PUMP # 2 TEAR DOWN REPORT
Serial # 675UEFGHT101

July 13, 2005, Revision-0

Pump Tear Down Report

CAN-K in the presence of Suncor's personnel Fernando Gavaria commenced the tear down of the ESTSP # 2 High Temperature pump.

The purpose of the tear down is to study the mode or modes of failure and aim towards improving the design, manufacturing process, or any other to increase the life of the pump and approach towards MTBF to 25,000 working hours. It is CAN-K's objective to achieve this target at the earliest opportunity.

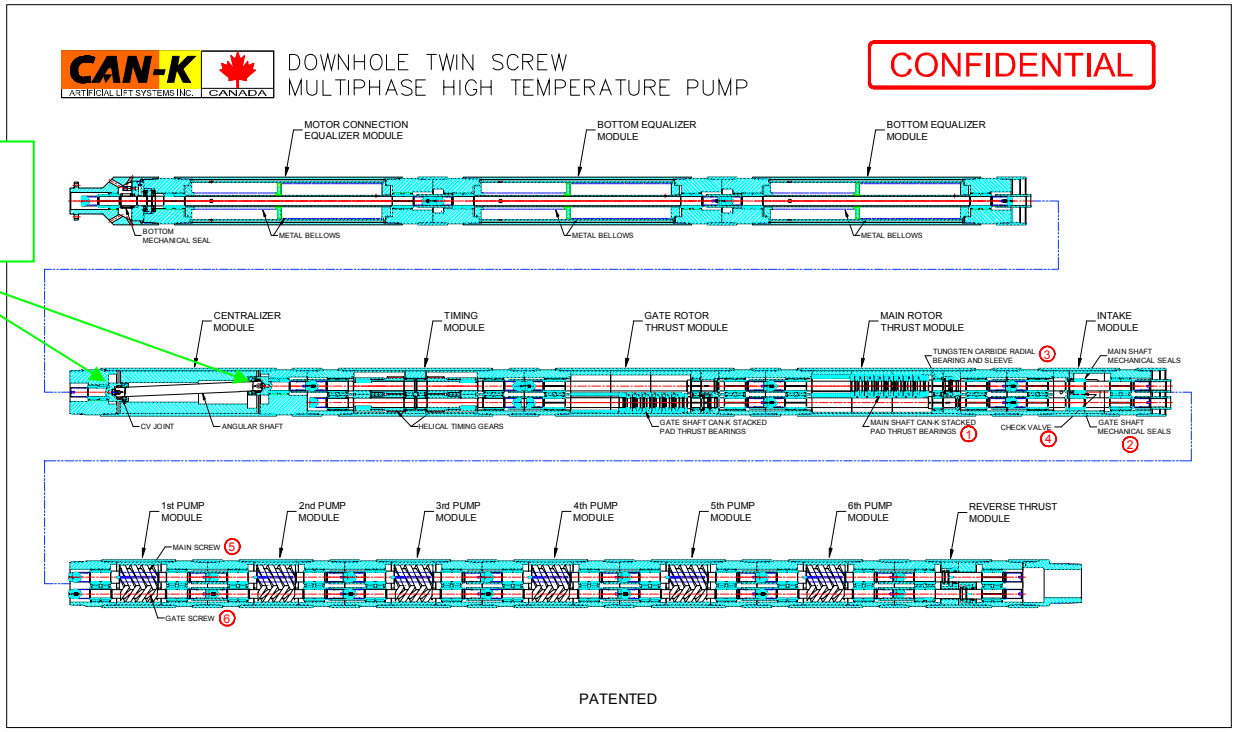
Standard Tear Down Procedure:

- Turn the pump manually and observe if it is turning
- If it is turning then install it on the test bench and run the pump and observe performance. If it did not turn, to start breaking up the connections from the top while the bottom barrier fluid section is pressure tested. The bottom flange will have to be removed first to observe the bottom mechanical seal.
- Pressure test the pump barrier fluid (clean section) for leaks- observe for leaks at the top mechanical seals, bottom mechanical seals, equalizers seals, ORB ports and check valve or pump faces metal to metal faces by applying soap water or dipping the system in a water tank (after cleaning the outside if dipping in water) and look for air bubbles.
- Start breaking up connection from the top and proceed towards the bottom.
- After removing each connection to turn the pump and observe if the pump is turning.
- When a possible failure mode is observed to stop and identify causes and only then to proceed further.
- Completely dismantle each and every piece, visually inspect and proceed to do dimensional check and compare with original QC report.
- Prepare a detailed tear down report for the end user with complete findings with recommendations and suggestions of improvement in design or manufacturing process.

Actual Tear Down:

It was decided to change the standard procedure and start dismantling the pump from the bottom end.

