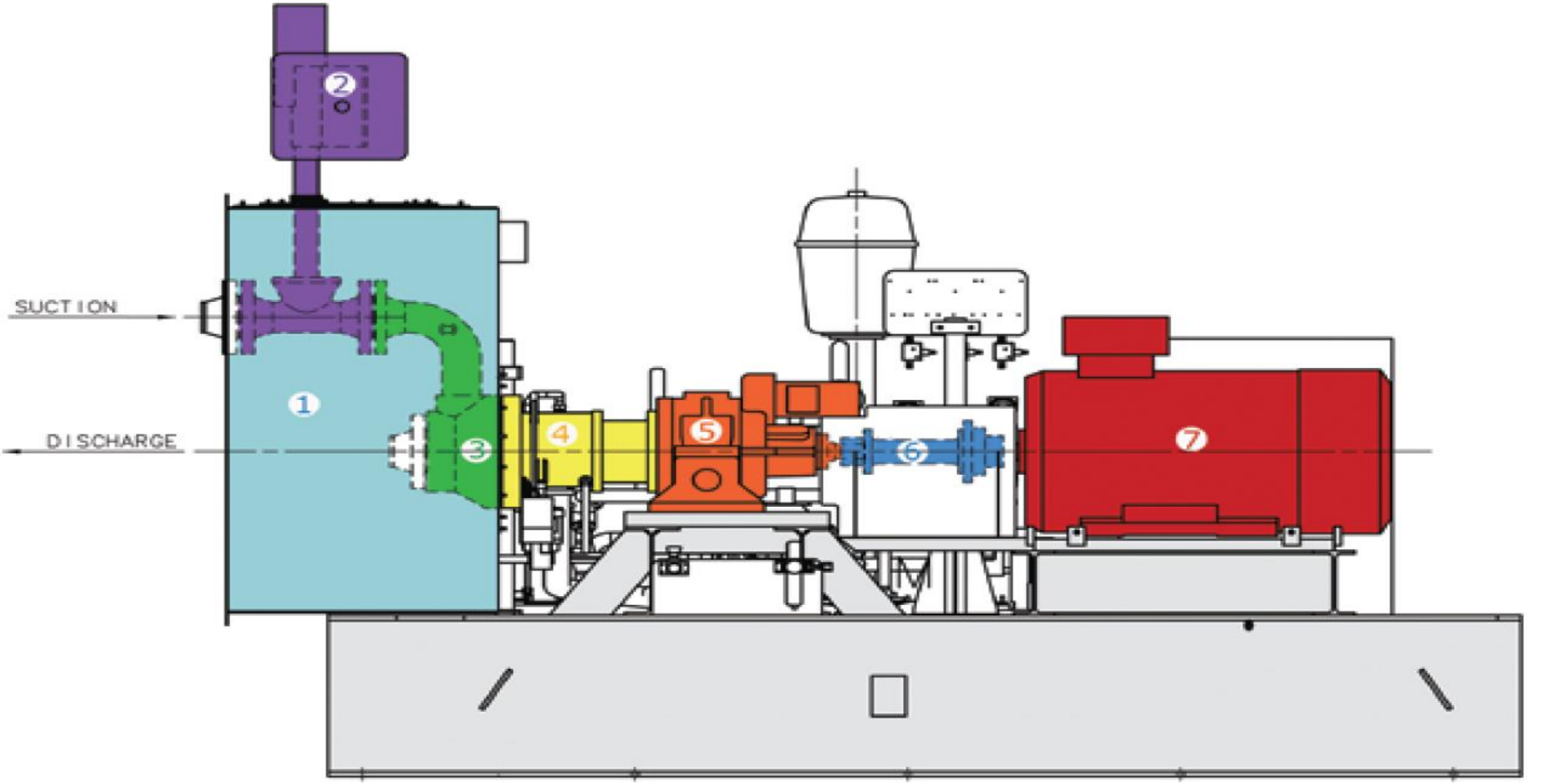
Ethane 1800 KW Turbo-Expander Reliability Improvement: Vibration & DGS Seal Failures

