

# Head-flange O-rings on Barrel Type Centrifugal Compressor Units at RasGas: issues & resolutions

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## **Abstract:**

RasGas is operating many centrifugal compressors from different major OEM's. Of an OEM product-line, twenty-four (24) centrifugal compressors with a total rated power of roughly ~ 900 Mega-watt are in operation, out of which 16 are barrel type (BCL).

Driven by an end-cover or Head-Flange (HF) O-ring failure during early months of operation, indicated via gas leak in to atmosphere, a series of actions were taken due to serious uncertainties of the HF O-rings reliability, for both the units already in operations and the ones under Pre-Mechanical Completion.

Actions included materials properties, tests data, selection (e.g. spliced versus single piece) and manufacturing processes and O-ring makers and supplier's traceability. A comprehensive Risk Assessment led by Project Team and supported by EM experts was carried-out to determine whether HF O-rings already installed in similar unit shall be replaced right away prior to putting it in to full operation.

Test schedule to accept or reject assembled HF at site was defined. Small modifications for continues monitoring of the HF O-rings during operation was also established.

This Case Study is intended to share some lessons of technical aspects reviewed including selection processes. Site challenges to replace the HF O-rings for such barrel type centrifugal compressors and the site test schedule are also covered.

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# Objective

LL sharing from HF O-rings failures on large size barrel-type centrifugal compressors.

- ✓ *Best practices – vent monitoring & recovery system, leak test procedures*
- ✓ *Single-piece mould O-rings, factory and/or site leak tests at commissioning phase, post intervention*
- ✓ *Precautions: selection, manufacturing records, preservations*

# Problem description

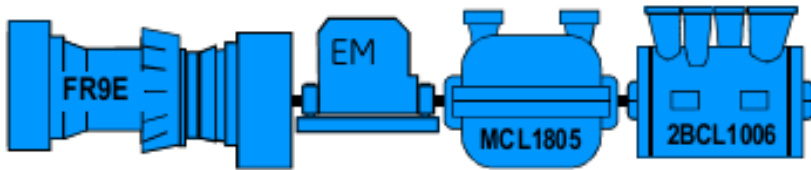
*During commissioning of mega LNG trains in 2009, gas leak from barrel end-wall was experienced during pressurization process. This problem was also noticed on existing compressors which were in operation for about 5 years.*

Site view: compressors driven by F6B and F9E



# Arrangements

## MIXED REFRIGERANT



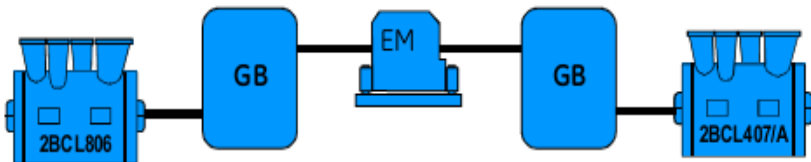
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## **16 BCL units**

- BCL 803 HF O-rings failure during commissioning
- BCL 806 leakage after ~5 years operation, 35 % LEL at split line, 0.0 at ~ 0.5 m.
- BCL 806 leakage after ~ 5 years
- 2BCL1006 upgrades, opportunity



