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Conversion of a horizontal split centrifugal compressor with a closed impeller to an open face impeller with a one piece diaphragm.

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He has a Bachelor of Engineering with specialization in Mechanical Engineering from RMIT (Royal Melbourne Institute of Technology)

Abstract

A 1970 vintage polyethylene plant faced a market driven requirement to improve its polyethylene grade.
The improved, new grade required a new highly reactive catalyst and needed to be ready for customer's product trial in less than 12 months.
The catalyst licensee recommended that a new replacement compressor would be required for the new grade however this would require a high capital outlay, a three week outage for installation and 18 months lead time.
A review of the original horizontally split compressor and its suitability to be converted to an open face non fouling design was made. This included the potential to use a one piece inlet diaphragm. This approach resulted in an upgrade that was 60% the cost of a new compressor, a fast tracked delivery in 9 months and a conversion that was completed in a 1 week outage.

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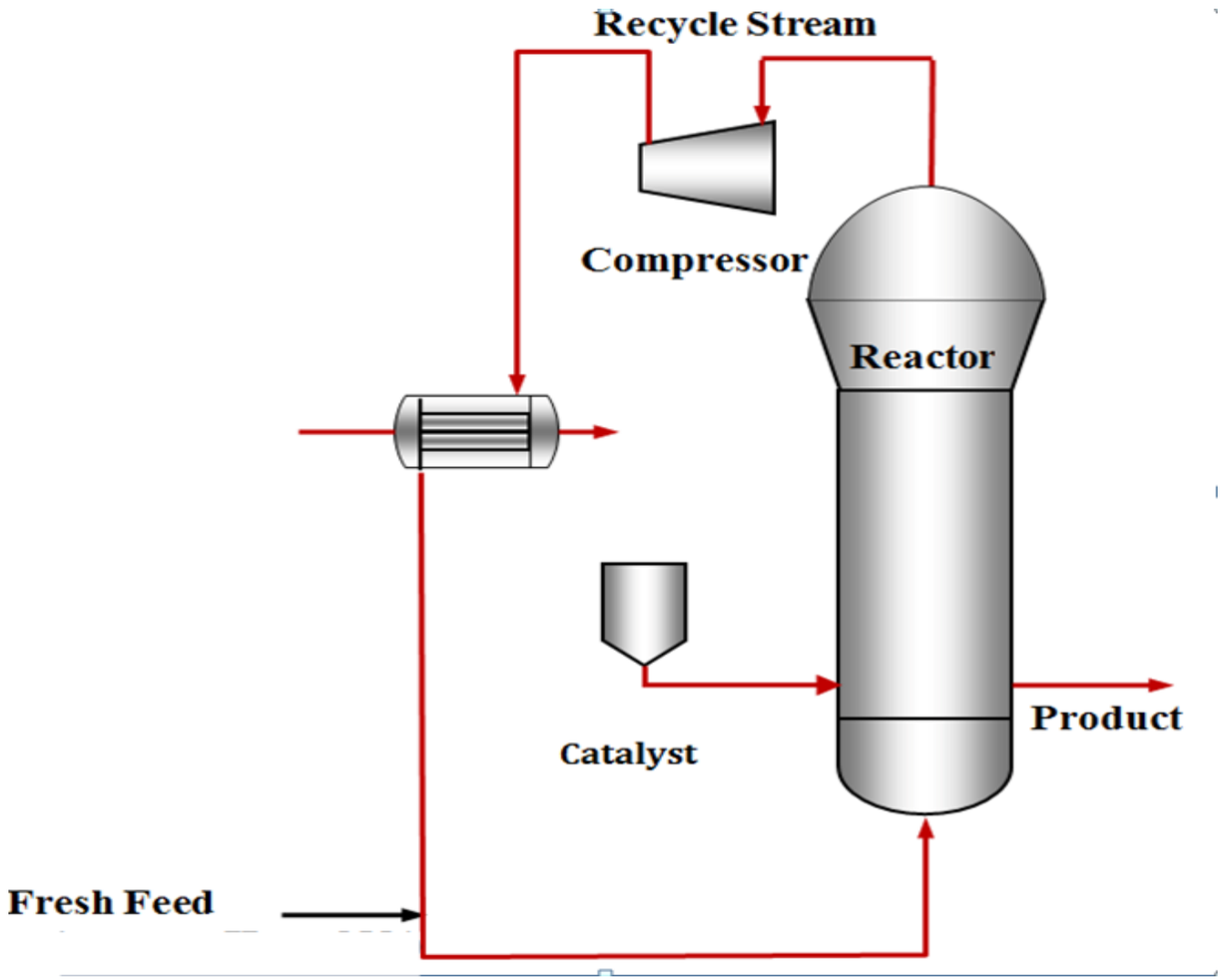
Introduction

- Polyethylene fluidized bed reactors
- Exothermic gas to solid phase polymerization reaction
- Cycle gas compressor
- Cycle gas cooler
- Distribution plate
- Fouling and its impacts to production and quality



Problem Statement

- Requirement to change polymer/catalyst grade within 12mths to stay in business.
- Catalyst licensee identifies major risks associated with existing compressor design and recommends compressor replacement.
- Replacement compressor review finds
  - High capital outlay,18mth delivery,3-4 week installation outage for replacement.
- Do nothing and chance the new grade/catalyst with existing hardware ?
- Can the existing compressors internals be modified within the available time?

