IMPROVING RELIABILITY ON A CENTRIFUGAL COMPRESSOR EXPERIENCING FREQUENT BEARING FAILURES.

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ABSTRACT

A 1957 vintage multi-stage centrifugal compressor, critical in a refrigeration process, had a history of poor reliability and LP stage bearing failures. Around 1995 the HP casing had been replaced and upgraded. In early 2010, the compressor suffered a major failure, including rubbing internally due to a thrust bearing failure, and damages to the shaft and drive end coupling. A new rotor and new gear type coupling were installed, both matching the original design. Since the start up after this, the thrust and journal bearings had failed approximately once per month greatly reducing the reliability of the compressor and plant profitability. To eliminate this problem, it was decided to change the coupling and to redesign and replace the bearings from the LP compressor, within the very limited spacing of the original bearing assemblies.

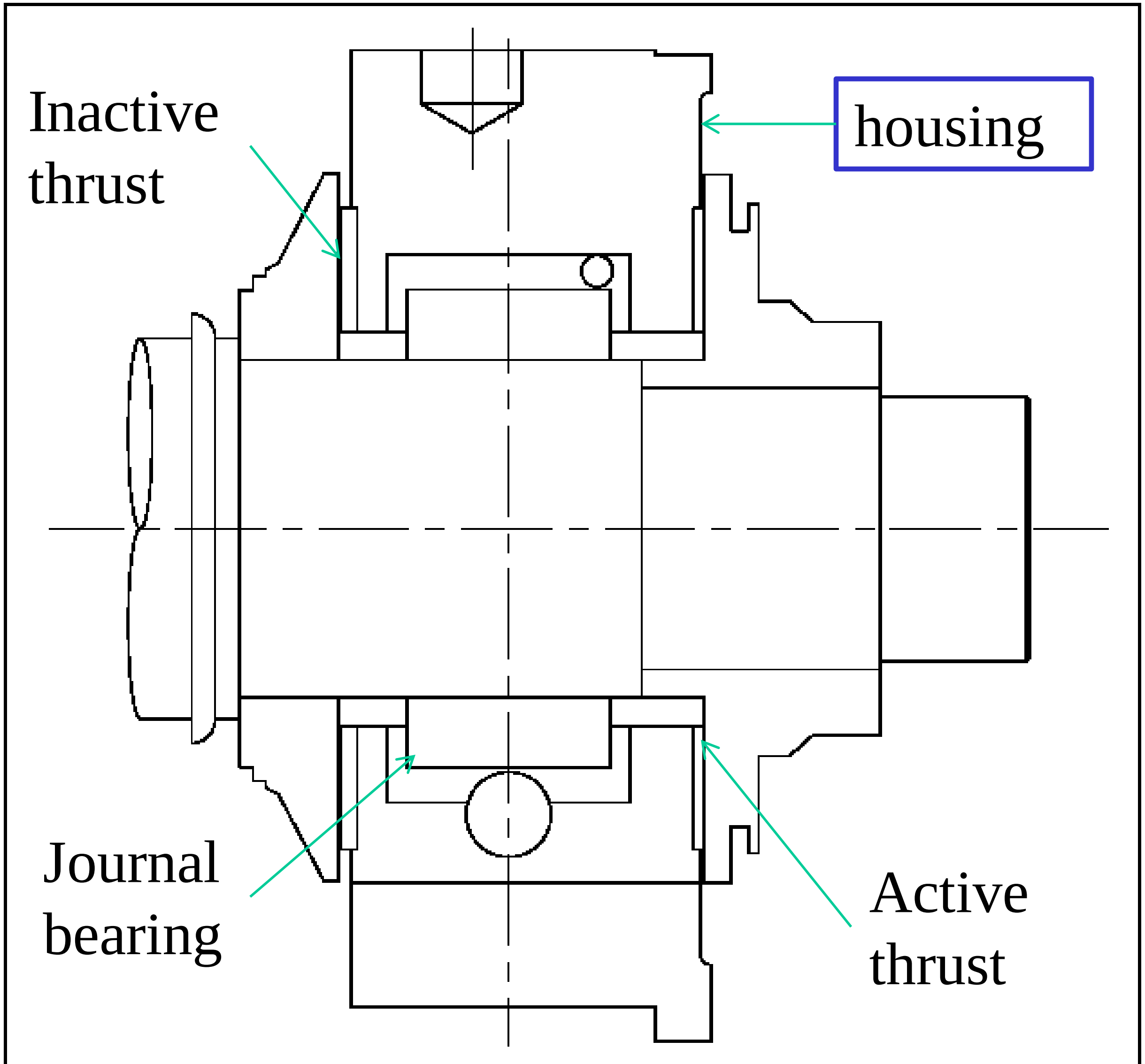
Original Bearings description:

The original journal bearing is a lemon type sleeve, flooded, split, with each half bolted to the housing, at both ends of the shaft: 70 mm Drive End and 60 mm Non-Drive End.

The thrust bearings are each a taper land fixed plate, babbitted, on each side of the housing.

All original bearings have no capabilities to support misalignment.

Original bearing



Problem(1):

A rotordynamic analysis revealed that the original bearing had significantly lower stiffness in the horizontal direction than the vertical.

If the compressor experienced high horizontal loading on the bearing, it would lower the second critical speed into the running range.