By Abdulrahman Alkhowaiter 2017



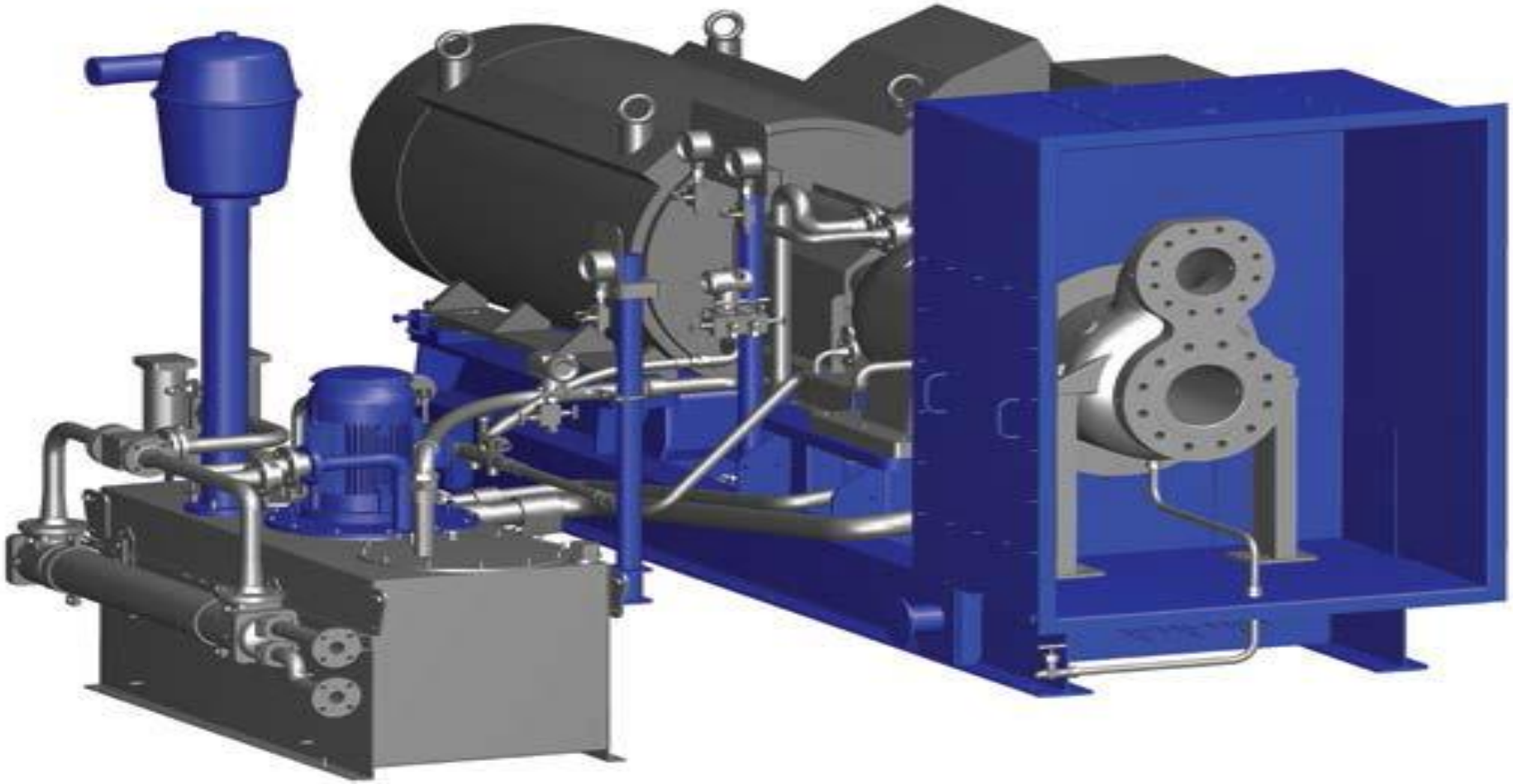
Introduction to Problem

The KGP Gas Plant NGL recovery was designed to utilize 2 x 100% Turboexpander-Generators of 1.80 MW size and 28,500 RPM to increase Ethane recovery from Sales Gas. Upon commissioning in 2010 the plant experienced many technical deficiencies with both Turboexpander generator units. Poor reliability with only one to two months operational. Losses were USD 38.0 MM total per year due mainly to Ethane Recovery Deficiency.

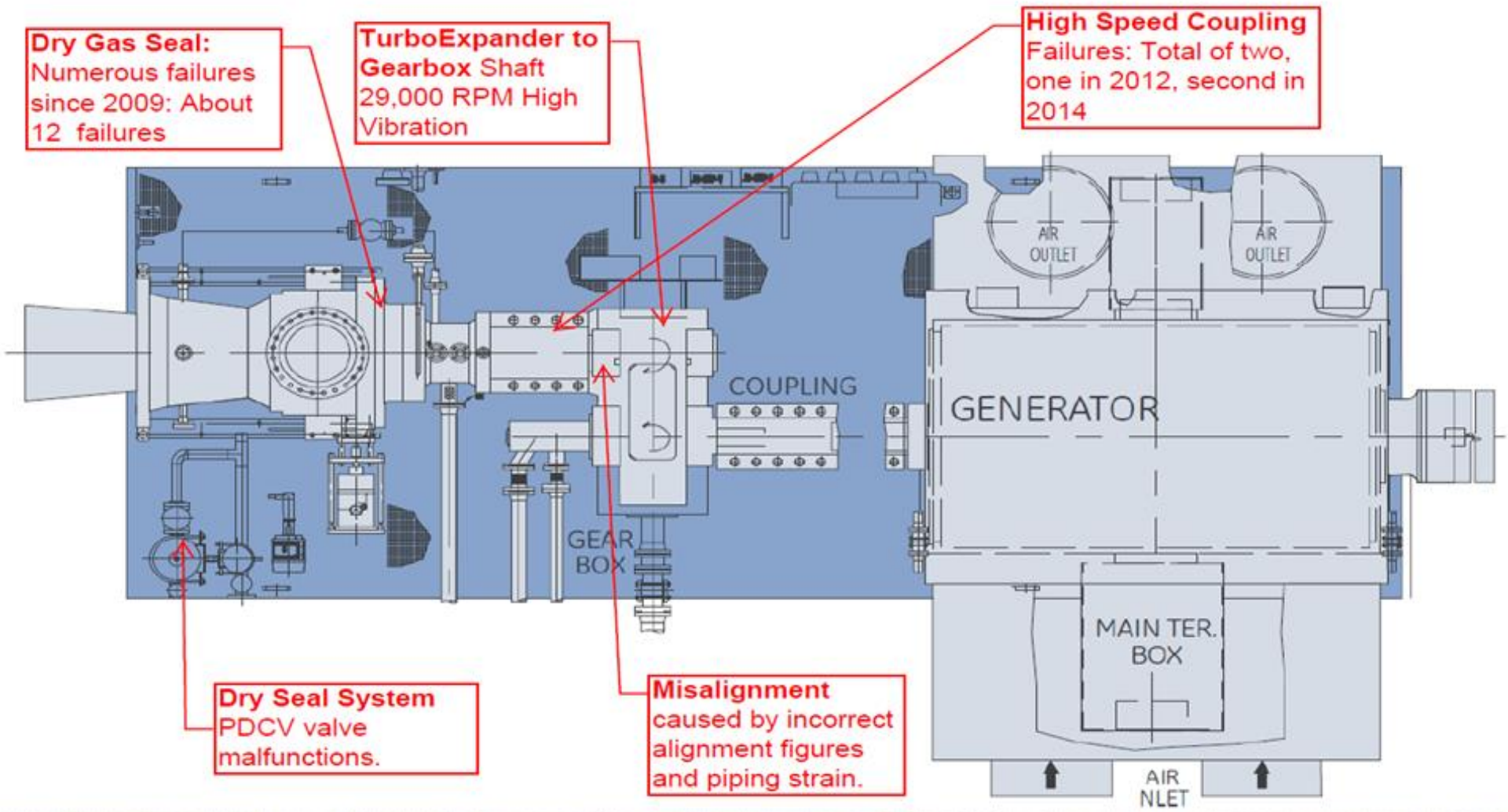
Plant requested to analyze the problem, main failures experienced:

- Gearbox pinion high vibration of 1.25 to 2.0 mills on both expanders high speed gearbox pinion to expander shafts. Frequency was at 1X operating speed. No vibration problem on Expander shaft bearings. Alarm: 1.0 Mills, Shutdown 1.50 Mills.
- Twelve Dry Gas Seal face failures due to manufacturer design errors in the Seal Cartridge and Auxiliary DGS system.
- Two High Speed Coupling Diaphragm Fatigue Failures.

