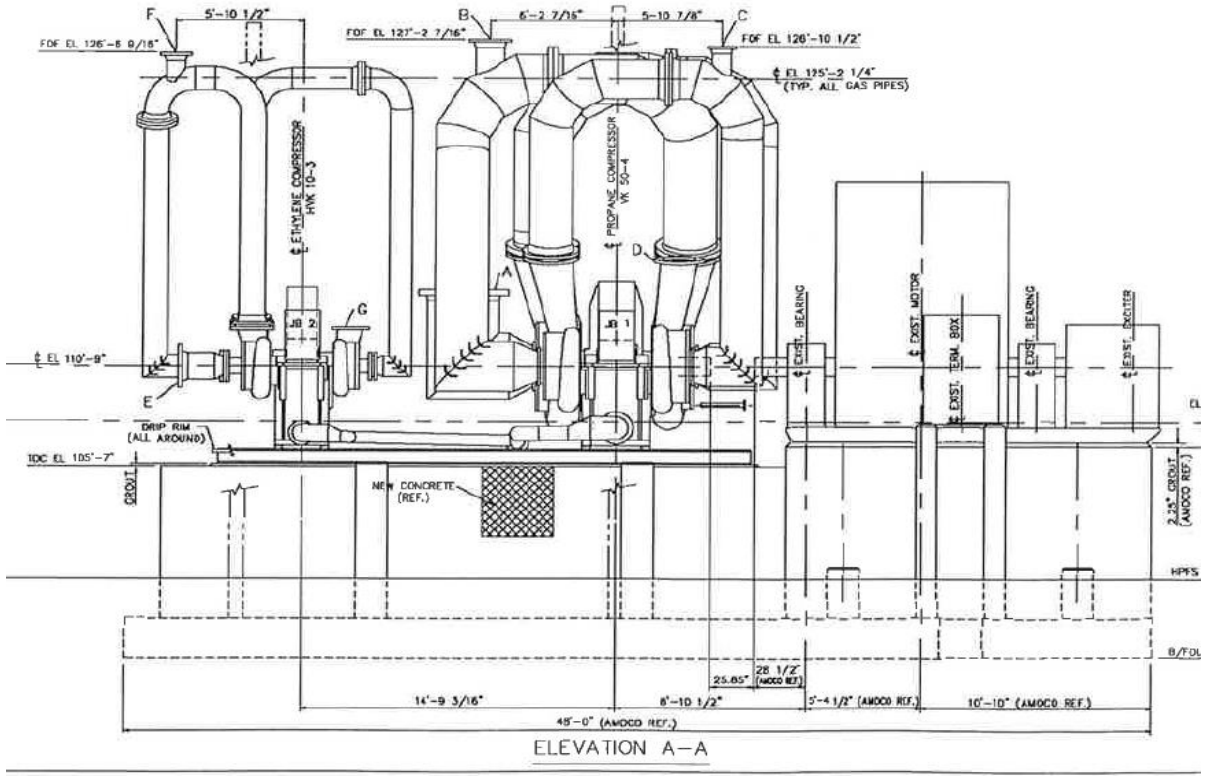


Sequence

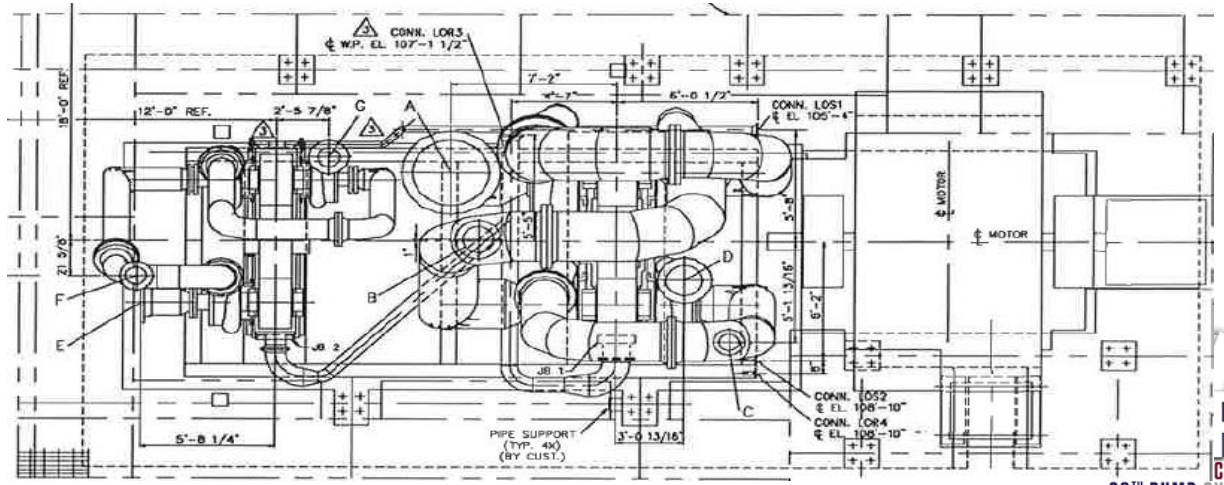
- Performed sequencing of stages starting from 1st stage in chronological order
- Adjustment of spring cans made with no nozzle load on compressor volute
- Monitor deflection at stages
- Monitor gearcase twist through levelness
- Once pipe strain was complete on volutes then moved on to the next stages until complete

After completion of reassembly, machine restart was successful and has been running

Side View



Top View



Learnings

- Pipe strain on integrally geared compressors can have a large effect on volute deflection
  - If the volute has external load via pipe strain, the volute will move out of position relative to the pinion/impeller assembly causing metal to metal contact between the impeller and laby seals within the volute

- Establish and follow a piping installation procedure and pipe strain monitoring plan
  - Sequence
  - Coordination / Communication / Shift and crew change management
  - Procedure documentation for QA/QC
  - Engineering hold points
  - Inclusion of acceptance criteria per OEM and API RP 686 section 4.9

- System monitoring and protection systems shall always be running specially during commissioning phases