It was theorized that the new installed gear type coupling could have increased the horizontal loading on this LP compressor rotor. It was manufactured identical to the first gear coupling, but with much tighter tolerances. It was observed the tighter tooth clearances were contributing to the increase of the horizontal loading.

Problem(2):

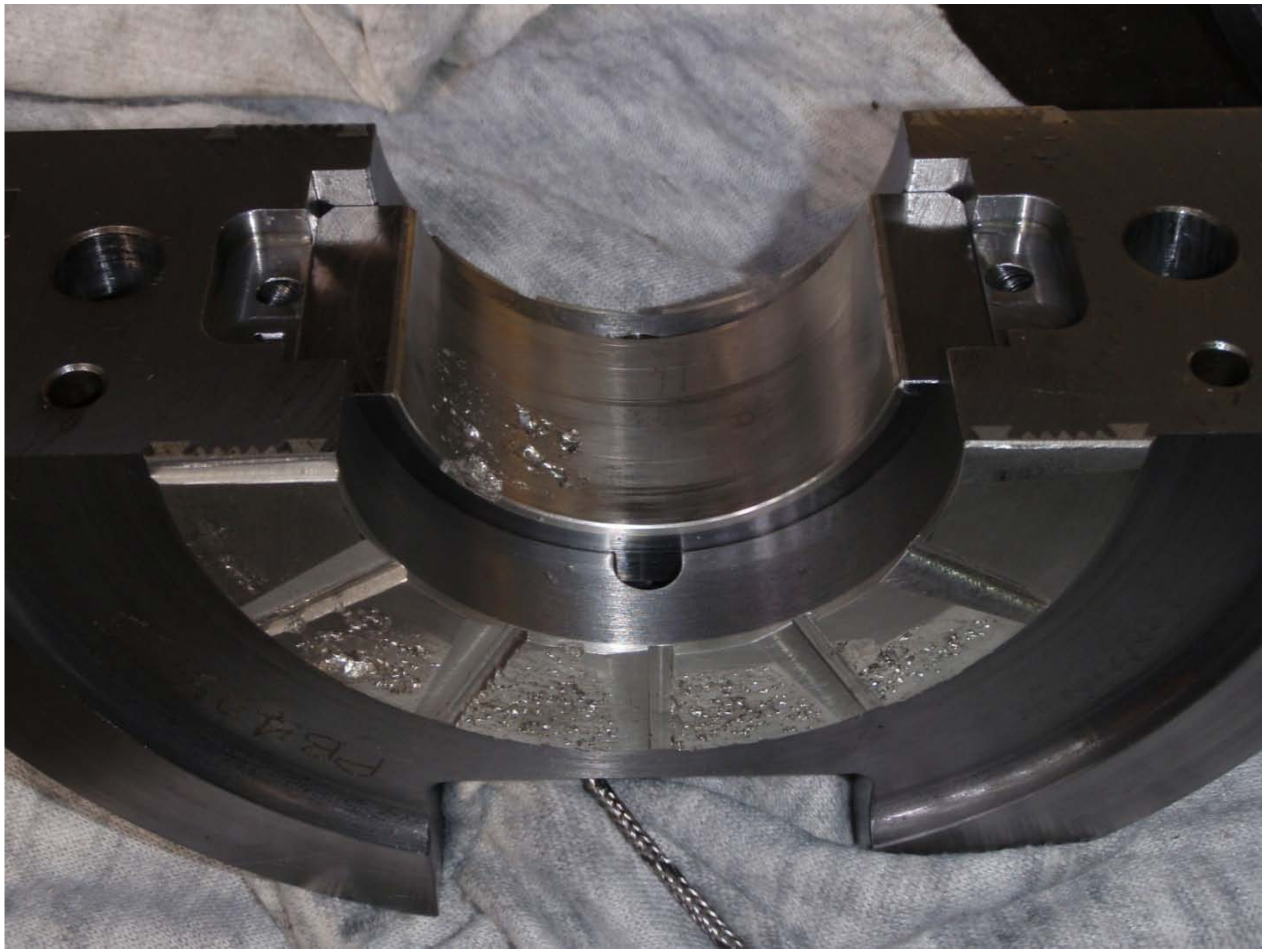
To confirm this theory a special team was created to perform an RCFA and a RDA as well as a failure analysis.

The analysis results were all consistent with the theory that the gear type coupling was more stiff and introduced horizontal loading in the journal bearings, thus reducing the second critical into the running range.