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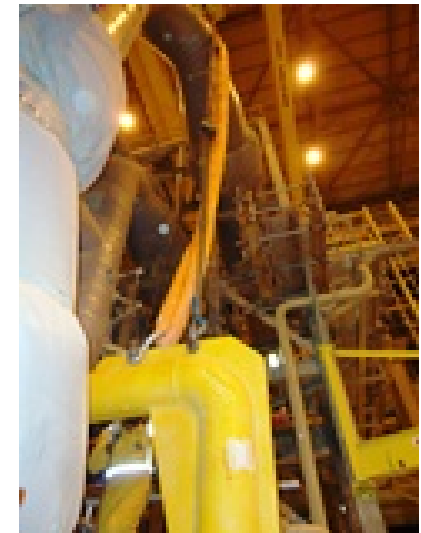
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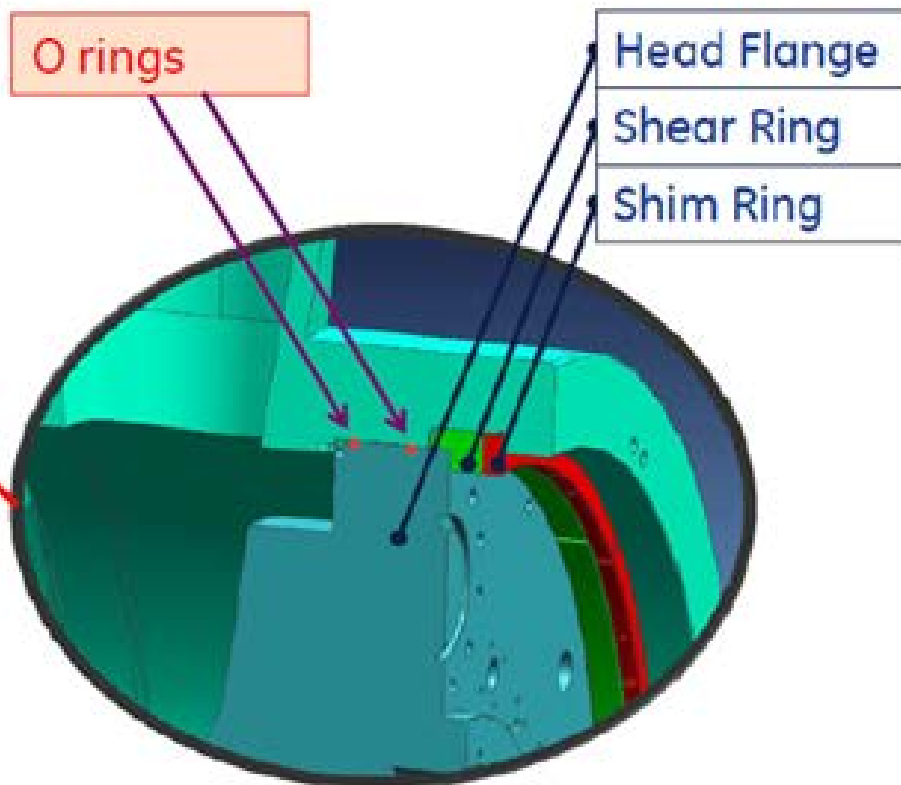
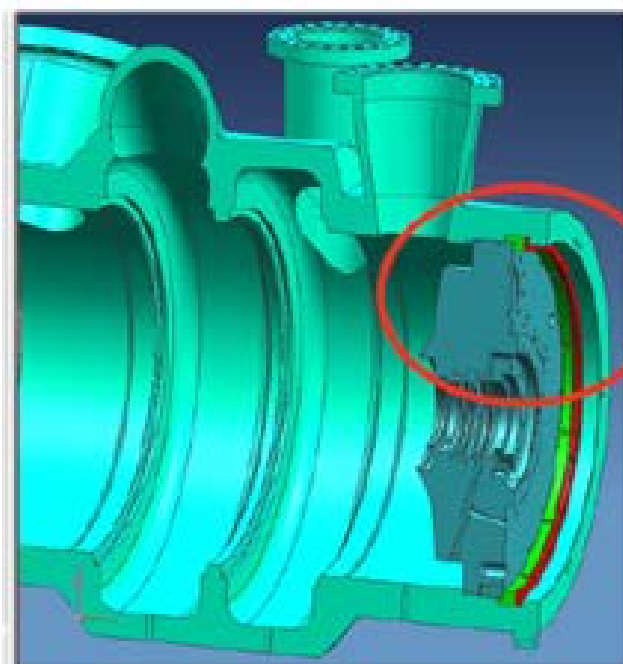
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# Field Challenges

- Time
- Large size, heavy components and assemblies
- Tooling for HF removal
- Space
- Risks associated during removals / installations HP couplings, bearings and seals, shear and shim rings

