Thrust Balance Line Bolts Failure

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Robert Briggs, Pipeliner Product Line Manager
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Slide 2: Presenter/Author bios

Felix Cestari

BSME (1975), MSME (1980), Felix has over 30 year of experience the in Oil & Gas industry in the areas of research and development (R&D); rotating and reciprocating equipment, troubleshooting and field technical support, and most recently as a compressor design engineer at Siemens.

Robert Briggs

BSAAE (1990), MSME (1996), Rob has over 20 years of experience working with Mount Vernon compressors in the Oil & Gas Industry, and is the foremost technical expert and design authority for the Mount Vernon Pipeliner product line. Rob has spent many years as a compressor design engineer, compressor team lead, assistant chief engineer, and most recently as product line manager at Siemens.

Regis Fowler

BSME (1990), Regis has over 27 years of experience in the energy sector providing products and services to a global market, has had roles of project engineer, chief engineer, production and fleet packaging, and most recently Head of Product, MTO, at Siemens.

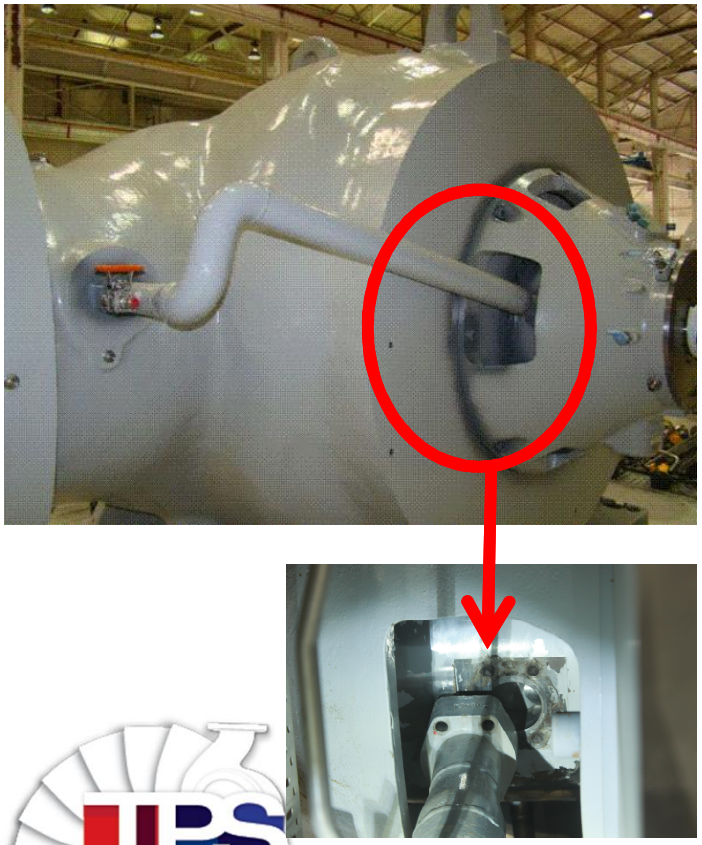
Ge Jiangang

BS Organic Chemistry (1997), Ge has over 17 year of experience in compressor unit operation and maintenance technology of steam turbine drive, motor drive, and gas turbine centrifugal compressor unit. Most recently as Manager of compressor office of PetroChina PWPC Production & Operation Department.