Turboexpander is Lubricated and Uses Geared HS Shaft Drive to Generator



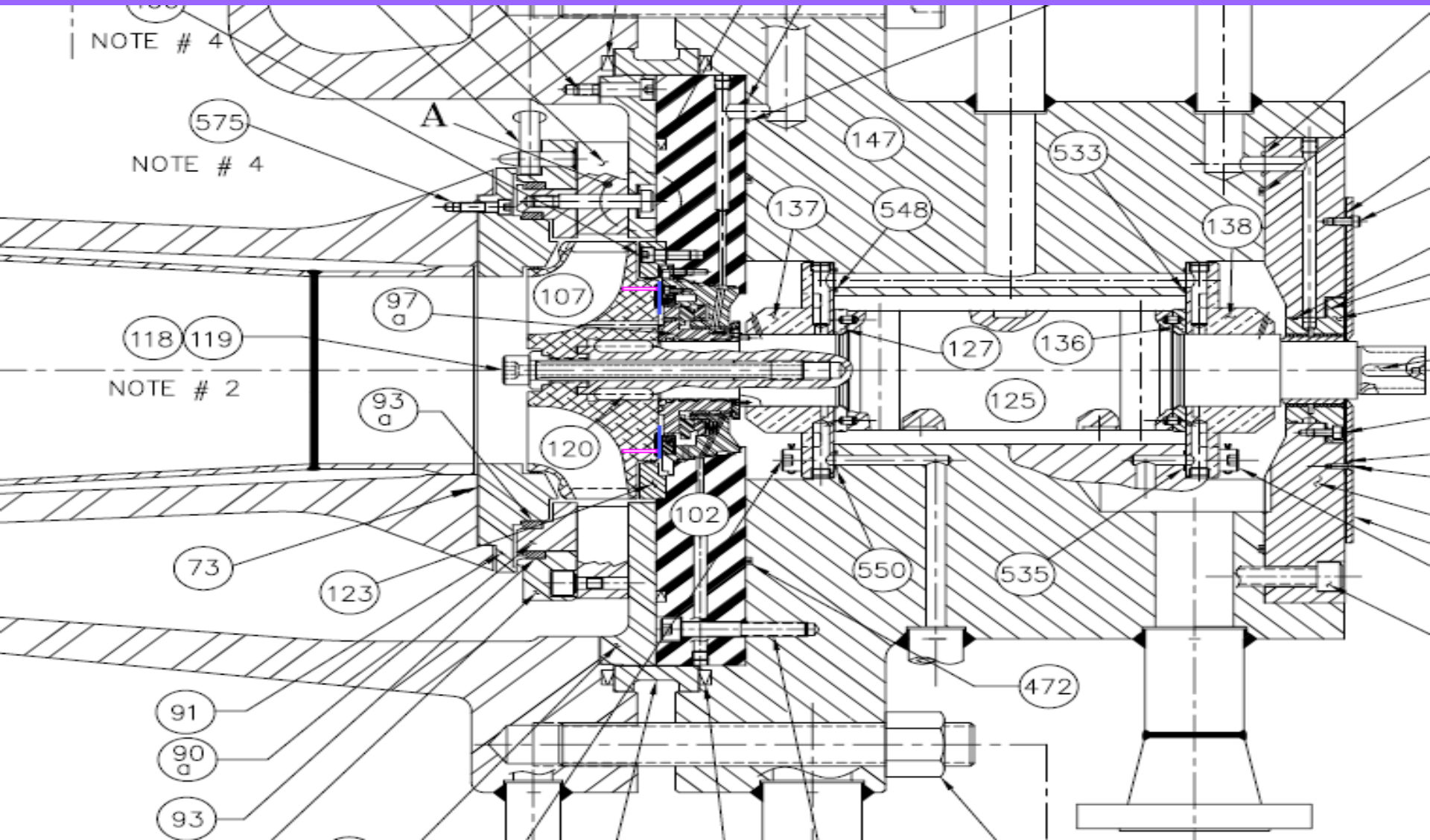
Mechanical Failure Locations



Initial HS Pinion Vibration: Root Cause Analysis Finds Several Issues

1. Turboexpander support footing on skid was studied and deemed too flexible with poor structural support to Turboexpander. OEM proposed a high strength and stiffness support cradle to be fabricated locally New support has 500% increase in stiffness compared to old. We had recommended this design with comment that new welded steel base plate thickness to be 25 mm minimum.
2. High Inlet-outlet Piping Strain was found due to poor LSTK design of piping. Piping engineers changed the design to reduce stress.
3. Turboexpander Coupling guard was redesigned to be a sealed coupling guard to exclude dirt and moisture. The coupling alignment figures were improved with hot Laser Alignment.
4. Shaft Coupling failures; OEM utilized the existing 28,500 RPM HS coupling. We recommended that they upgrade to better design couplings but OEM wanted fair trial of Existing Coupling.

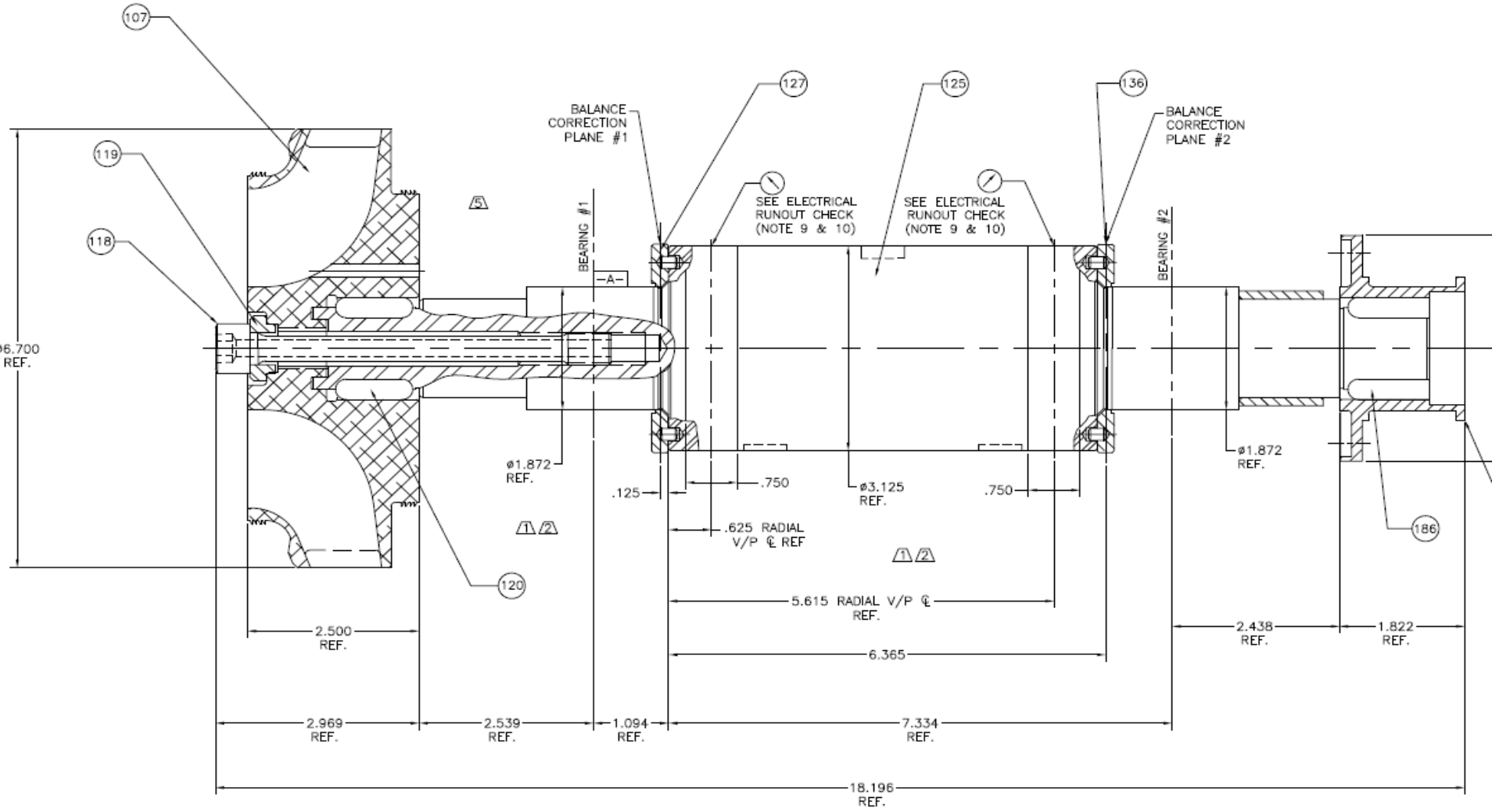
Drawing of Turboexpander: DGS Seal is Single Stage No Backup