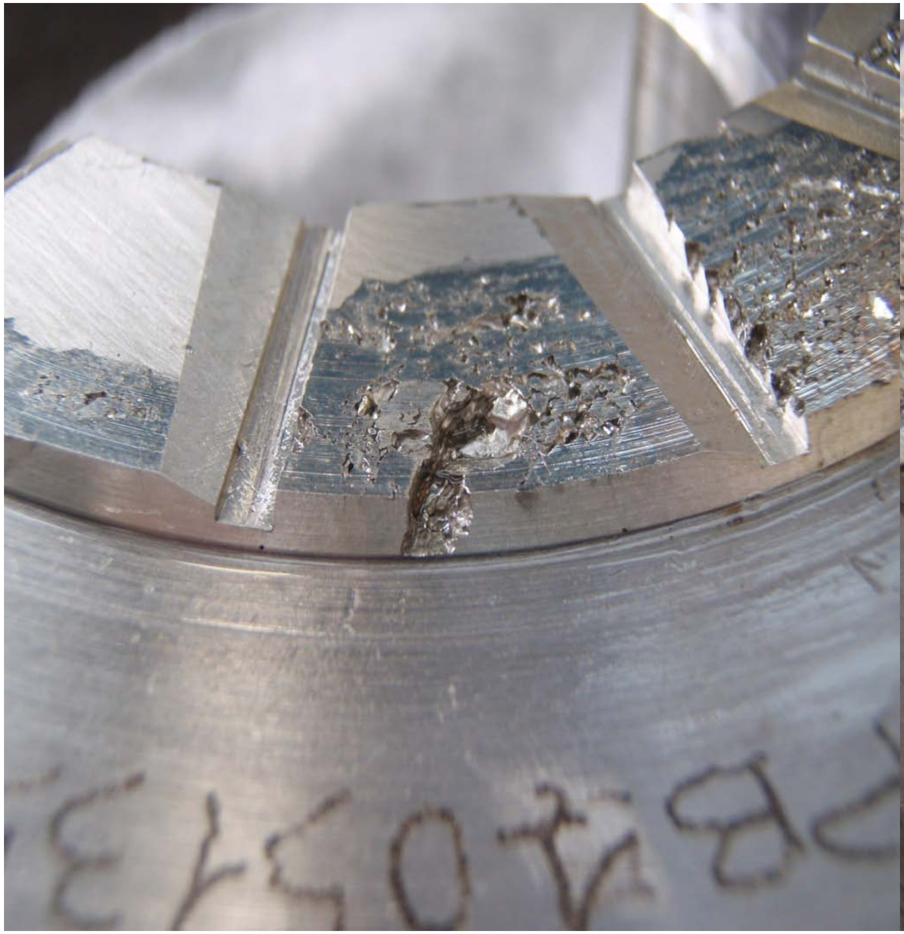
The results also eliminated other possible causes for the repeated failures.

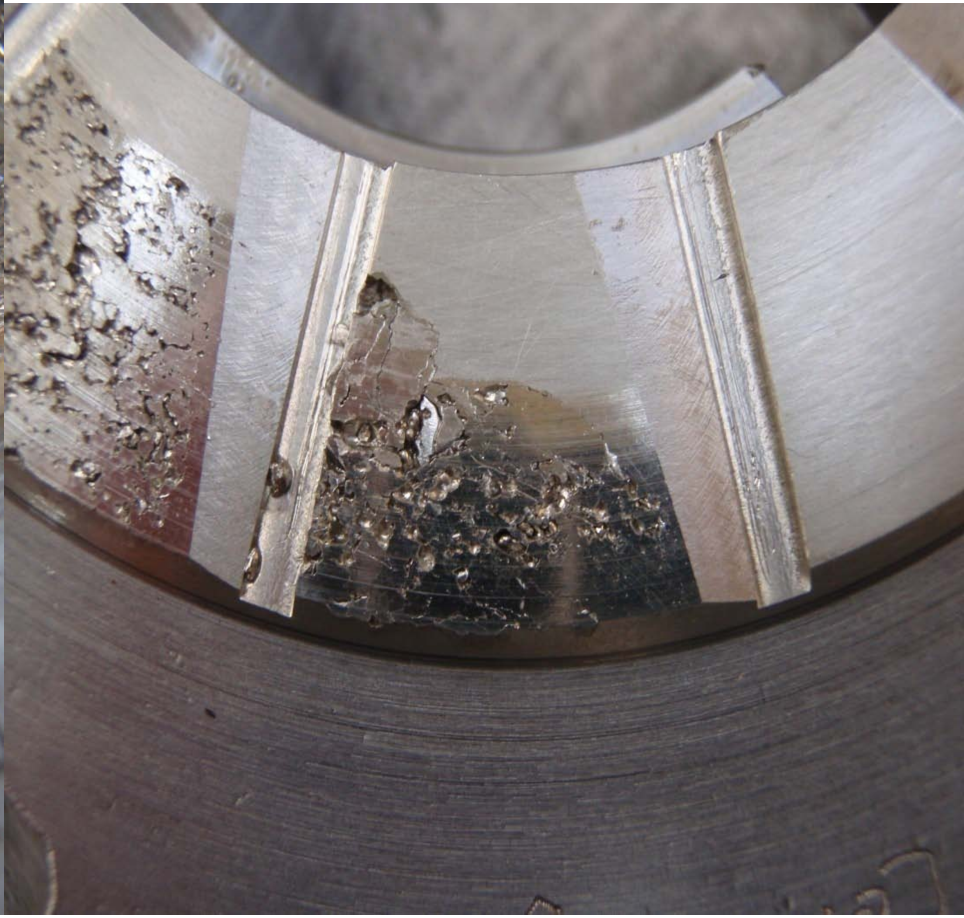
From these studies it was agreed to replace the coupling with a flexible type coupling and to replace the journal and thrust bearings with tilt pad bearings, both these changes of equal importance in solving this problem.