- CAN-K tried to turn the pump manually and the pump turned but the mechanical seals at the intake were not turning indicating that there was a disconnection somewhere between the bottom and the pump's portion
- A pressure test was conducted to test if the check valve and the mechanical seals were leaking. There were no leaks at all. The check valve was then pressure tested to open and checked for resealing. It resealed at 18 psi. The intake section after complete tear down of the pump was kept in its original assembled condition and tested in water for several days to check for any kind of leak. There were absolutely no leak at all. It is now confirmed the pump check valve and the mechanical seals are in good working condition.
- The bottom flange connection was removed to expose the bottom mechanical seal
- Each equalizer was removed and the pump drive shaft was turned. The shaft turned but the pump above the intake did not turn. All the three equalizers were removed and each time the shaft was turned, we noted the pump above the intake was not turning.
- The angular shaft was removed. The pump was turned and the pump turned, clearly identifying the failure is in the angular shaft module.
- It was then decided to tear down the angular shaft module. At the bottom of the angular shaft the bullet area of the CV joint was completely worn out. The thrust seat where the ball is located was also chipped at the bottom.
- The angular shaft was completely dismantled. Both ends showed wear, but the end at the bottom closer to the motor was the one which was completely worn out. The bullets showed no wear at all in both the cases.
- On closer examination we found that the split rings when assembled at both ends were pushed in during assembly. This obstructed the free movement of the angular shaft while rotating. The split rings were gouged in by the bullets. The procedure of assembly was reviewed. It was concluded that the angular shaft was not assembled correctly.

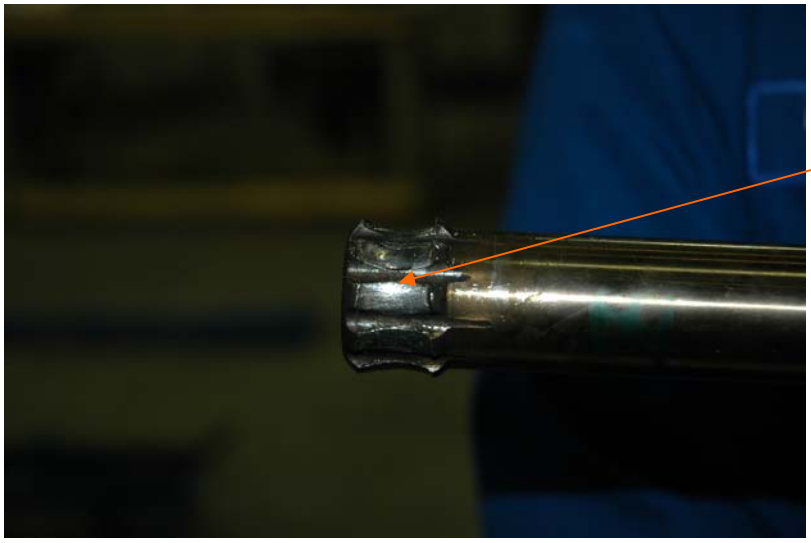


Angular Shaft CV Joints .

Pump Schematic for easy reference.

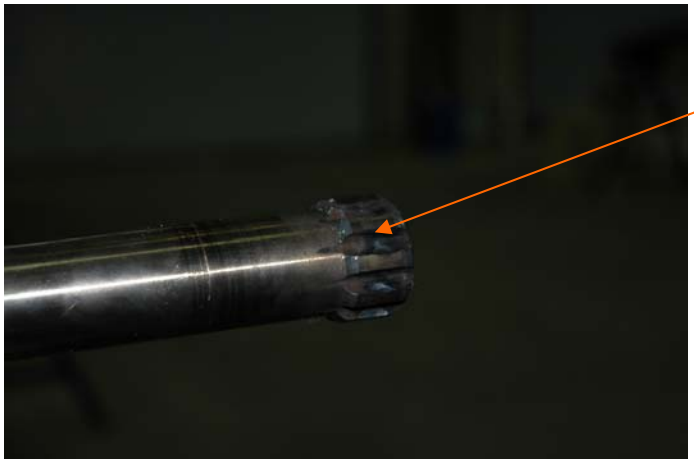
This section is prepared with mainly pictures with self explanatory comments on the pictures to identify areas of concern, areas of interest, damage and show the condition of the parts. The pictures are not compiled in chronological order of the tear down.

Angular shaft- Bottom CV Joint



Bottom Bullet grooves damaged completely. No positive drive.