Dry Gas Seal Failures: Design Solutions Which Resolved All Failures

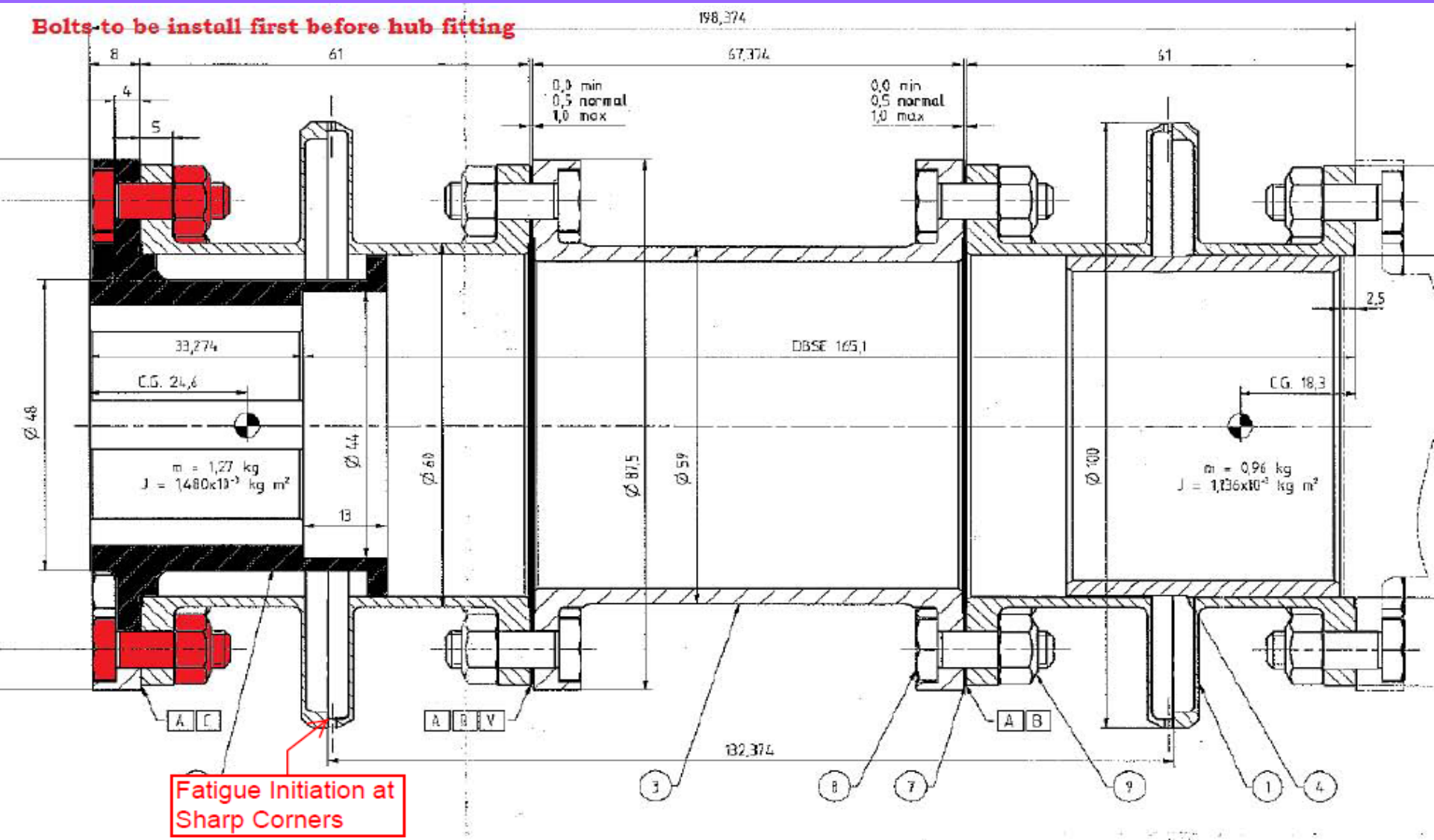
1. The dry gas seal cartridge oil deflector was modified to make a new larger OD design that excludes oil entry compared to old design. In addition we pointed out a new flow path that was allowing oil entry to seal coming from bearing 45 degree angle holes. OEM agreed to plug bearing leakage holes and drill new ones away from DGS seal cavity.
2. The Turboexpander heat barrier wall was redesigned with additional larger holes for DGS seal inlet gas flow and leakage vents.
3. A new seal gas control valve PDCV from Masoneilan was proposed with correct CV rating only 5% of original failed PDCV valve for review and approval. We commented that this valve is superior to existing.
4. DGS Seal Gas Filters to be upgraded from existing 3.0 micron size down to 0.5 micron. We suggested using 1.0 micron and this was applied.
5. OEM recommended changing to volume flow control of Seal gas feed, instead of existing pressure differential control. We rejected this as pressure control is more robust system. Middle solution was pressure control but maintain volume flow for monitoring purposes only.