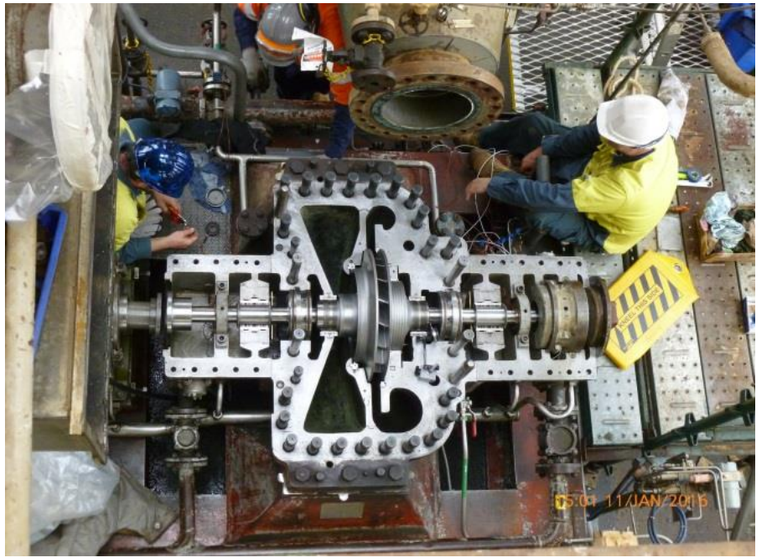
How to tackle/resolve the problem

- Examine the differences between the recommended compressor and the current operating compressor.
  - Open face impeller overhung design vs closed impeller between bearings design
    An open face impeller eliminates eye seals and fouling points
  - Minimal internal hardware vs multiple hardware sets in horizontally split casing
    An open face overhung compressor allows for a single piece gas inlet volute.

- What retrofit designs could be completed within the available timeframe?
  - Less than 12 months to commence product trials with customers
  - 1 week production window to implement any improvements

- What constraints from ancillary equipment would a redesign need to meet?
  - Available drives power, seal and lube oil system capacity, purge systems capacity.

Existing compressor hardware and fouling issues



Investigation into compressor re-design options

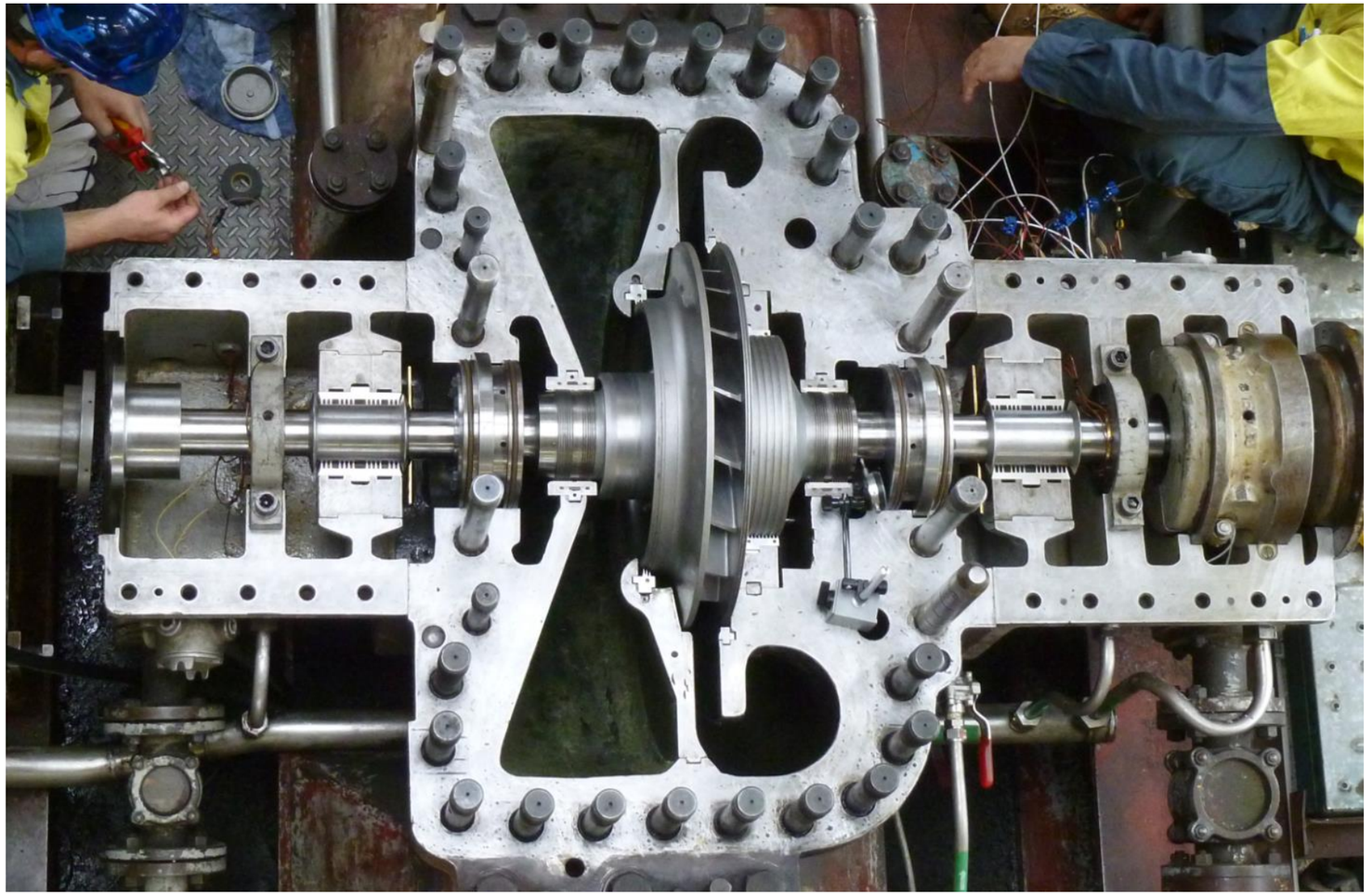
Consultation with the existing compressors OEM set the objectives for a re-design option as:

- *"as few components to be used and no dead zones to be created where fouling could occur".*

- A non fouling open face impeller that matches the Compressor duty point while still satisfying the available compressors drive power rating.
- Replacement internals to match an open face impeller design tolerances.
- The existing purge system for fouling prevention and its delivery pressure and rate could not be exceeded to satisfy the open face impeller design.
- The existing bearing system and oil film sealing system were to be reviewed to establish if there were any areas to improve overall reliability.
- The redesign hardware must be completed within an 8-10 month window to meet the polymer grade transition.