Slide 3: Abstract

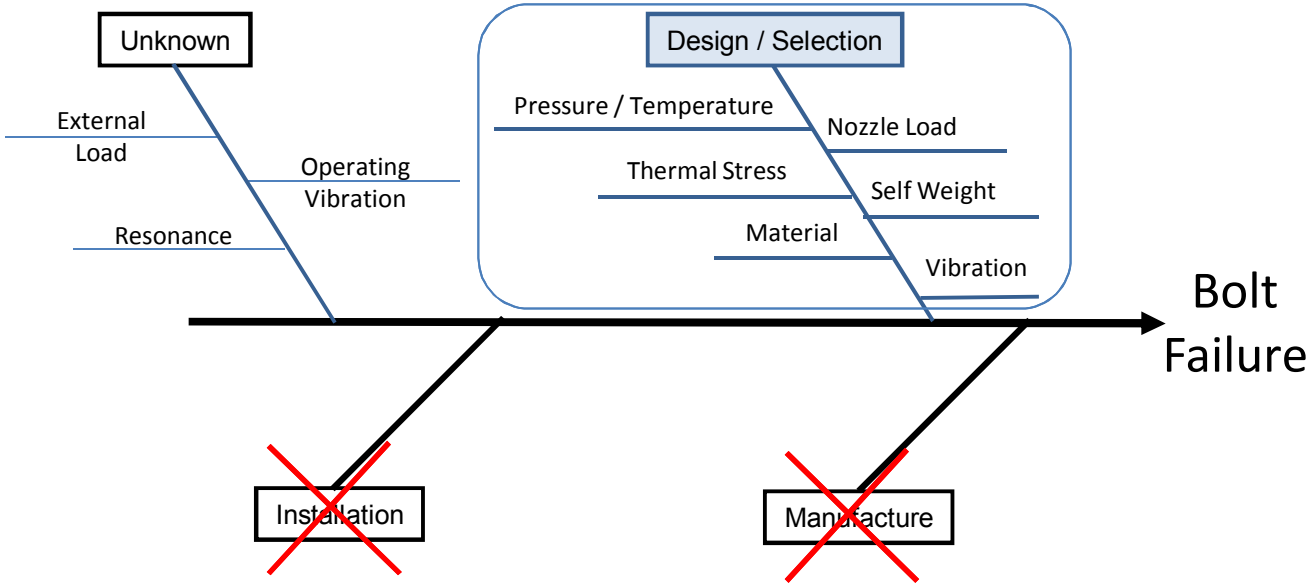
The flange bolts of the thrust balance pipe failed on two different RF36 centrifugal compressors at a natural gas transmission station. One such failure resulted in high gas leakage inside the building leading to an unsafe condition as well as significant damage to the compressor internals due to changes in the thrust loading. Bolt failure was attributed to high-cycle fatigue as a result of excessive nozzle loading and high structural vibration due to a weakened pipe supporting system.

Background of the Incident



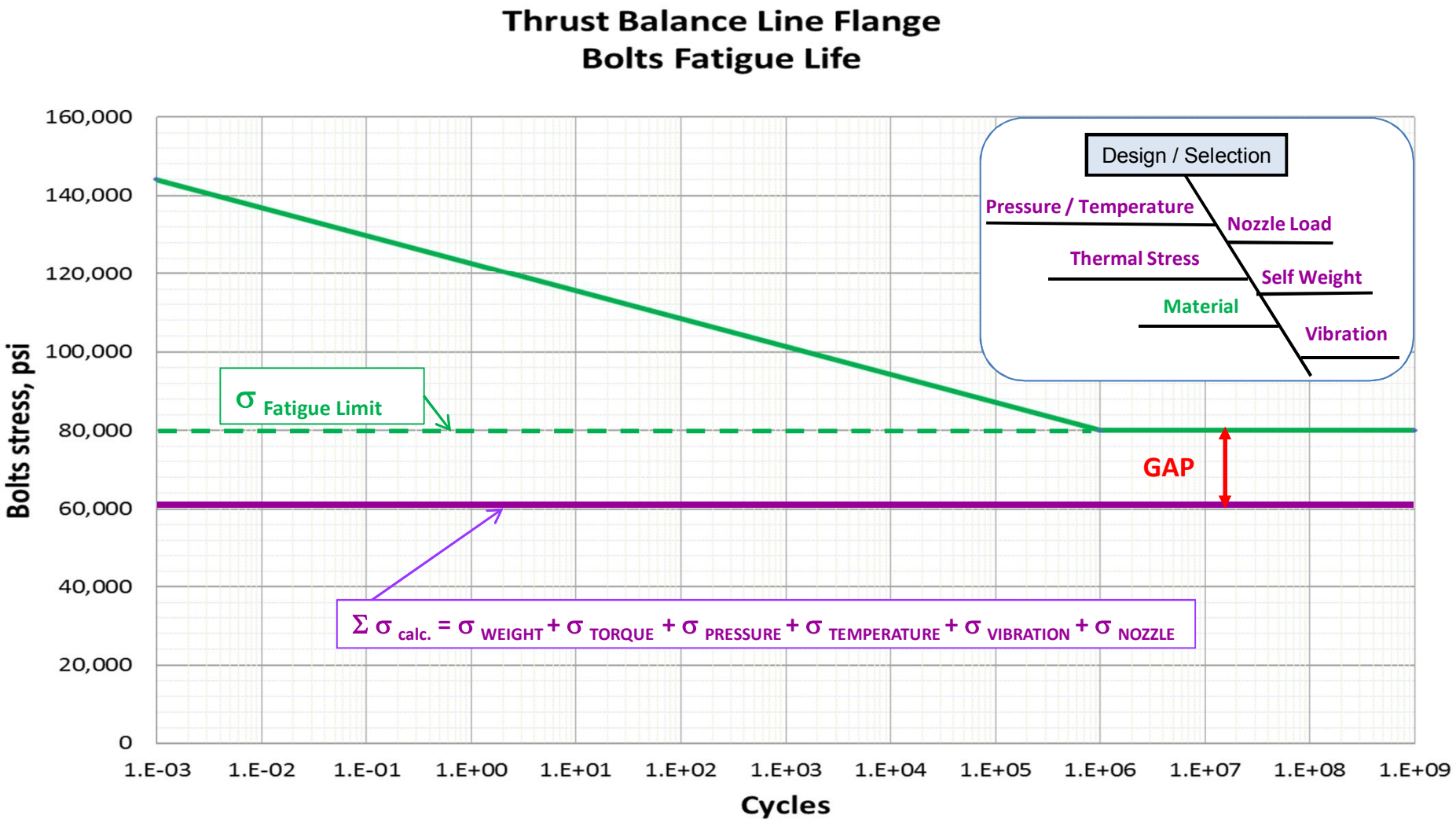
- High gas leak tripped the gas detectors safety system of the building.
- The station was evacuated for a Level I hazard (potential for gas ignition and explosion).
- Thrust balance line (TBL) detached from its flange connection allowing the gas to escape.
- Bottom picture shows the permanently deformed TBL, as found after the failure.