Expander Rotor 28,500 Rpm
Large Diameter Bearings Max Vibration
0.30 Mills, Hydrostatic Bearings 400 Psig

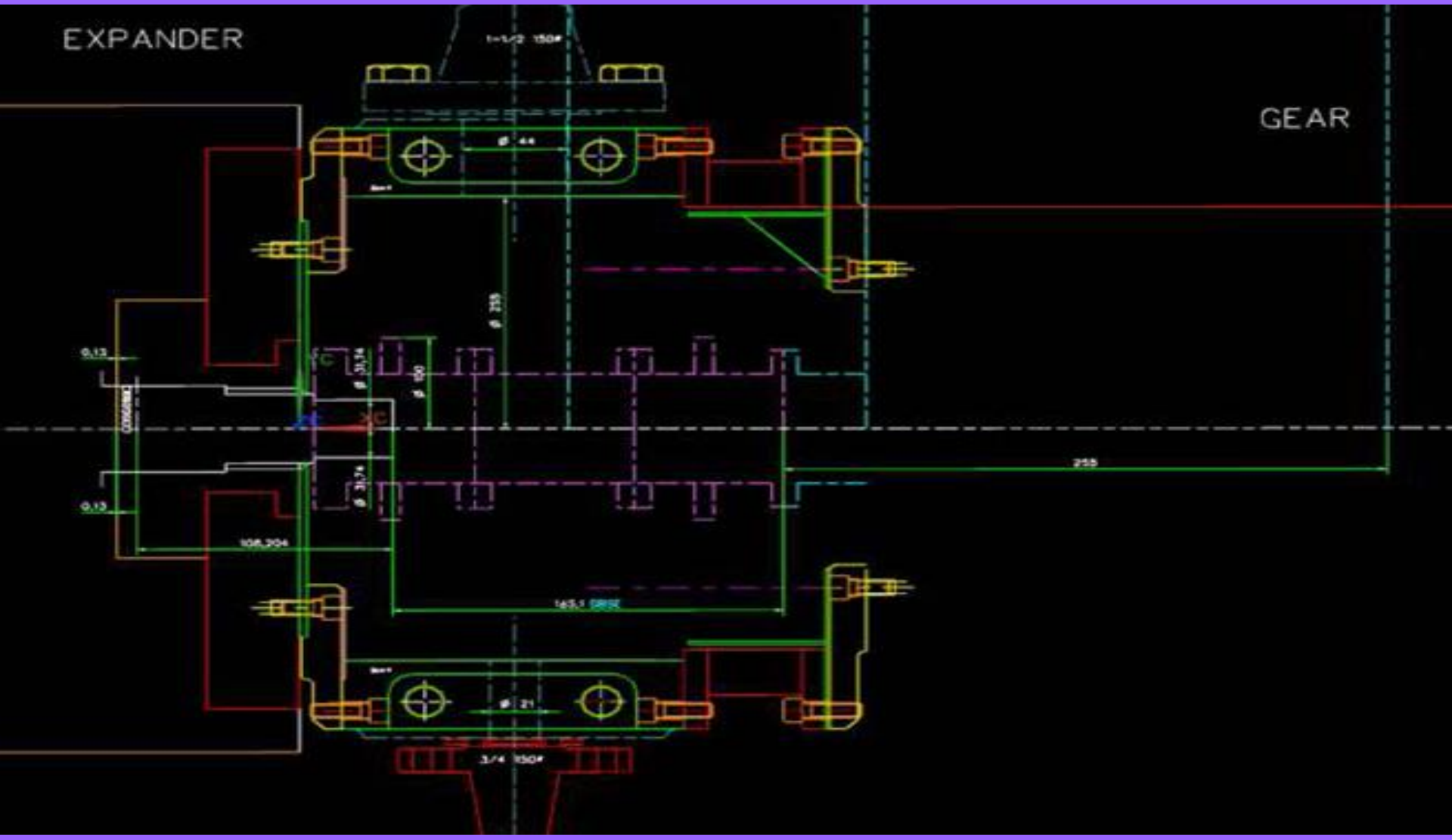


High Speed Coupling 28,500 RPM
No Sealed Guard: Dust Unbalance-Corrosion

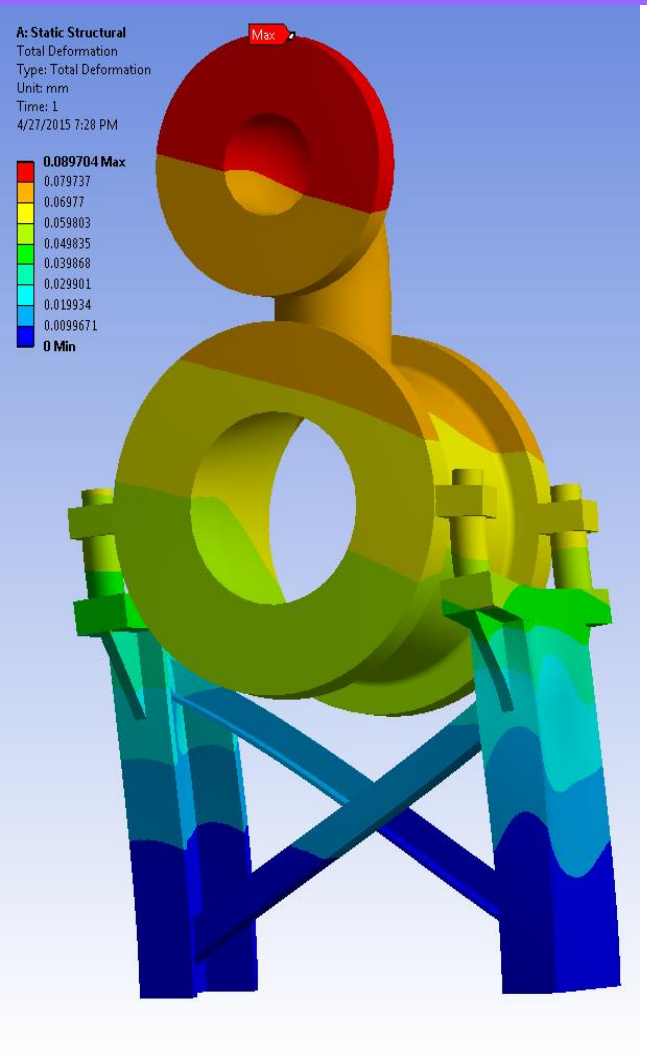
High Speed Coupling Failed Membranes Due to High Misalignment