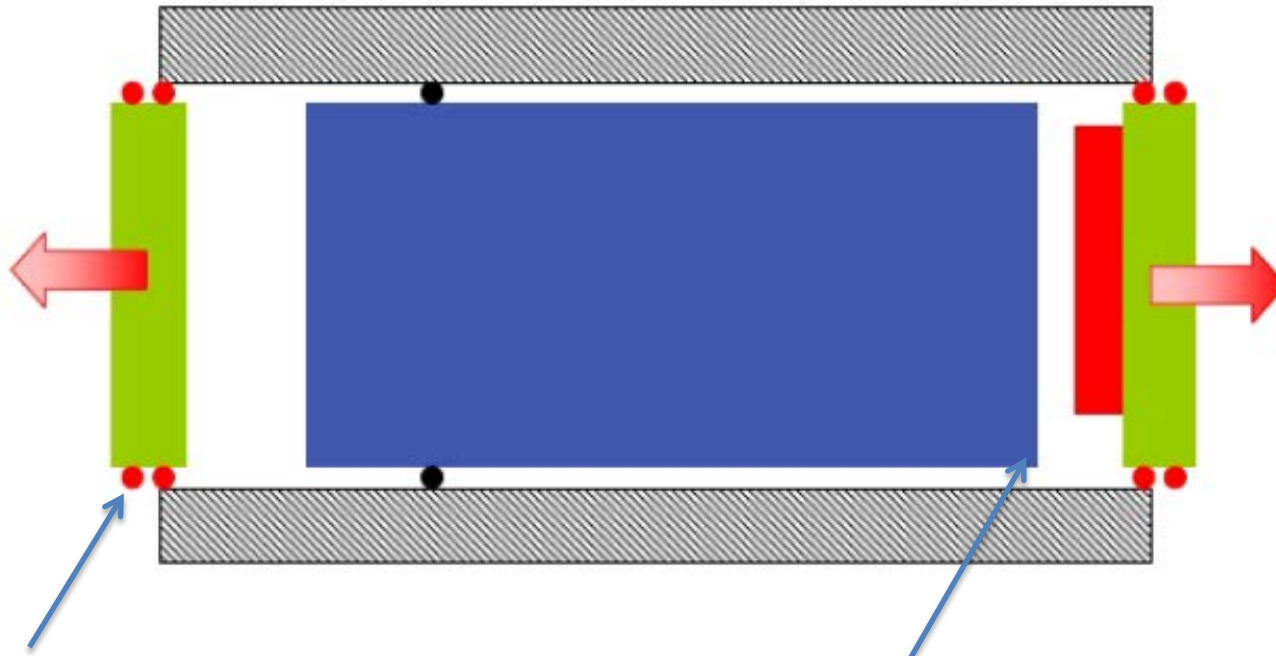


# ***Centrifugal Compressor's head-flange and the O-rings***





# Typical BCL compressor diagram



Head-flange / end-cover O-rings,  
used earlier was split design.

Compressor bundle with  
O-ring.

*Data of suction head flange:*  
Weight = 13220kg  
Outer diameter = 2360mm  
Width = 270mm about

*Data of discharge head flange:*  
Weight = 13200kg  
Outer diameter = 2360mm  
Width = 270mm about

*Data of discharge diaphragm, bolted to  
discharge head flange:*  
Weight = 4000kg

# Failure analyses and techniques (failed LGR machine O-rings)

- Defective O-ring material: specified FKM materials would have been suitable for the duty specified.
- Spliced O-rings: A leak from the casing head flange on the drive end (discharge end) of the T6 Lean Gas Re-compressor (LGR) was found in June 2009 during the duty runs (dynamic test runs). Upon inspection, technicians found the two O-rings were defective. The outer O-ring had two splice joints that had failed; the inner O-ring had one spliced butt joint that had failed and a mechanical tear. Both O-rings had surface imperfections.
- O-ring groove geometry: found as per design. However to meet new material, cord dimension was increased.

# Failure analyses: spare O-rings condition in warehouse, stored for few years



- Preservation condition acceptable, however, defects (cracks) on joints were visible.
- Spare O-rings presented evidence of cracks without any bending and failed by bending @ the bonded joint.
- No evidence of vulcanization except adhesion.

# Failure analysis and techniques (failed LGR machine O-rings)

Shop test was at 66.8 bar G / 30-min / with N<sub>2</sub> per API 617. No leaks observed. Spliced O-ring might pass 30-min leak check, but fail once in service at operating temperature (100+C) and pressure pulsations.

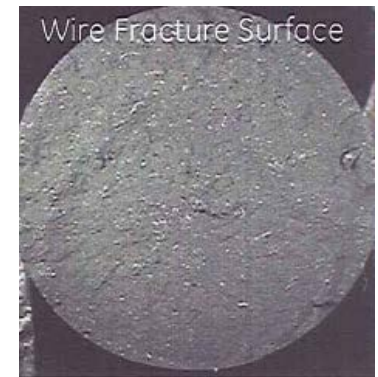


# Failure analysis and techniques (failed LGR machine O-rings)

- Explosive decompression : Visual inspection of inboard O-ring indicated minor blistering phenomenon revealing explosive decompression. FKM75 would have resisted to ED provided compliance with the specs.
- O-ring extrusion : Cross section and dimensions verification did not reveal any extrusion.
- Fracture surface inspection.
- Shore A hardness test : Result is 68 against requirement of 75.
- Density test : Result is 1.85 gm/cm<sup>3</sup> as per specification.