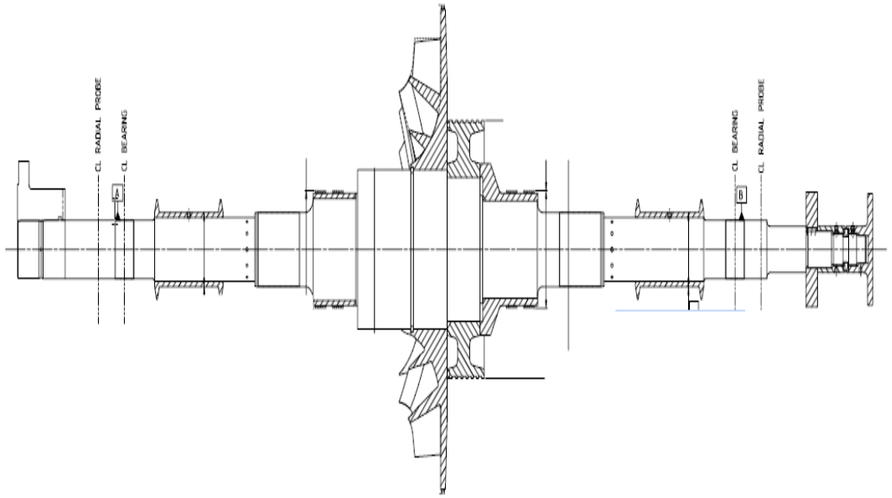
Non fouling one piece diaphragm for a split compressor casing

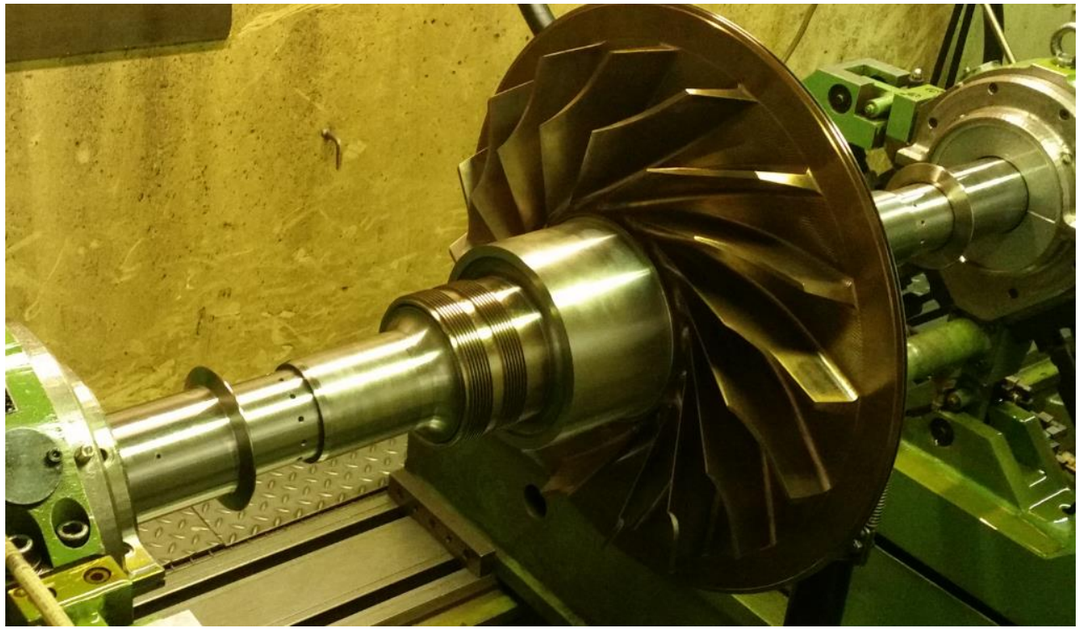
- Eye seal elimination
- Axial adjustment to set Open face blade to diaphragm clearance
- Abradable coating requirement
- Casing connection and space limitations
- Constructability and future maintenance



Redesigned hardware

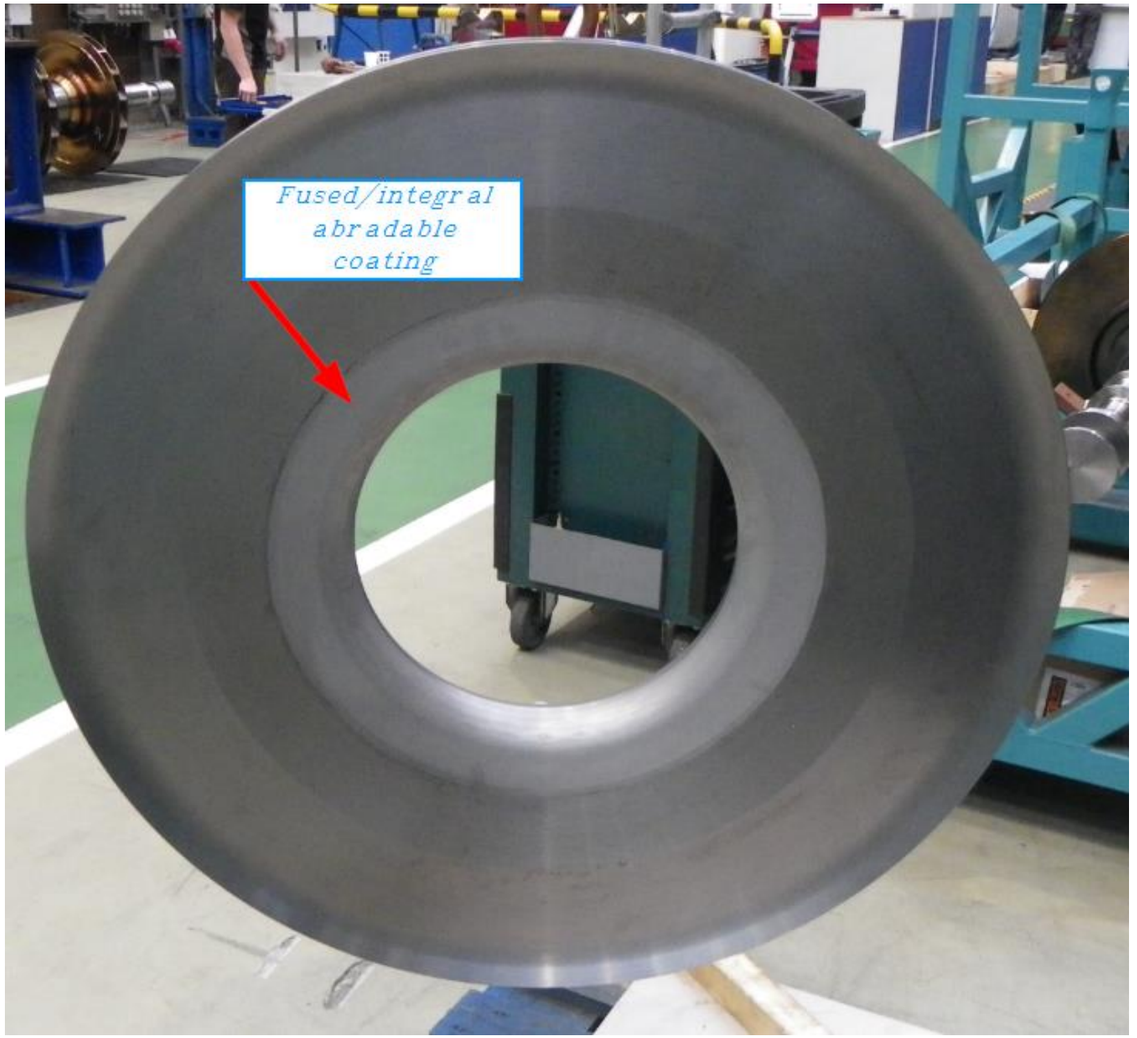
- New rotating shaft assembly complete with open face impeller.
- New radial bearings.
- New low oil consumption floating ring oil seals.
- Retained thrust bearing assembly