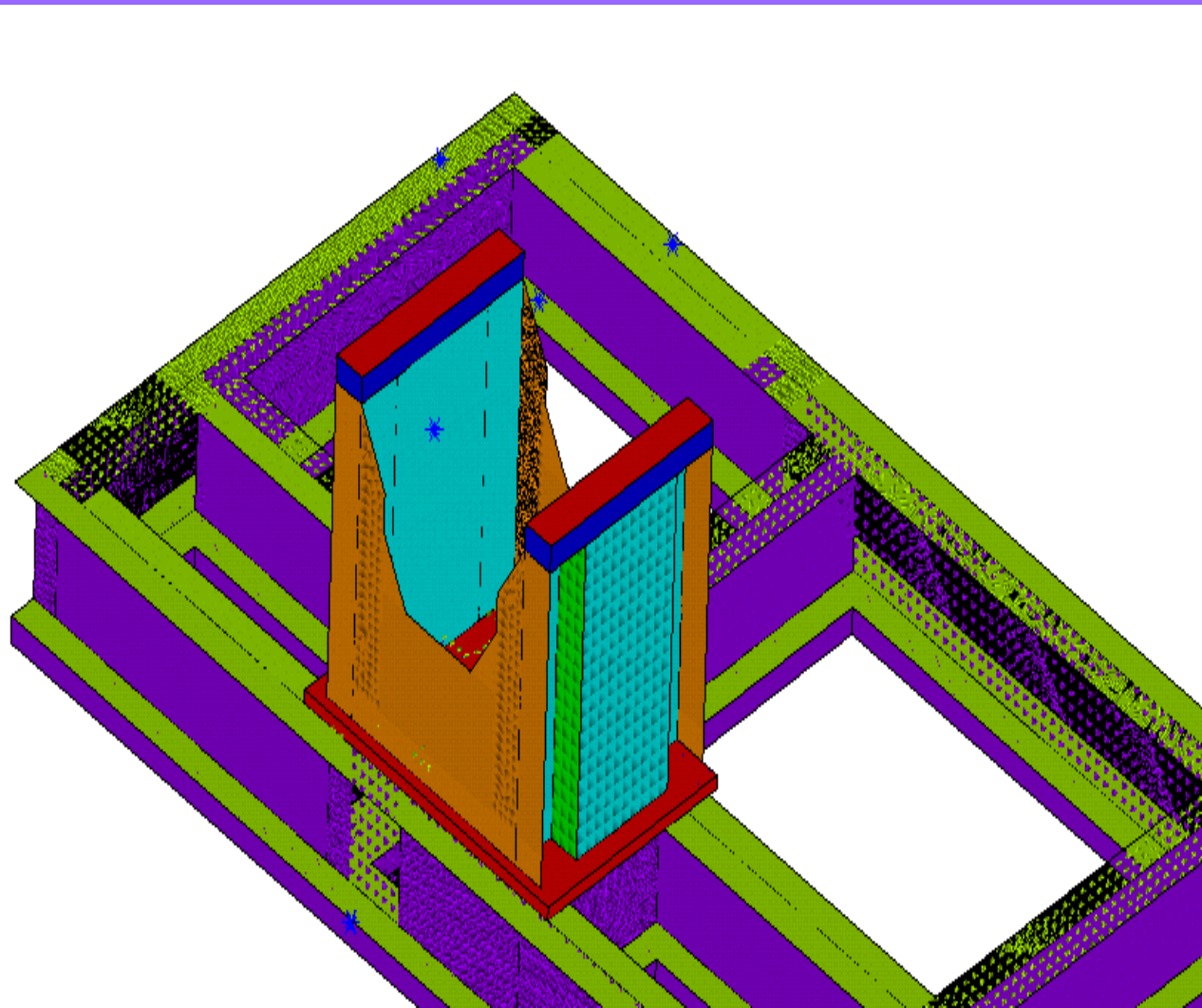


New High Speed Sealed Coupling Guard Designed By Manufacturer

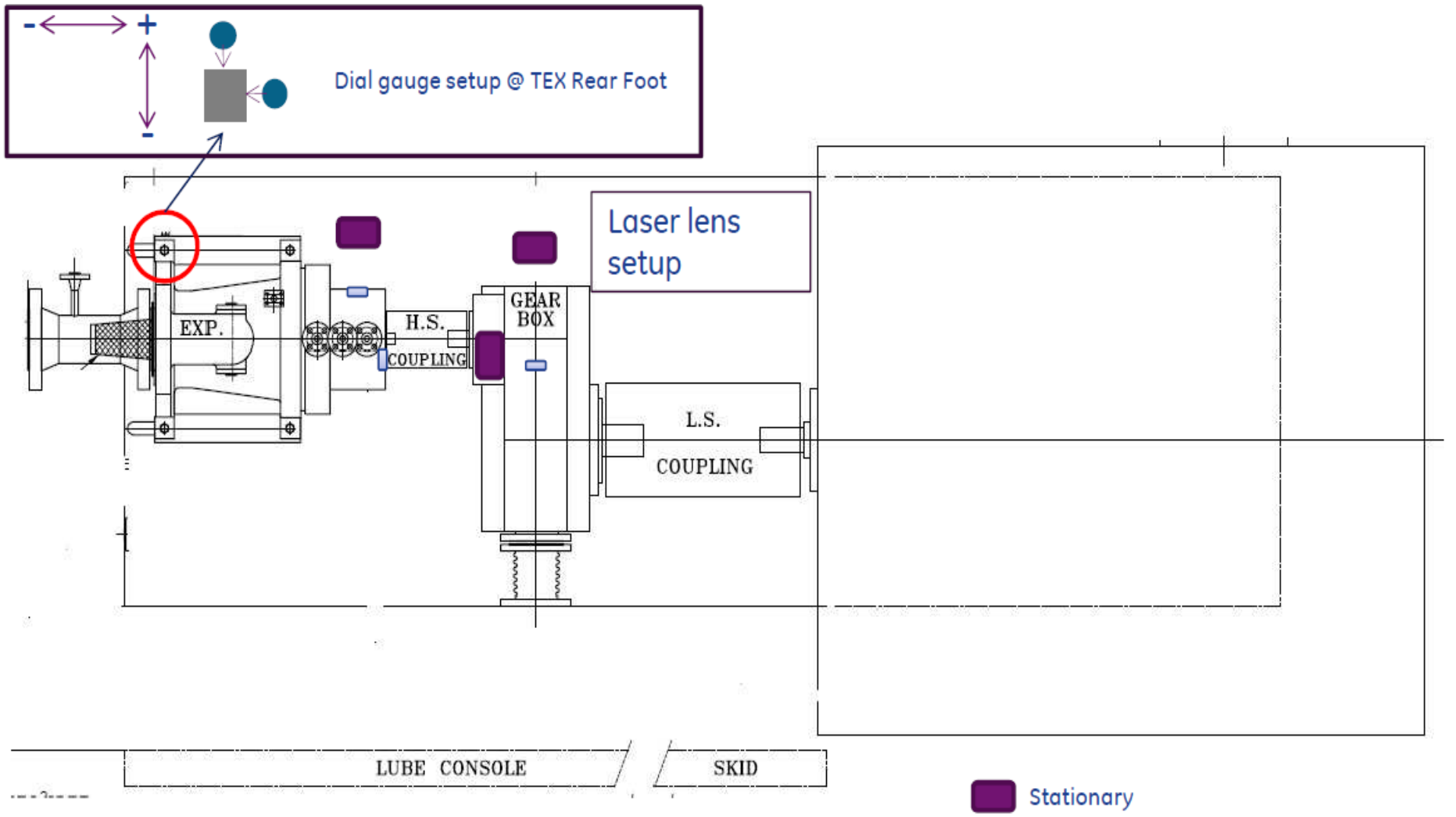


Expander Has Excessive Deflections: Poor Support Design; New Support 5x Stiffness