The Failed Original Bearings



Thrust bearings failures





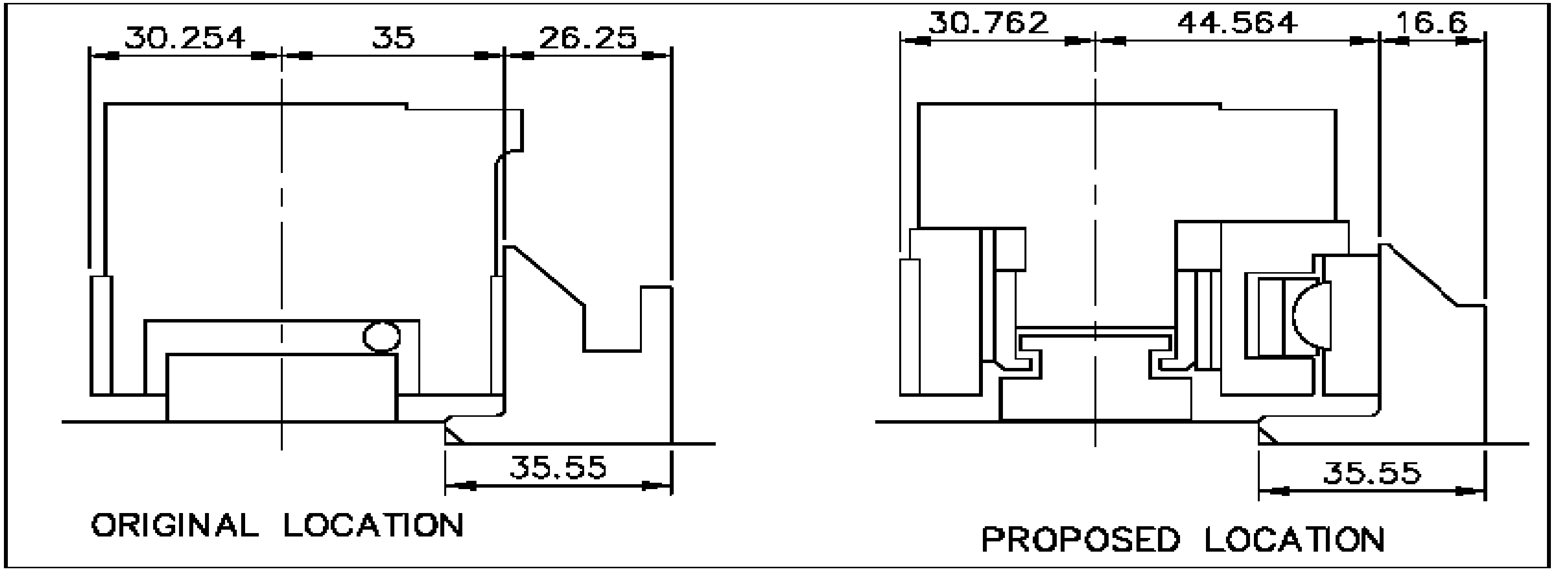
Solutions:

- Replace the gear coupling with a flexible diaphragm type coupling, with it's properties verified by the rotordynamics studies to be acceptable and to significantly reduce the possibility of horizontal loading on the compressor.
- Replace the "lemon" type bearings with tilt pad bearings at both ends of the LP shaft and replace the taper land active thrust bearing with a tilt pad type, both capable of reducing misalignment problems as well as not affecting the second critical speed.

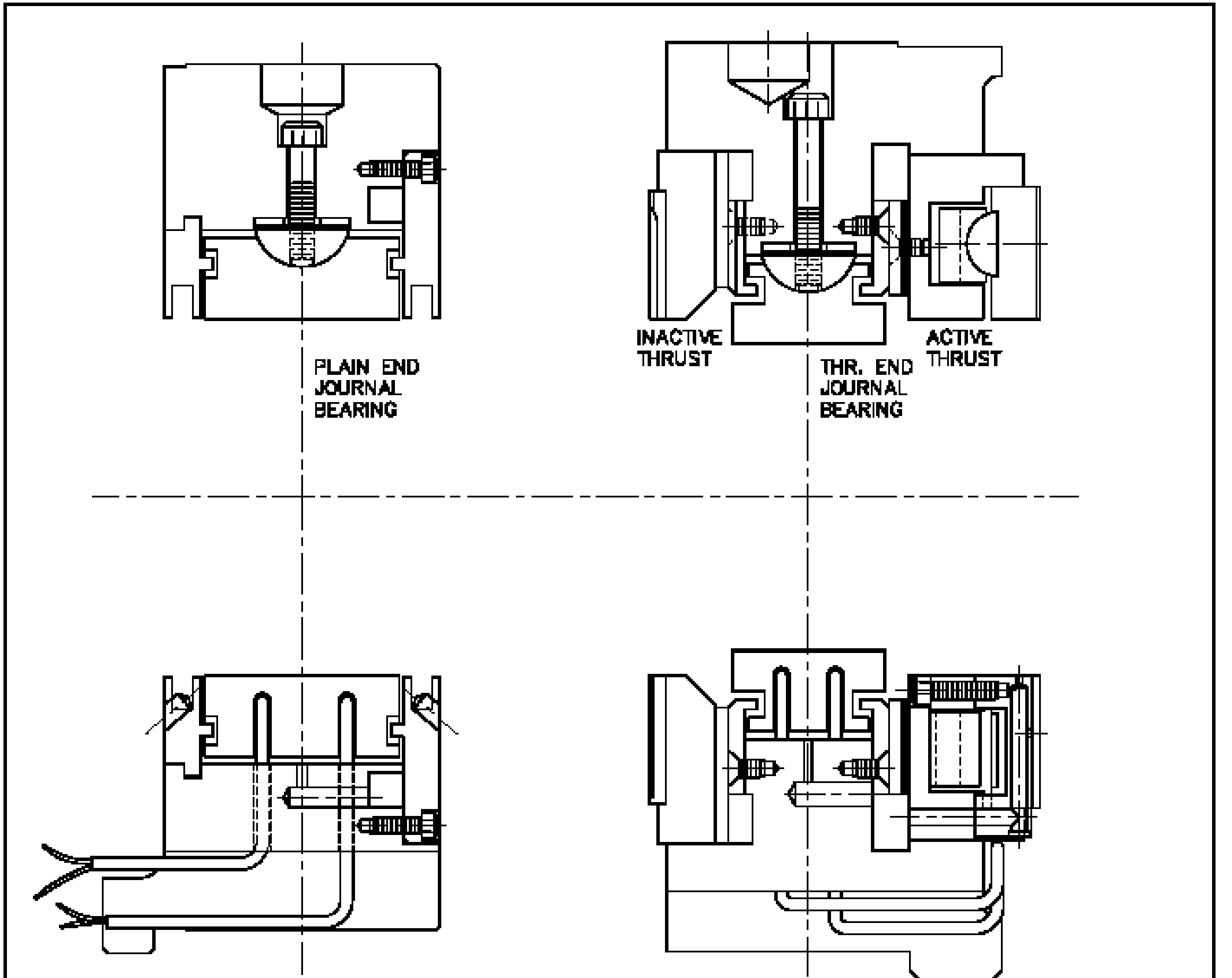
Solution (cont.):