Angular shaft-Top CV joint

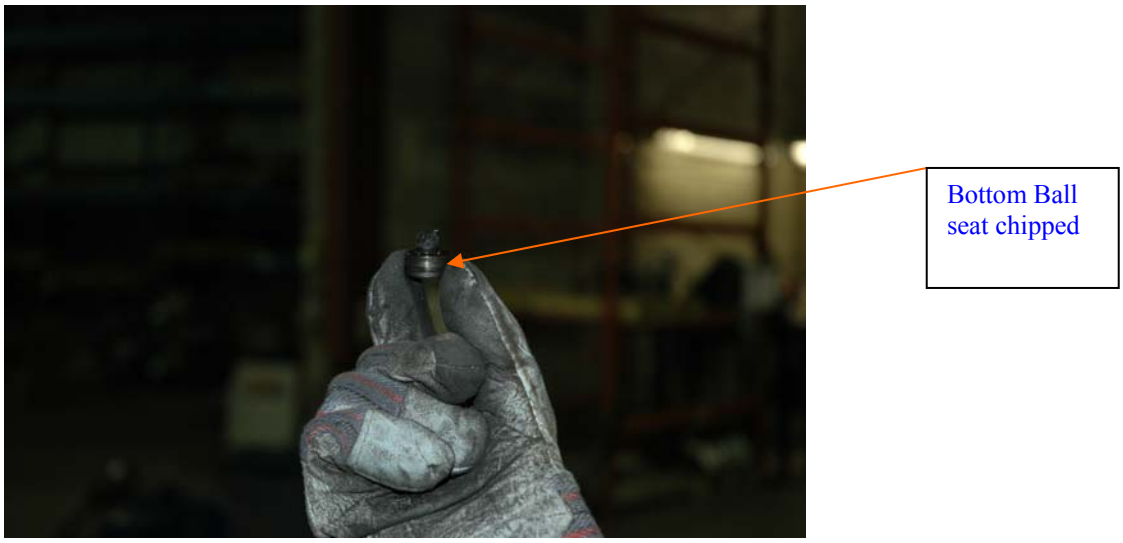


Top CV Joint. There are some wear but very minor

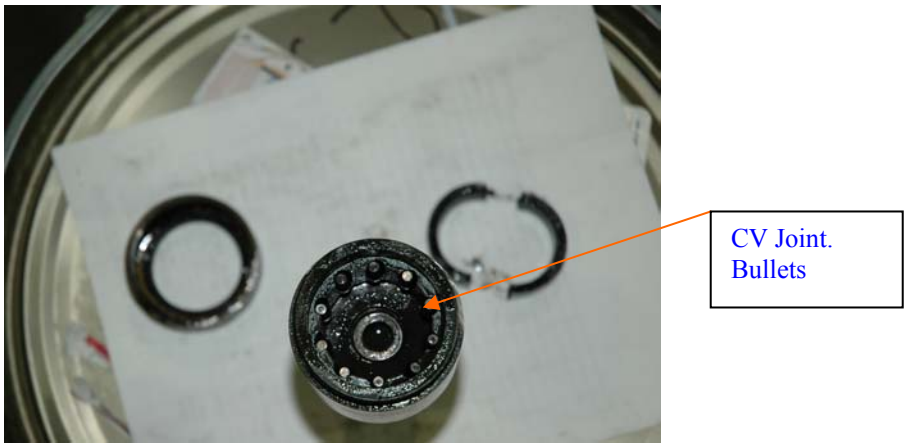
Angular shaft-another view- Top

Same piece giving a side view. Minimal wear.