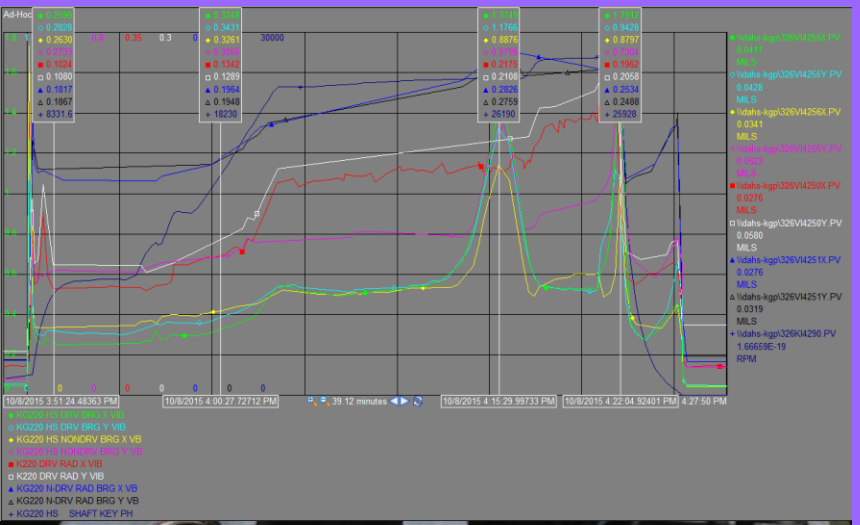


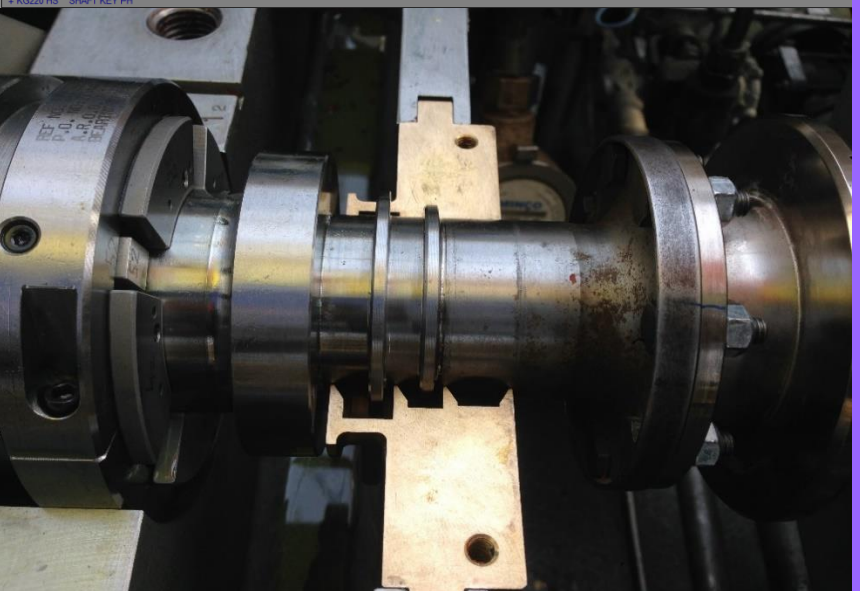


Highly Sensitive to Misalignment; We Requested to Perform Hot Laser Alignment



Bad News! After Design Modification: Vibration 1.70 Mills at Startup…..Back to Drawing Board





During startup on October 8, 2015, experienced Turboexpander HS pinion gearbox vibration 1.70 mills at 1 X and ½ X was experienced after loading at full speed. We initially focused on a rub indication at HS gear pinion shaft. In addition, the bearings did not show correct damping of vibration.

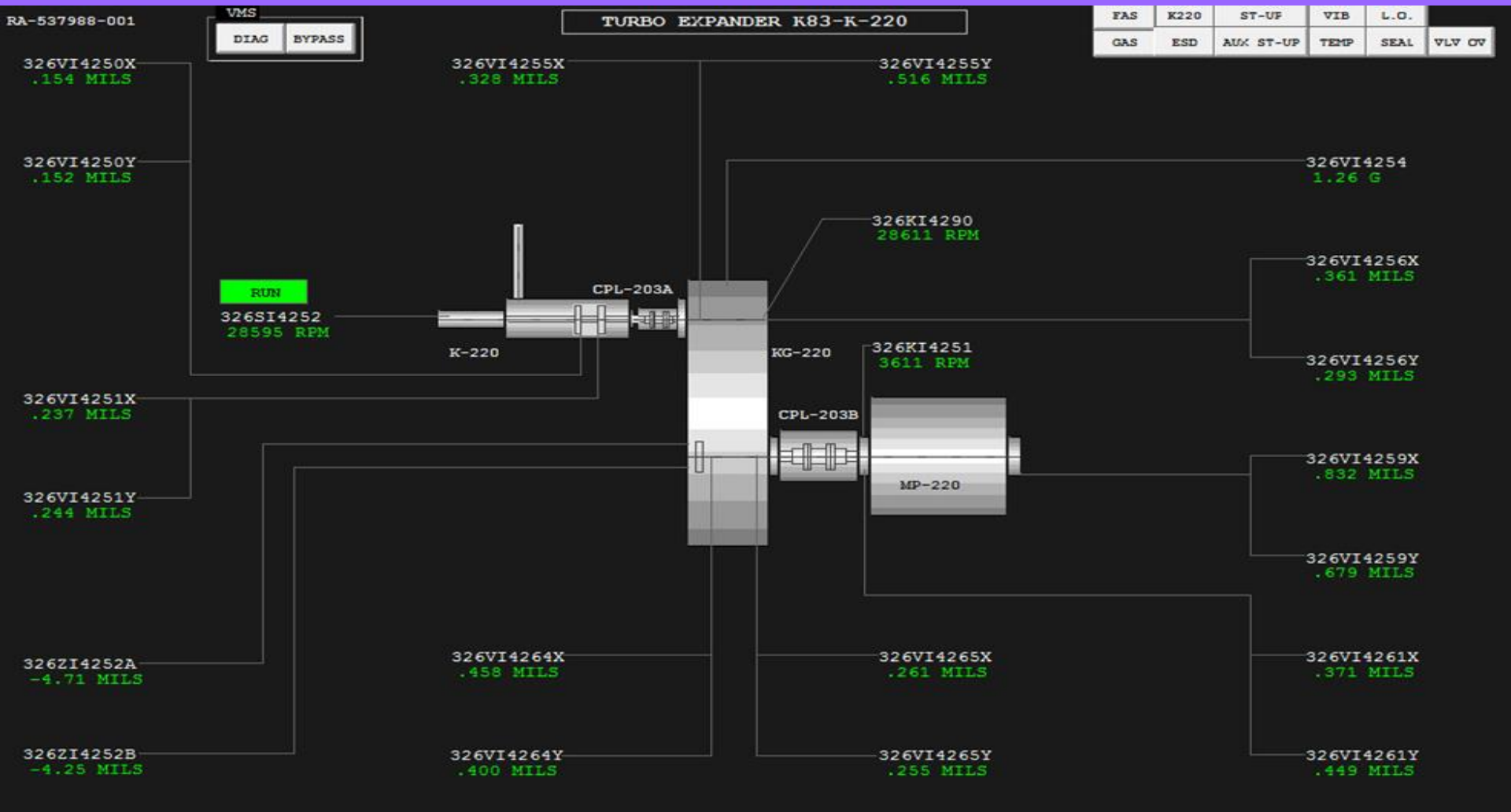
Findings of rubbing at oil seal labyrinth, and bearing high clearance to shaft. The gearbox manufacturer considered that the HS bearings at 28,500 rpm shaft speed were properly manufactured however we disagreed and installed shims inside bearings to *reduce clearances by 50%.*