Cause – Effect: Fishbone Diagram



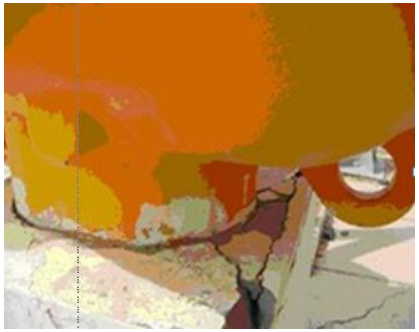
Summary of Investigation Findings

- No bolt quality issues (material, manufacturing, etc.).
- No problems with thrust balance line installation (bolts torque, TBL alignment, flange gap, etc.).
- Customer vibration survey useful but inconclusive.
- Low rotor vibration.
- Bolt size / material selection correct for the application.
- Calculated bolt stress below material fatigue limit.


Thrust Balance Line Flange
Bolts Fatigue Life
Bolts stress, psi
160,000
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
1.E-03
1.E-02
1.E-01
1.E+00
1.E+01
1.E+02
1.E+03
1.E+04
1.E+05
1.E+06
1.E+07
1.E+08
1.E+09
Cycles
σ Fatigue Limit
GAP
Σ σ calc. = σ WEIGHT + σ TORQUE + σ PRESSURE + σ TEMPERATURE + σ VIBRATION + σ NOZZLE
Design / Selection
Pressure / Temperature
Nozzle Load
Thermal Stress
Self Weight
Material
Vibration

Site Visit September 2014

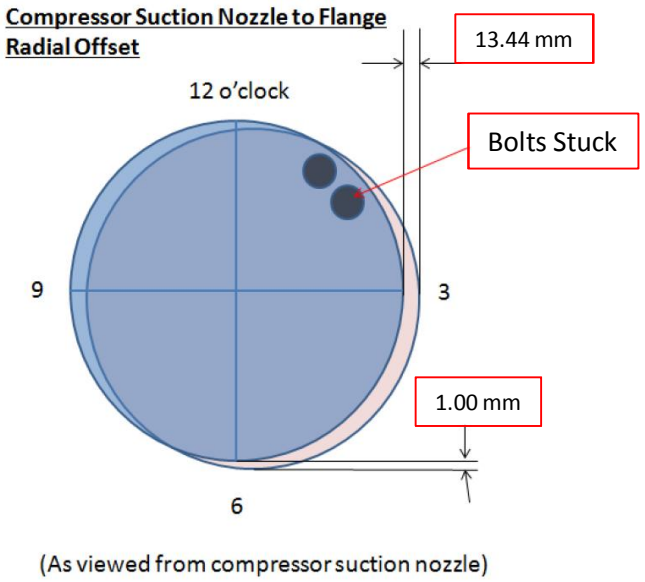
- Unsupported piping & valves.
- Soil settling in the valve yard.
- Severe damage in yard valve supports.
- Sandy soil composition.