# Failure analysis and techniques (failed LGR machine O rings.)

- Joint resistance Test: Rupture at 35 kgf and 55 kgf for NDE side O Rings and that is 18 and 35 % of specified base material strengths.
- Wire Resistance test : failure produced with 120 kgf that is 61 % of expected strength.
- FTIR analysis : Sample spectrum compared with library and material confirmed to be Fluoroelastomer (FKM or Viton).

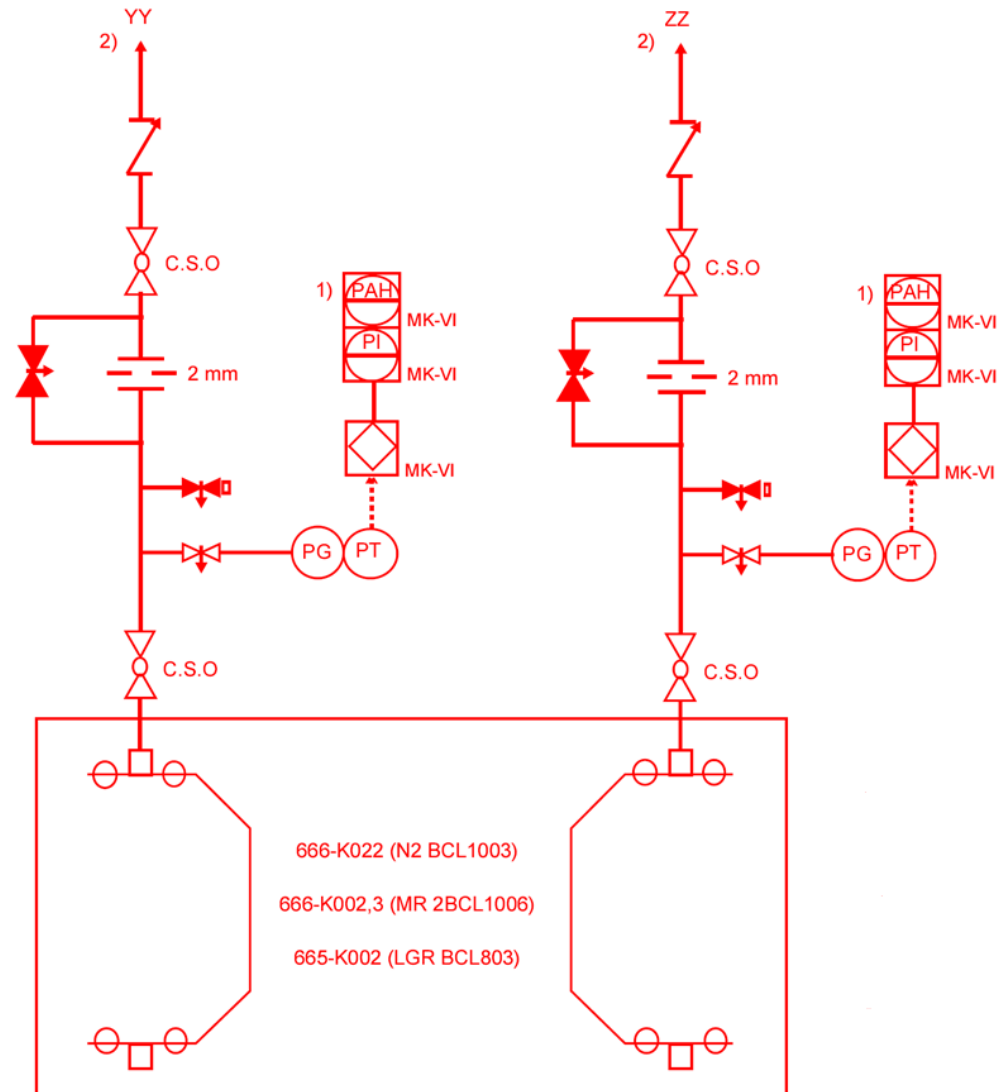


# Failure analysis and techniques (failed LGR machine O-rings )

- Joint of was not obtained from from vulcanizing process, but more of a gluing process
- Poor quality of the joint glue, irregular interface and the lower strength materials all combine to make a joint that will not last many pressure cycles. During normal operation, process gas enters the gaps in the joint. When the compressor shuts down, the pressure in the joint gaps pushes the joint apart.
- Thermo gravimetric analysis (TGA): Ashes mainly consists of Magnesium and that is representing filler (MgO). Viton is about 85 % and Ash 15%, weight loss temperature is 615 Deg C.
- O-rings for MR and N2 units: found to be Viton 90 and better splicing / vulcanizing techniques.