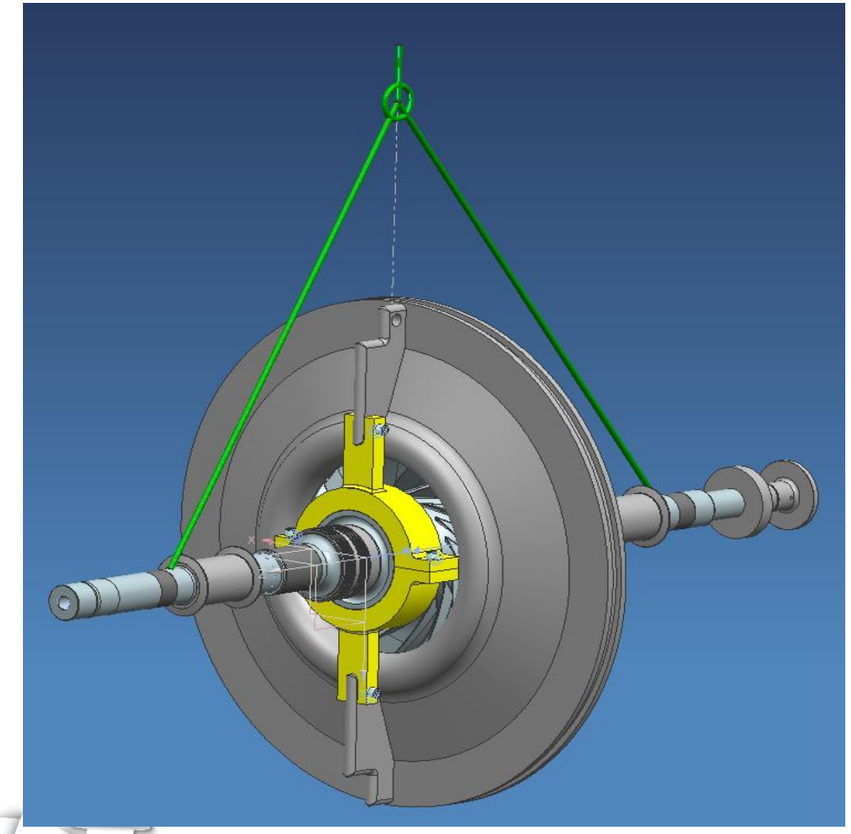
Redesigned hardware

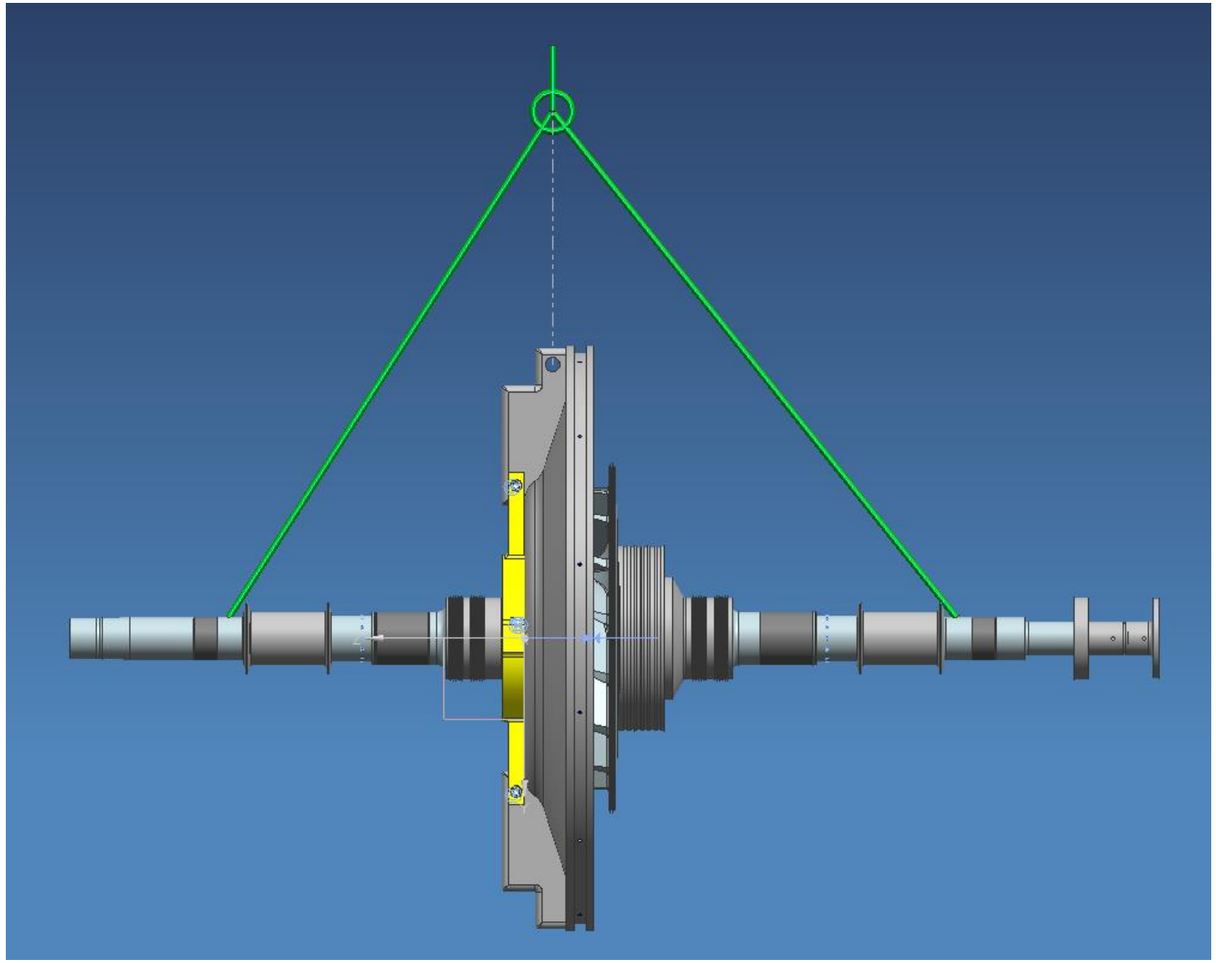
- New “solid “one piece inlet diaphragm assembly with split casing keys and an abradable coating at impeller blade tip area.