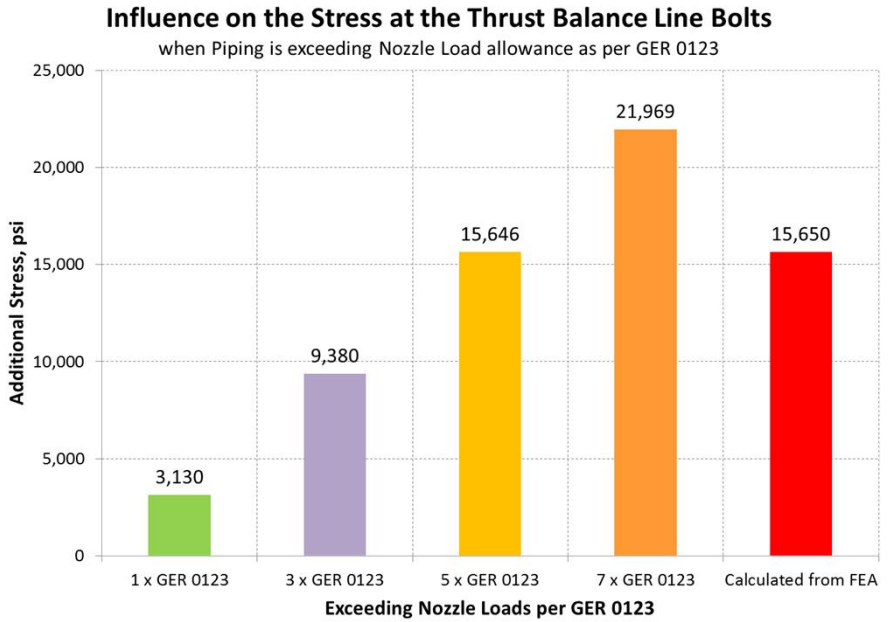


Site Visit (Cont.)

- Building floor with large cracks.
- Weakened piping supporting structure.
- Pipe underground support bent.
- Pipe underground support unsecured/loose.
- Loose / detached nuts from plate studs.