- The challenge was to implement the proposed bearing upgrade on the NDE within the available space limitations: with this very old compressor, there was only a small space available for the thrust and journal bearings.
- It was decided to make a new thrust collar to allow an extra 10 mm for the active thrust bearing width.
- The inactive thrust bearing was designed as an individual compound-taper thrust plate.

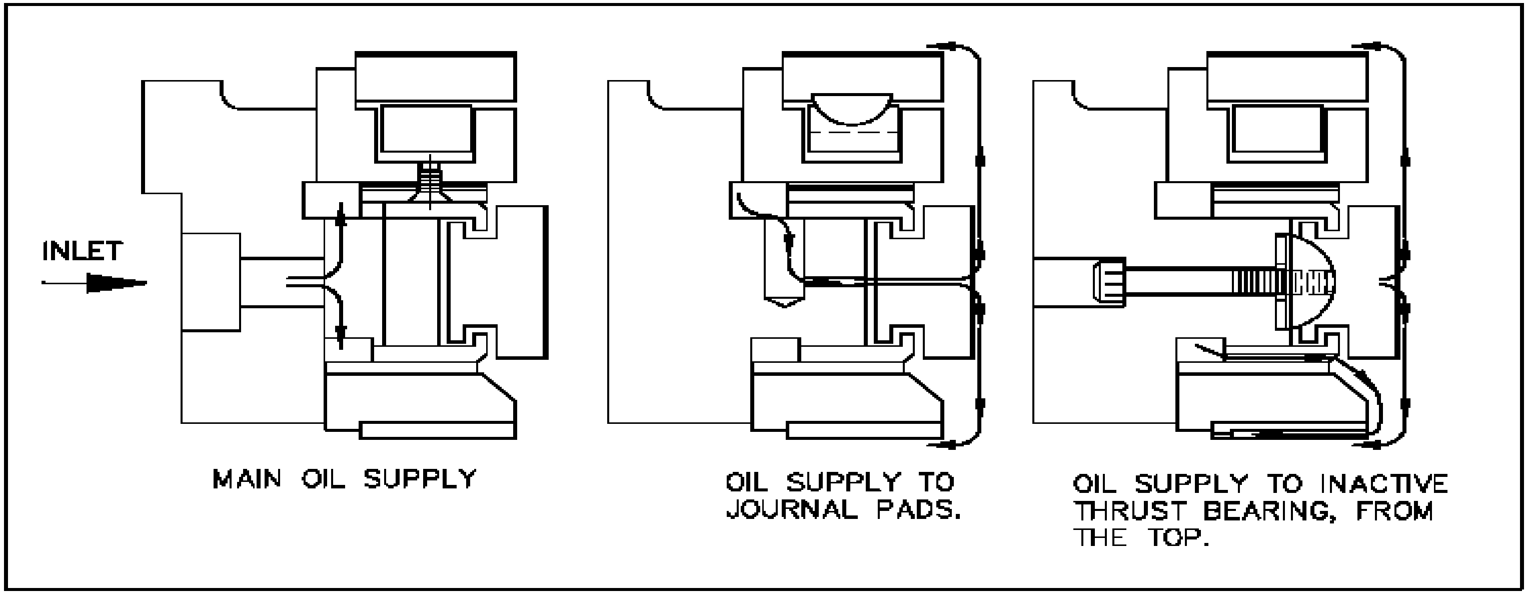
Available space for new design (dimensions in mm)