Redesigned hardware

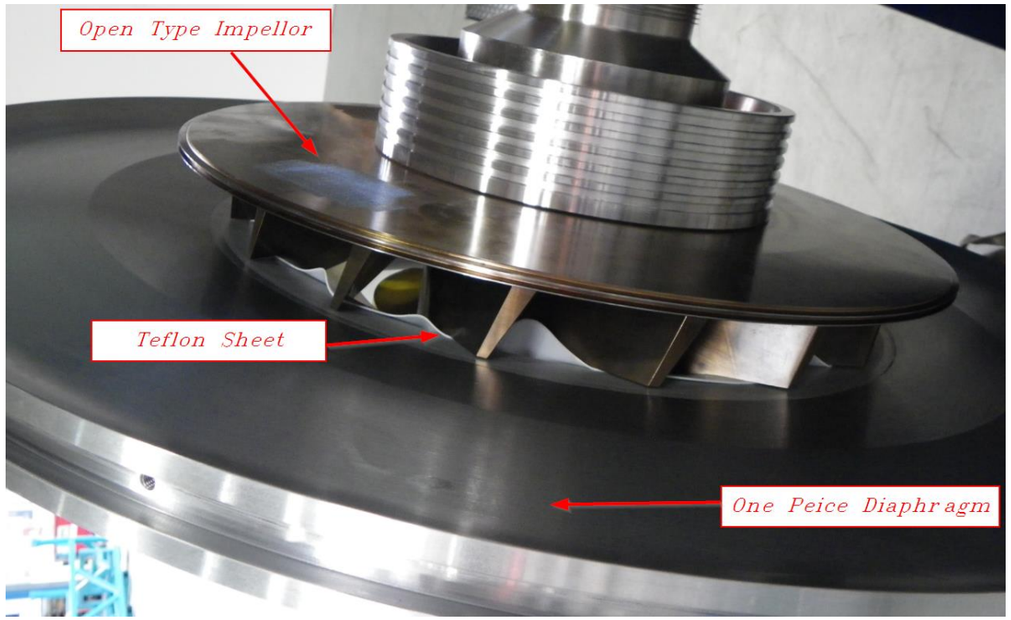
- New rigging assembly and locking tool to allow shaft/impeller assembly to be fitted and locked to the one piece diaphragm for field assembly





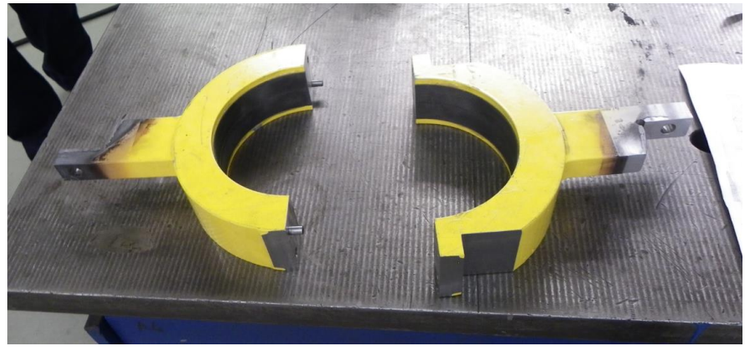
Factory acceptance testing

- A high speed balance was performed to confirm the rotor dynamic behavior
- A trial fit of the assembly of the one piece diaphragm over the impeller along with the protective Teflon sheeting at the abradable location was performed