# Best practice : Head Flange Vent Recovery System to contain leak

- The gas from the recovery system routed directly to flare line.
- Remote monitoring provided for cavity pressure (space between two O-rings).





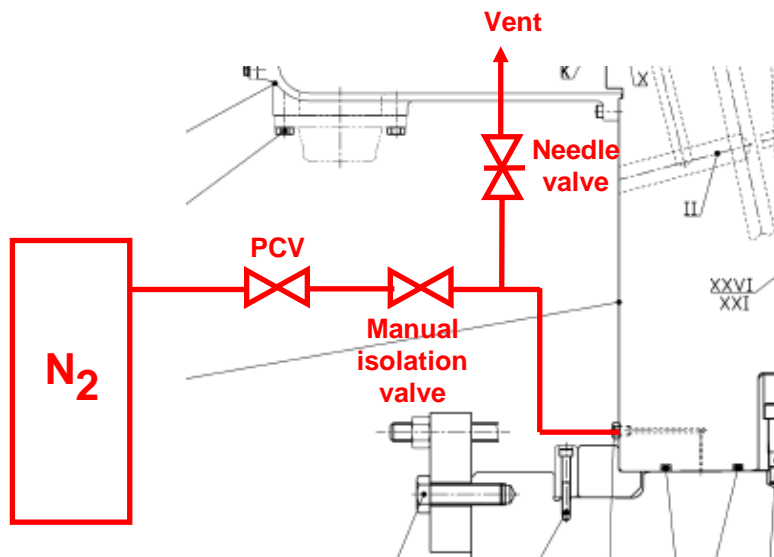
# Best practice: End wall O ring Leak Test Procedure

- Connect a source of nitrogen (e.g. line or bottles).
- Test loop shall also include: pressure control valve (PCV), manual isolation valve, needle valve

Acceptance Criteria :

Pressure indication can be helpful, but not easy to determine acceptance criteria.

API617 requirement states "... no bubble formation is observed".



# Best Practice: End wall O ring Leak Test Procedure

- Sprinkle compressor end-cover with foam.
- Close needle valve and leave open manual isolation valve. Set PCV at the required pressure and start pressurizing the cavity. Test pressure shall be compressor normal discharge pressure or, in case this is higher than nitrogen external source, maximum pressure available.
- Start searching for potential formation of bubbles on foam, evidence of leakage. After 15 minutes close manual isolation valve.
- Slowly open needle valve and gradually vent nitrogen.
- Repeat cycle 2 times for a total of 3 test cycles and for each compressor side (suction and discharge).

# Solution

Typical comparison of Old O-ring and New O-ring materials

Property	Old design, NGL5	New Design
O ring dia, wire diameter	1630 mm and 14 mm	1660 mm and 15 mm
Generic Material, PPE grade	FKM, V75J	FKM, V91J
Hardness ° IRHD	Shore 75	Shore 90
Min Max Temp °C	-15 / +200	-17 / 225
Tensile strength	17.4 MPa	24 MPa
Elongation at break %	300	210
Manufacturing	With joints	Single Mould

# Recommendations

- Material selection process to be improved. Detailed purchase specifications with QA/QC checks issued. Single mold O-rings are preferred.
- Usage of 90 durometer O-rings for better Explosive decompression resistance.
- Sub-vendor product records to ensure traceability
- Proper storage in temperature controlled environment and with proper packaging (see 'guidance' @ last page)
- Installation of Leak Monitoring and Recovery system to be specified from project stage. Also Leak test to be performed during start ups for O ring health check.

# Recommendations

- O-ring materials shall be compatible with all specified services and to ensure they are not prone to and will not be damaged upon rapid depressurization (explosive decompression).
- Installation of gas detectors near centre line of compressor.



# Recommendation: O-ring storage guidance

- *Stored between 15 and 25°C, away from direct sunlight/ultra-violet light, preferably in black bags.*
- *Protected from all sources of ionizing radiation likely to cause damage to the products*
- *Storage rooms should not contain any equipment that is capable of generating Ozone.*
- *Humidity should be less than 70%.*
- *Elastomer seals should be stored free from tensions or compressive stresses or other causes of deformation*
- *The seals should not be stored with or in contact with other rubber seals, liquids etc.*
- *Storage should comply with BS ISO 2230:2002 'Rubber products - Guidelines for storage'*