Site Outcome



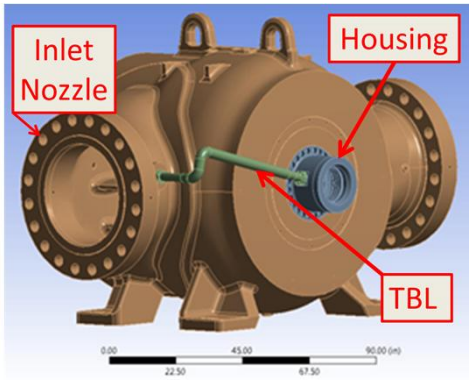


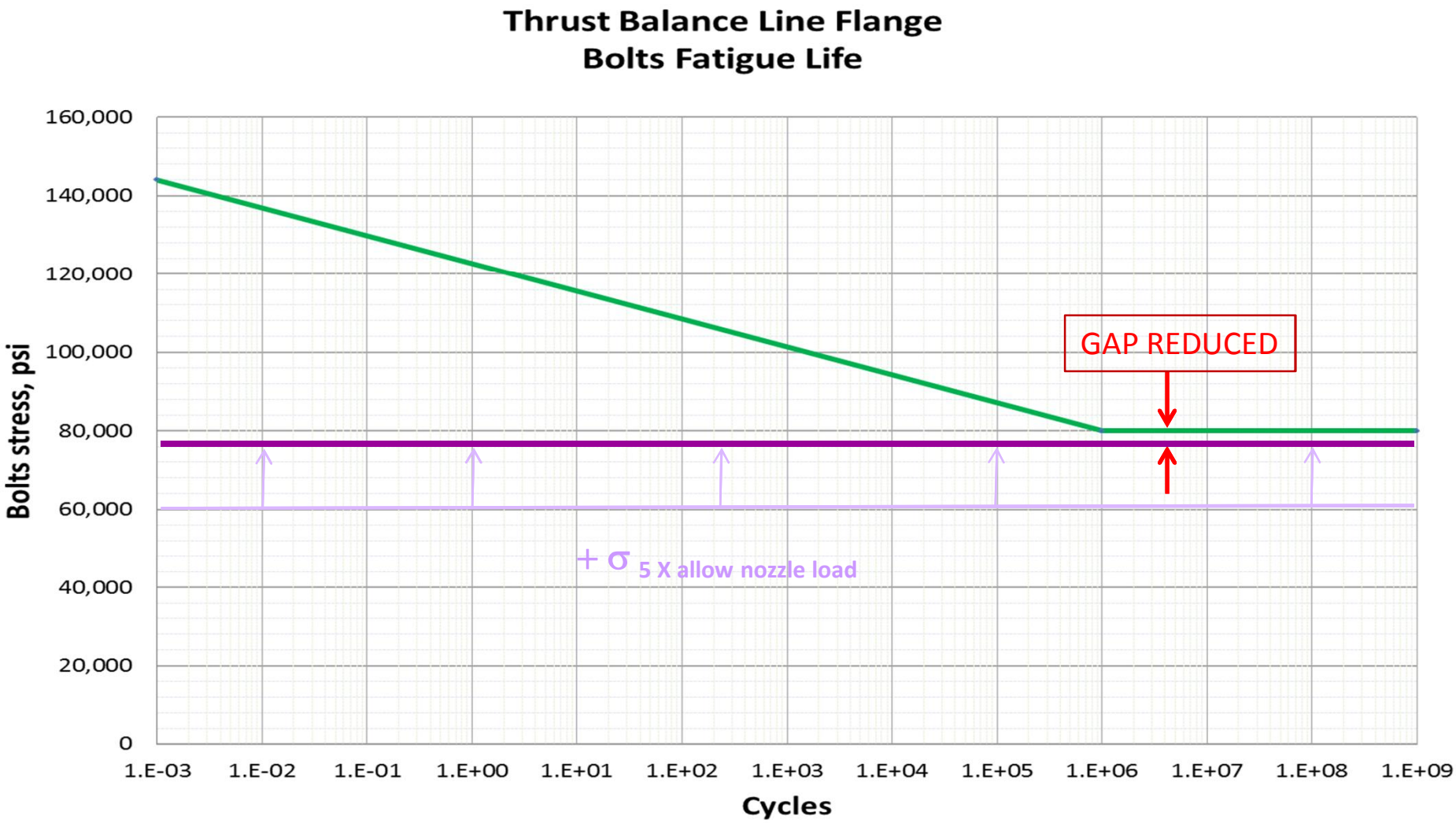
Calculated stress equivalent to five (5) times allowable nozzle load.

1 GER 0123 is at least 50 NEMA

More on Nozzle Loads…

- Nozzle loads are the net forces and moments exerted on the compressor flanges from the connected piping.
- These forces and moments are transferred to the casing at the connection flanges.
- The casing deforms, which also distorts the TBL, leading to stress at the TBL cap screws.
- The figure on the right shows the rigid TBL connected to the casing nozzle and housing.

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1.E+00
1.E+01
1.E+02
1.E+03
1.E+04
1.E+05
1.E+06
1.E+07
1.E+08
1.E+09
Cycles
GAP REDUCED
+ σ 5 X allow nozzle load

Solution: Short Term

- Restore and secure the piping support system.
- Inspect periodically the piping support system for cracks, looseness of nuts, piping movements.
- Keep existing damper at the thrust balance line.

Long Term Solution

- Provide solid foundation for the station piping system.
- Assure the piping supports system are at design conditions.
- Inspect the piping support system integrity.
  - ✓ Check nozzle flange-to-flange alignment.
  - ✓ Remove existing damper at the thrust balance line.

Lesson Learned

- Referring to the allowable nozzle load (GER 0123) in API 617 Data Sheet is not enough !
- Share and communicate this experience with customer early on at project kick-off/award phase.
- Include lesson learned note in API 617 Data Sheet.