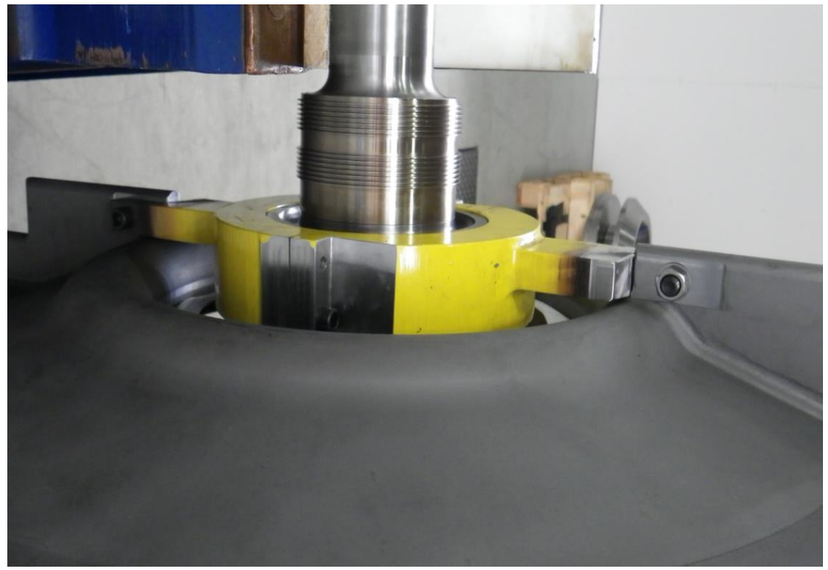
Factory acceptance testing

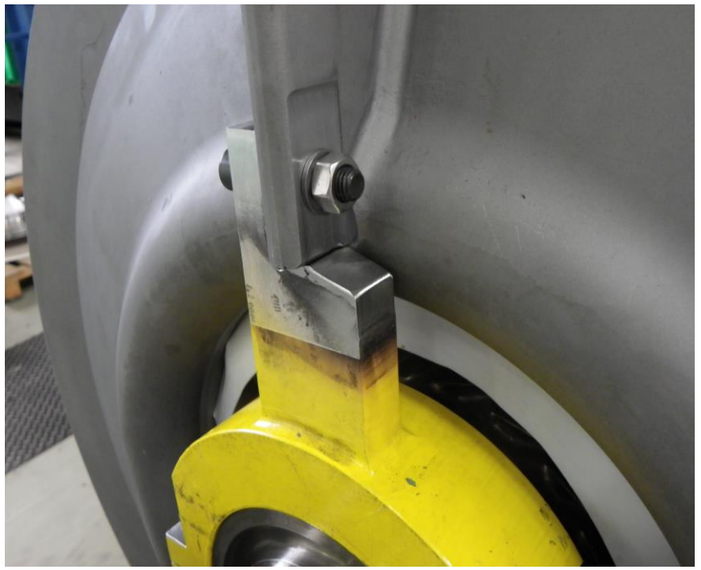
- A trial assembly of the tooling to lock the shaft/impeller assembly to the one piece diaphragm was performed



Factory acceptance testing

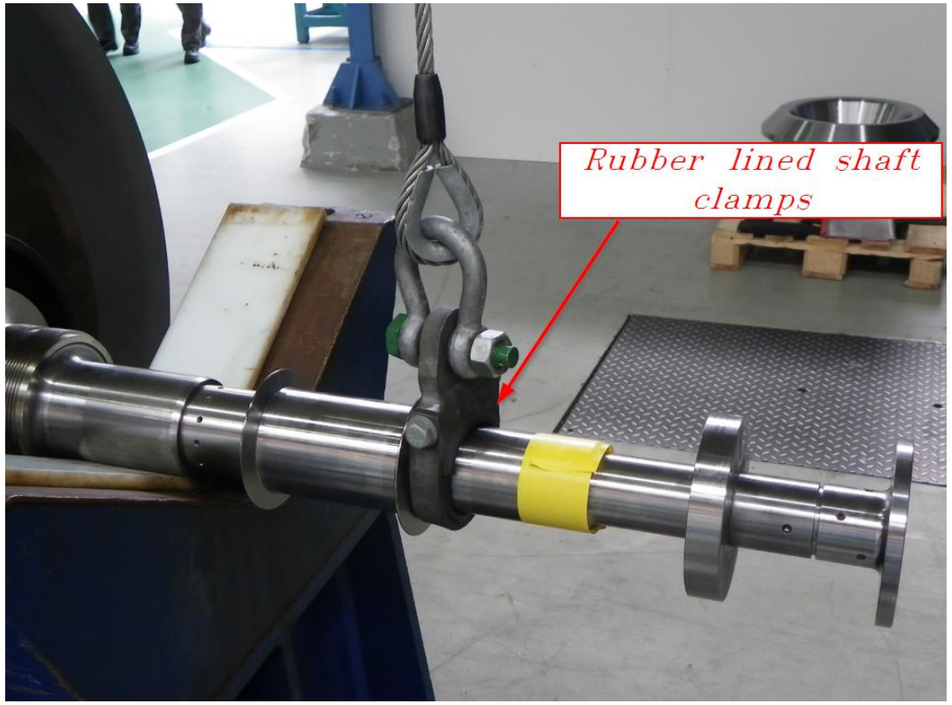
- Comparison with a full scale casing drawing to confirm that the tooling could be removed from the compressor lower casing half after it was installed





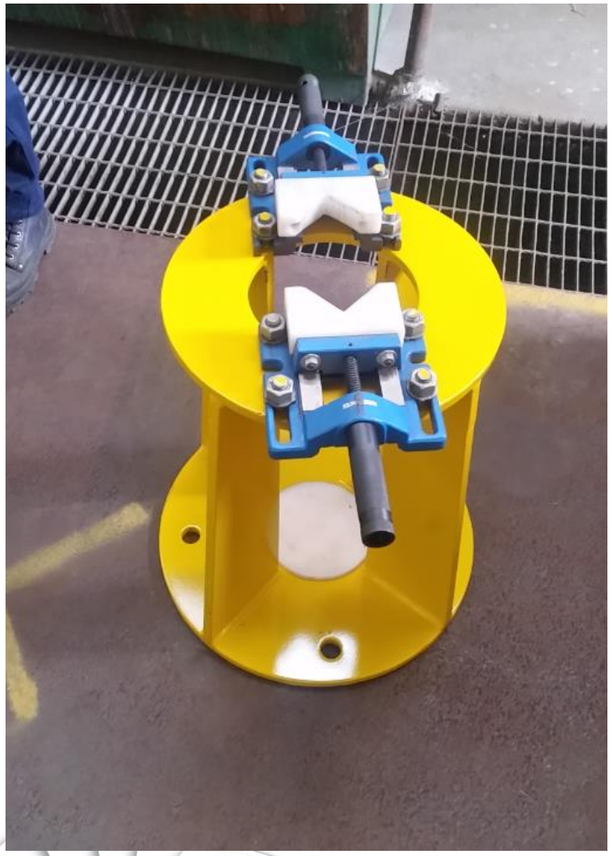
Factory acceptance testing

- A trial of the rigging tooling that would be used to lift the assembly into the bottom half casing