New design bearings

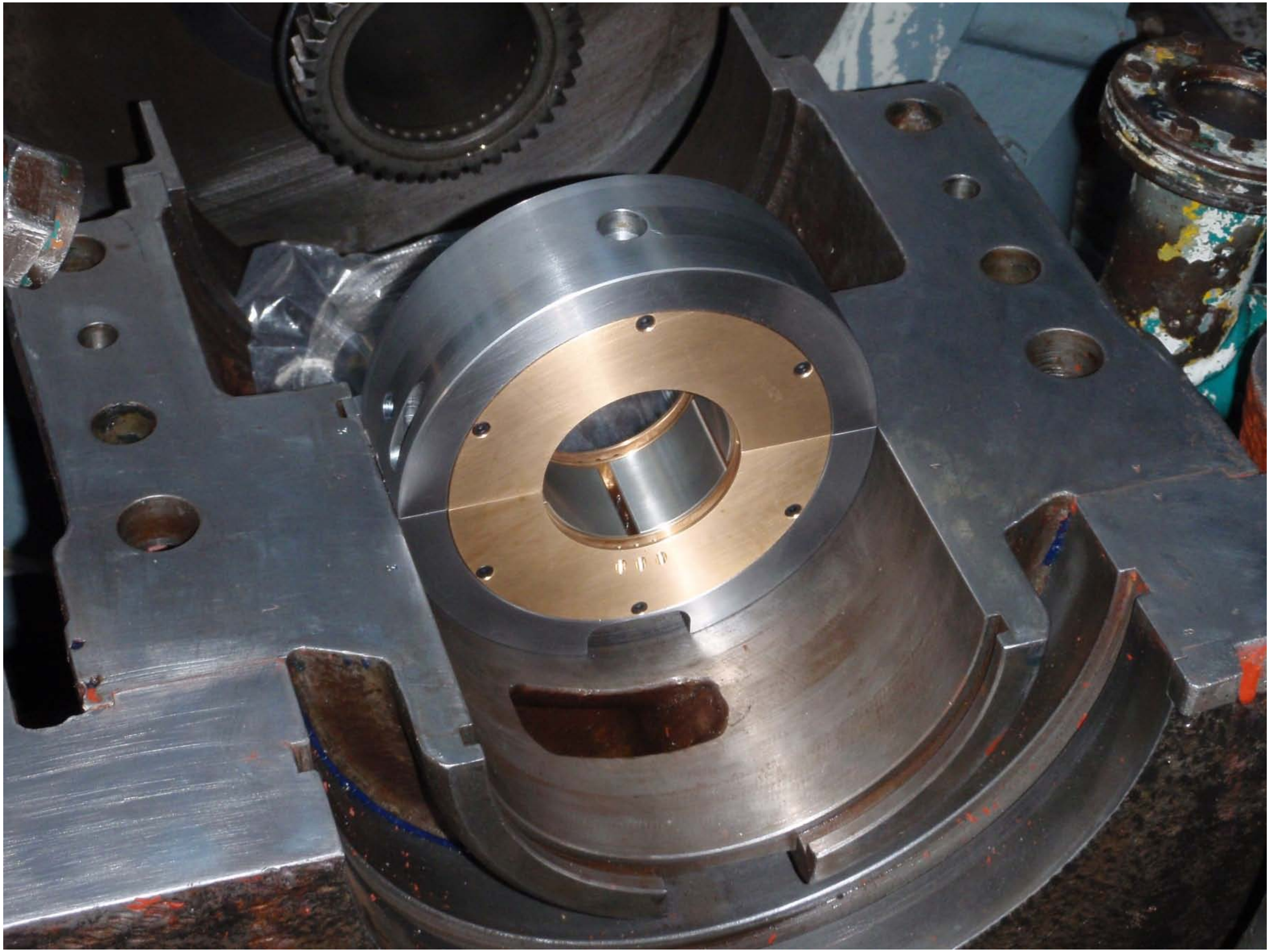


Oil path

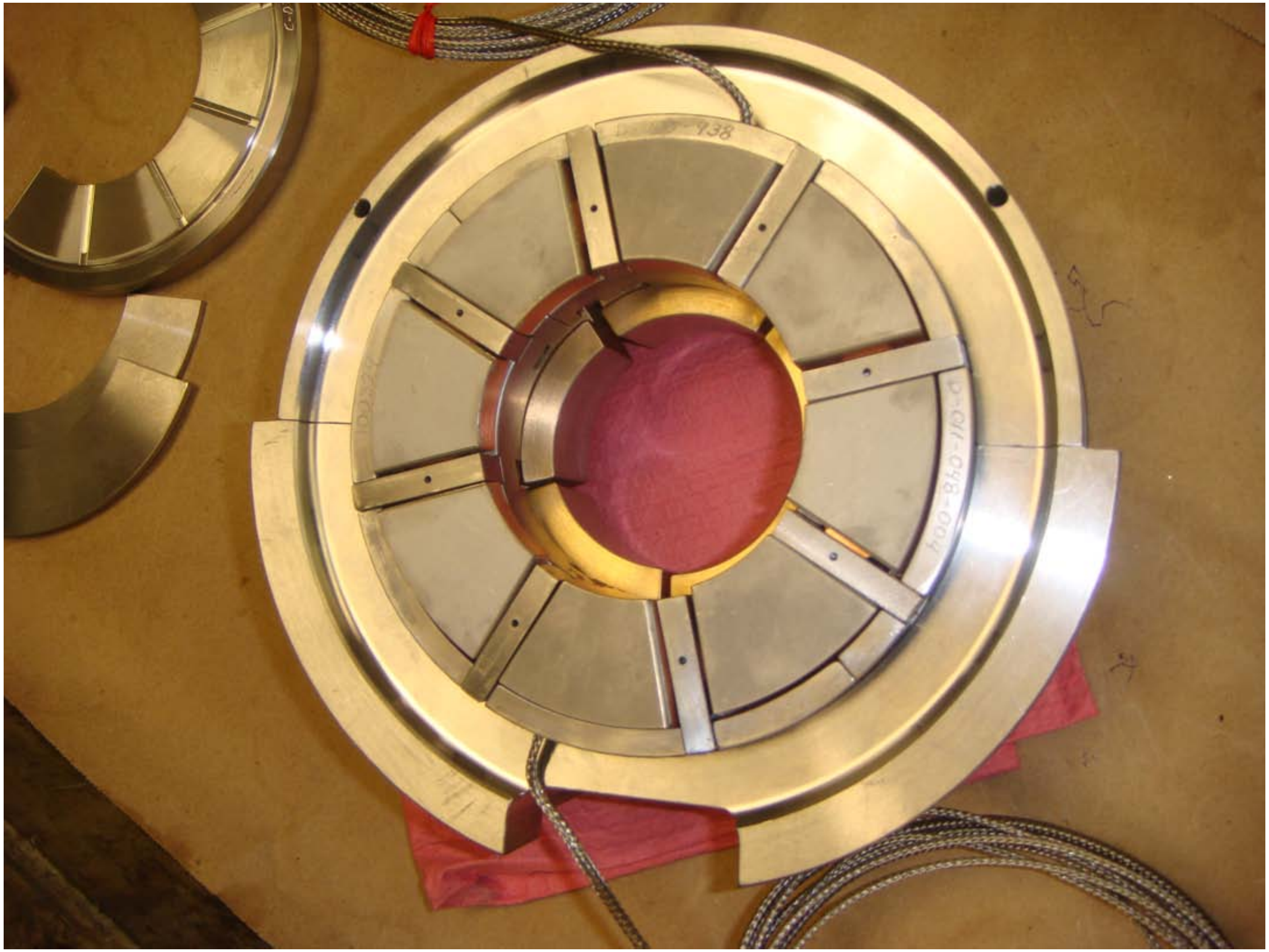

INLET
MAIN OIL SUPPLY
OIL SUPPLY TO JOURNAL PADS.
OIL SUPPLY TO INACTIVE THRUST BEARING, FROM THE TOP.