HS Gearbox Bearings Clearance Reduction and Removal Of Labyrinth Rubbing

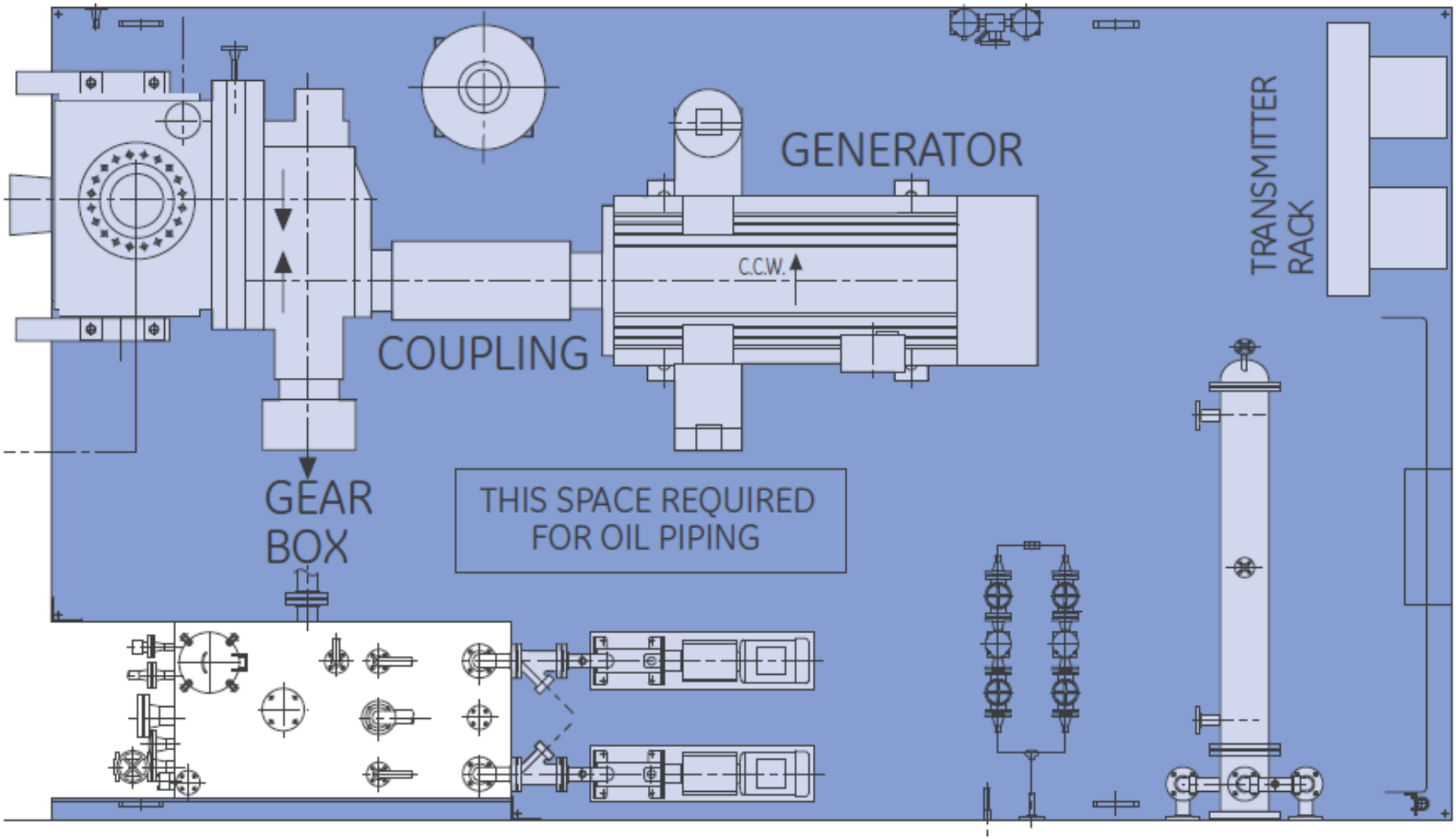
1. KGP Ethane Recovery Plant Turboexpander K-220 was started successfully on October 13, 2015 after major modifications. It met full Ethane recovery load of 1.75 MW electrical output, with all mechanical and process parameters smooth, only 0.53 Mills vibration HS. New deficiencies found were rubbing at HS pinion Laby due to OEM manufacturing, and gearbox incorrect bearing design clearances; these were reduced from 0.008 to 0.004 inch.

2. From the ten major design improvement ideas applied we developed nine of the ten design changes including new heavy duty support cradle under Turboexpander, new sealed HS coupling guard, new design dry gas seal cartridge, new dry gas seal auxiliary system components such as PDCV valve, improved piping supports, improved coupling alignment procedure, and new decompression shutdown valve. These improvements were completed in detail design by the manufacturer.

Both Turboexpanders have been functioning with excellent mechanical parameters in 2015 to 2020.
In 4.5 years zero vibration problems; only one machine shutdown due to DGS failure. MTBF was 1.0 Month, now 4.5 years= 5400% Improvement



In Future: Integral Geared Turboexpanders To Eliminate High Speed Couplings



Extreme Mechanical Reliability Improvement: 1800 KW TurboExpander

Reliability Engineering in Turbomachinery application: The study of Root Causes and formulation of root cause solutions is a two step process. The improvements to Machine, its Shaft Seal and Auxiliary system, its process piping system, came together to resolve the root causes of machinery failure. Payback is USD 38.0 Million per year.

1. There were 5 years of continuous problems in 2010 to 2015; now the operation staff have forgotten about them; they are quiet and never fail. No shutdown PM's needed.
2. Total cost to apply all improvements to both Turboexpanders was in range of USD 2.40 million. But then the OEM learned how to make reliable machines.....:)
3. There was only one DGS seal failure in the past 5 years period...it was OEM and Plant fault for having excess moisture in buffer gas which is fuel gas. We had requested a gas pre-heating unit but TurboExpander OEM had said not required.