Installation

- Pre outage planning and rehearsals/Site tooling and support cradles



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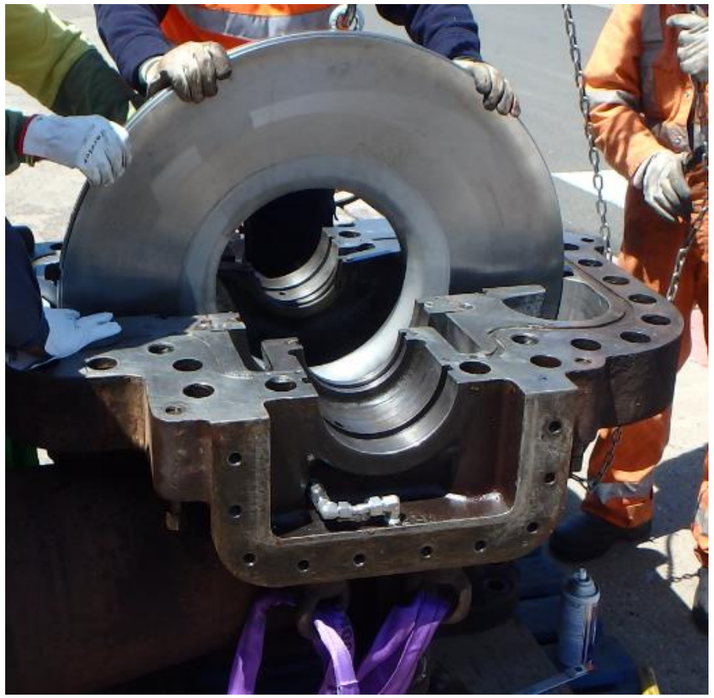
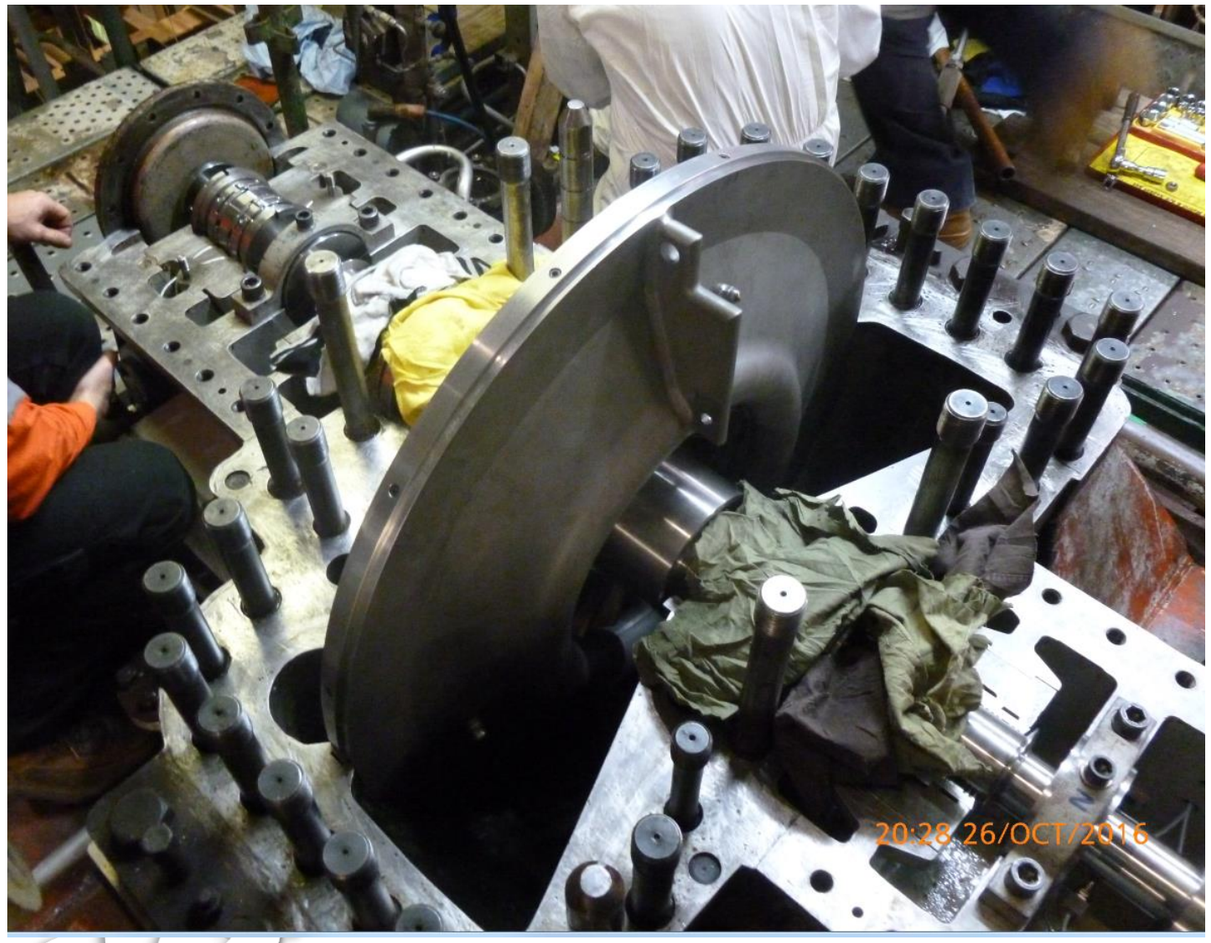
Installation