The new bearing DE

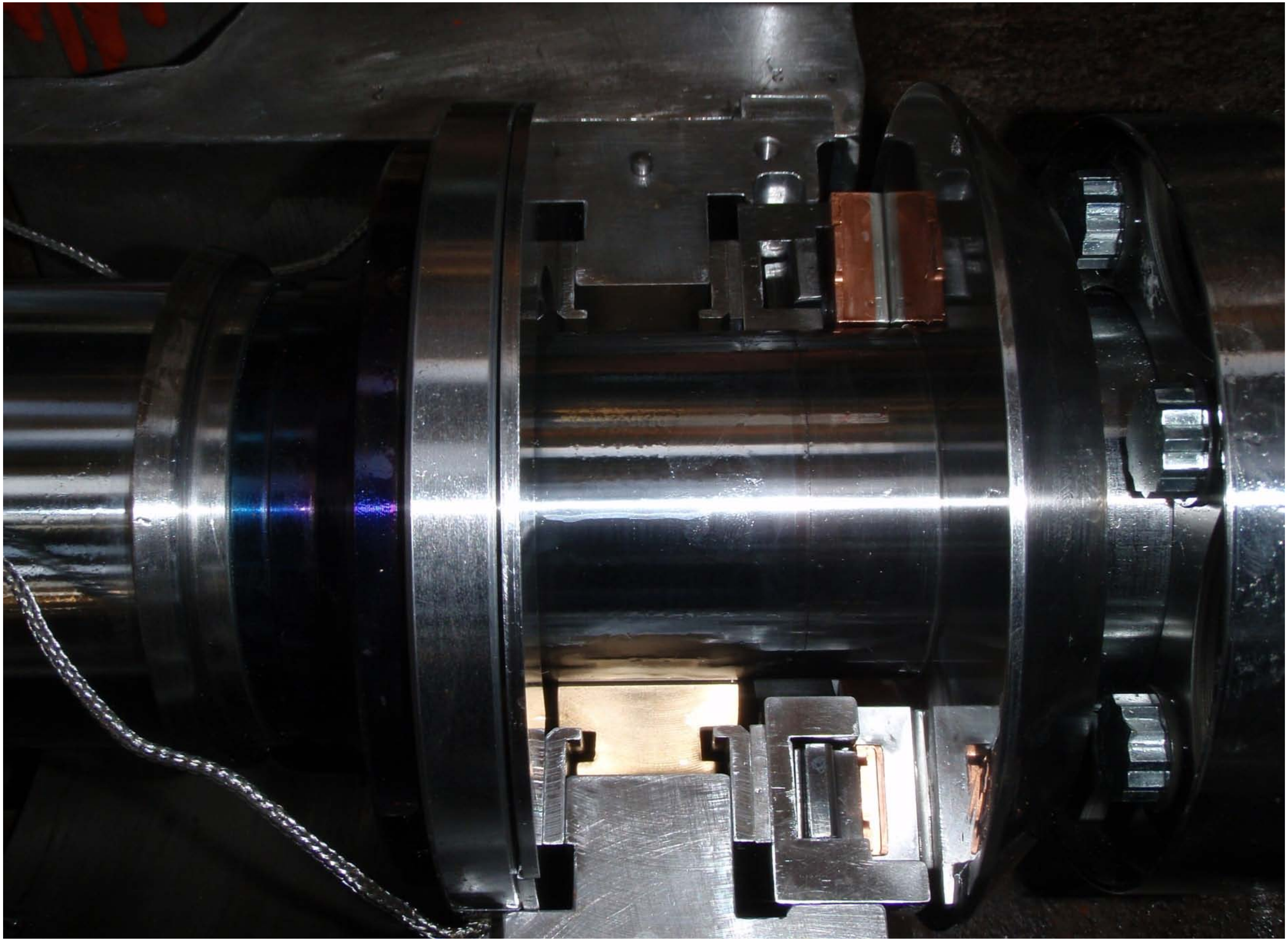
The new bearing DE - installed



The new bearing NDE



The new bearing NDE - installed



Conclusion 1:

The solutions were implemented and the compressor has run successfully since October 2010.

Confirm with the analysis results:

- The new coupling reduced the horizontal loading and the tendency to move the second critical into running range.
- The new bearings eliminated the soft horizontal stiffness, maintaining the second critical well above the running speed.

  Both solutions were proven of equal importance in solving this problem.

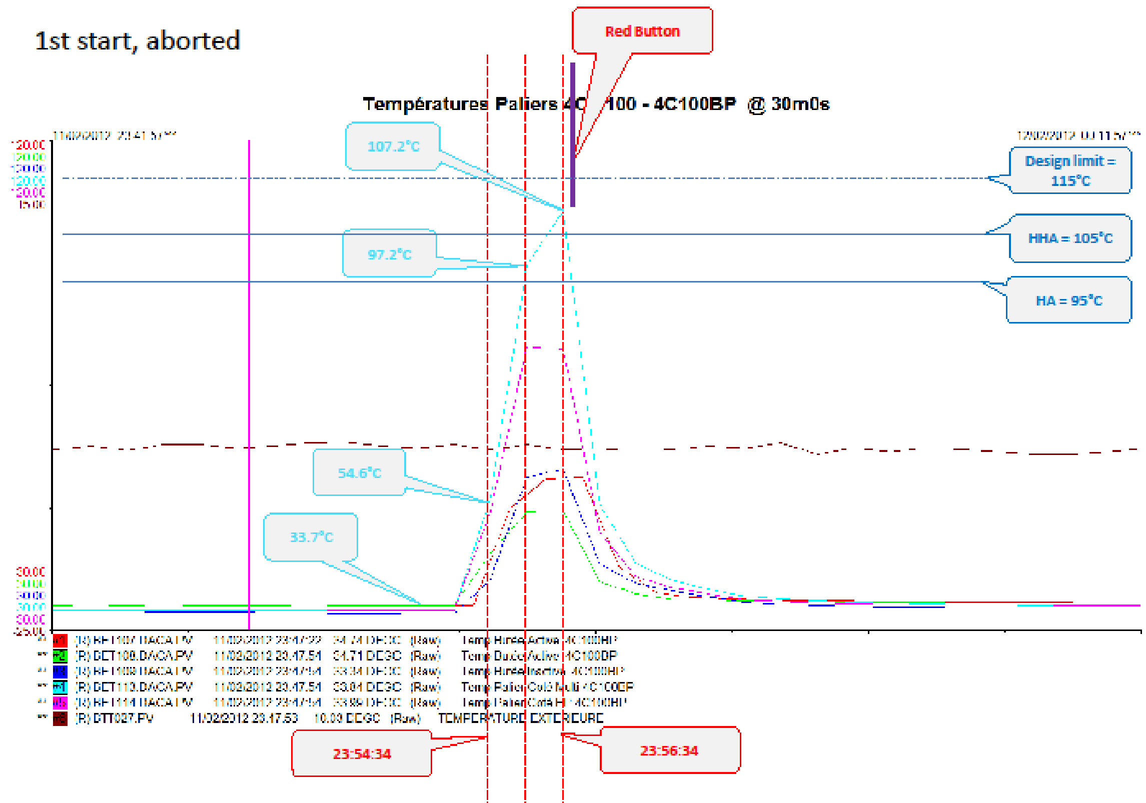
Conclusion 2:

Interesting facts:

- During the service of the newly designed bearings it was observed that the temperatures of the bearings are dependent of the ambient temperatures and the following graphs are presenting the situation.
- If the machine was stopped, in cold weather, when restarted with cold oil, the temperatures of the bearings spike. After trip and re-start with warmer oil and warmer machine, bearings are running normal temperatures.
- The start-up procedure included now the warm up of the machine and the oil, in cold weather.
- The bearings functionality was not affected by fluctuation in bearing metal temperatures.

Bearing temperature with cold oil

1st start, aborted



Bearing temperatures with warm oil

2nd start