Trial fitting and contingency plans for fitting the one piece diaphragm



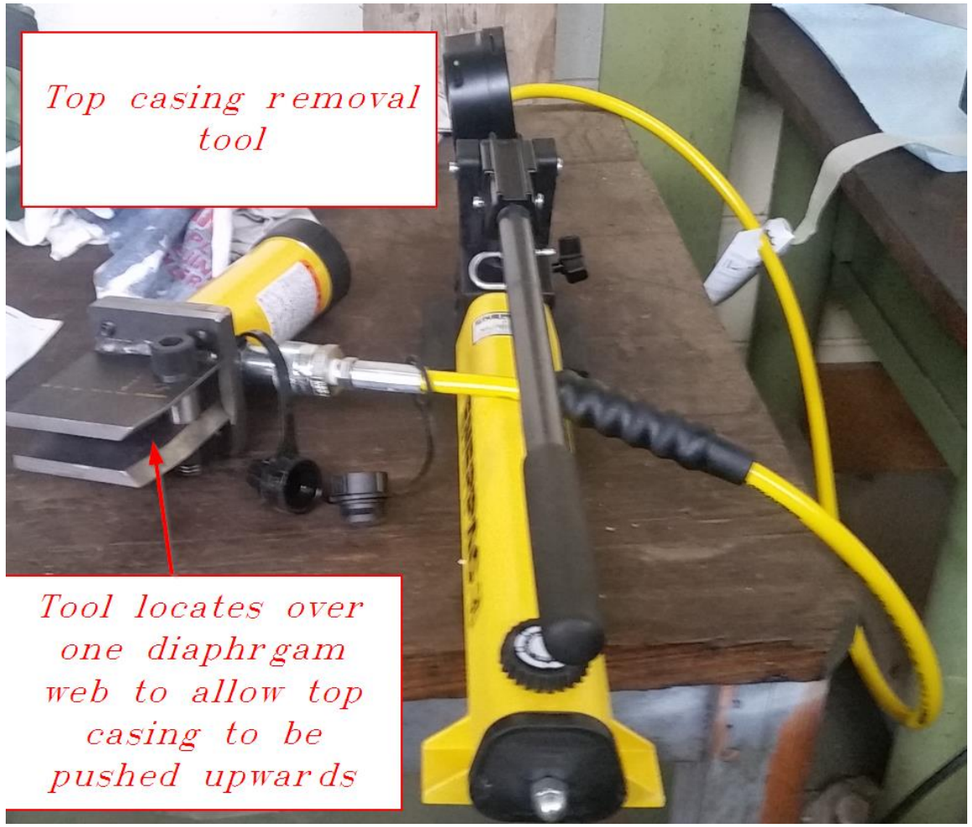
Final fit up

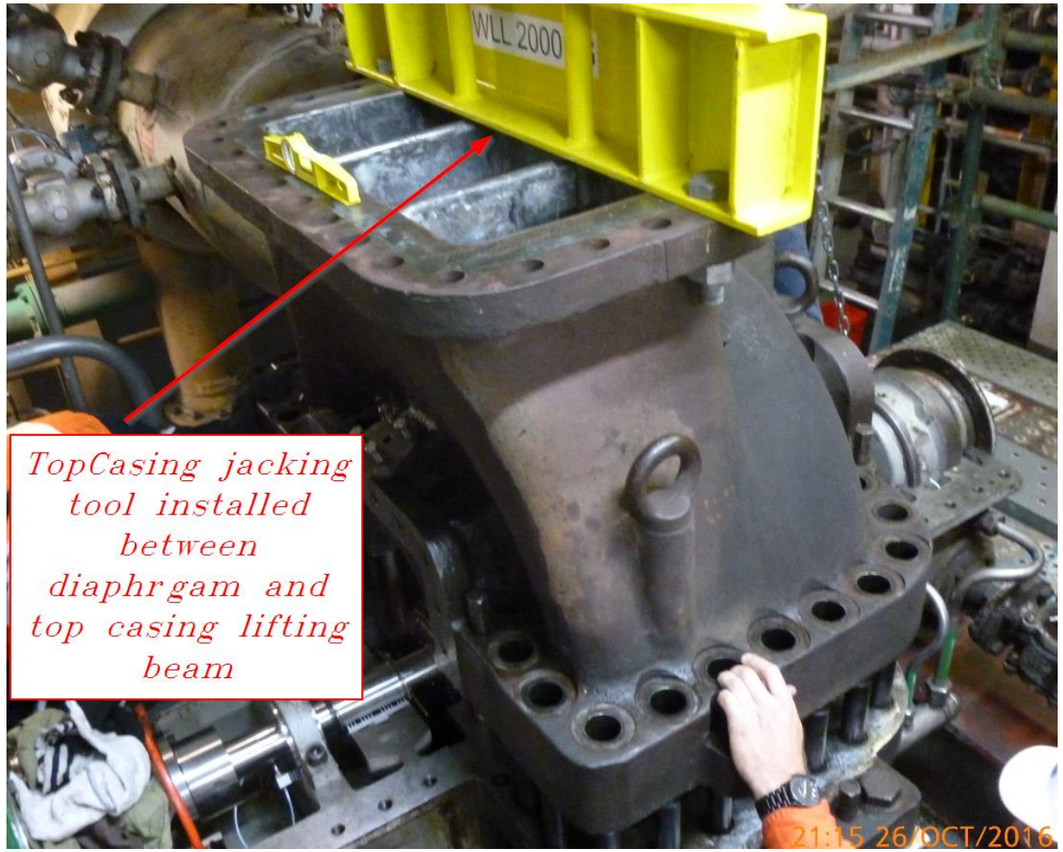
Final fit up



Installation

Future maintenance considerations





Installation

Future maintenance considerations

Commissioning and Performance

- The restart of the upgrade compressor occurred without fault and all operating machinery health indicators of vibration levels, bearing temperatures and lubes oil flows, seal oil flows, purge gas flows showed improved results.
- The process performance of the open face impeller exceeded the original process operating points of the closed face impeller. The initial commissioning and in-service operation indicating improvements in reduced power draw from the drive motor for the required gas flow and head requirements.

Business outcome

- The Open face impeller conversion Project was delivered **on time** and at 60% of the cost of a replacement compressor.
- Highlights:
  - Within 12 months from identification of requirement for compressor replacement/redesign an open faced impeller with one piece diaphragm was designed, manufactured, delivered to site, installed and commissioned.
  - Three new product and catalyst plant trials of increasing length (13 days, 16 days, and 34days) have been successfully conducted with no signs of compressor fouling. The move to 100% new product and catalyst operation by end Nov'17.
  - The new Polymer grade and catalyst versus the original polymer grade and enabled by the compressor redesign has improved daily Maximum Stream day capacity by a minimum of 13%. It is expected that a further 11% rate improvement may be achievable.

Conclusion

The most preferred technical engineering solution available to a 1970s vintage polyethylene cycle gas compressor was not adopted due to operating business constraints. In light of this however the work done to convert a horizontally split, closed impeller compressor to an open face impeller using a one piece inlet diaphragm has showed that lateral thinking can produce a design that also takes on board the preferred technical solutions features in relation to fouling reduction.