Angular shaft Ball seat- bottom



Angular shaft –CV joint



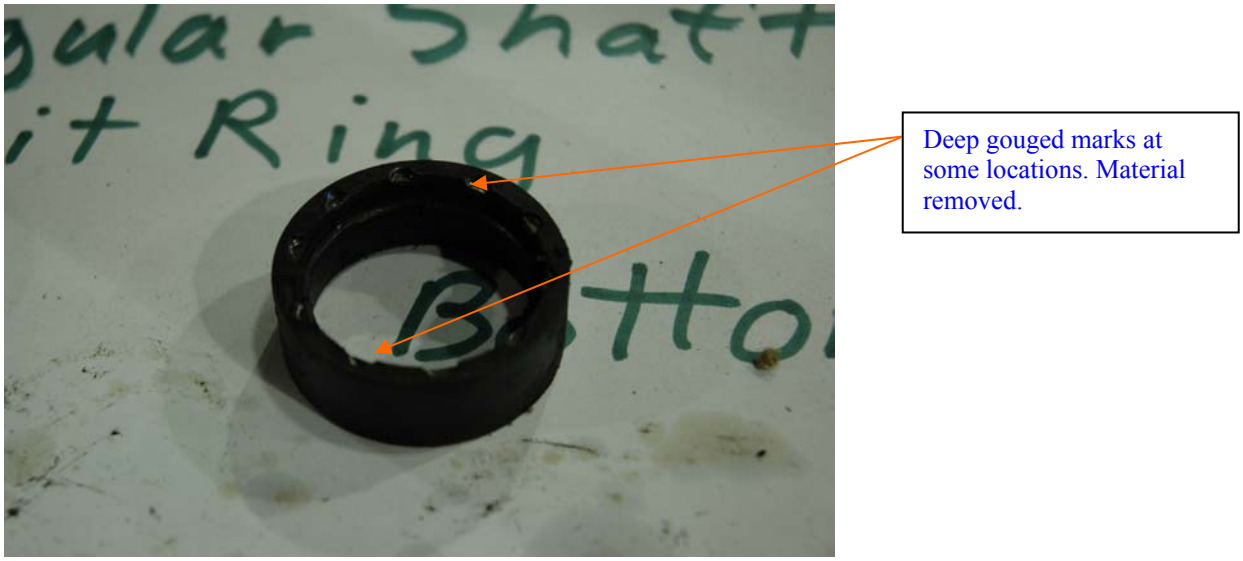
Angular shaft completely disassembled

Split rings –both top and bottom

Split rings. Top and bottom

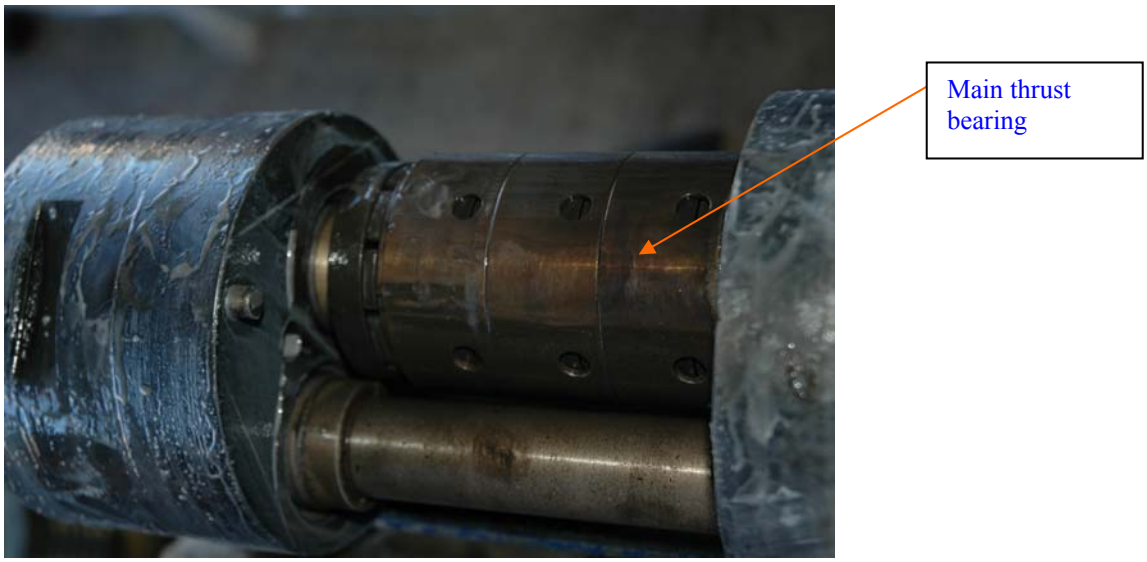
Top split ring of angular shaft module

Bottom Split ring of angular shaft module



Gate thrust Bearing stack. In excellent condition

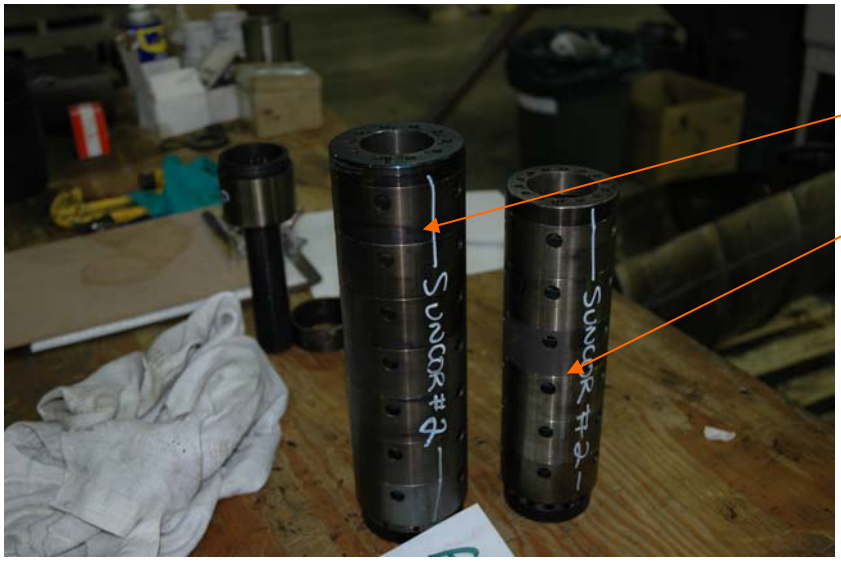
Main Thrust Bearing stack in excellent condition



Radial Bearing of thrust section in good condition

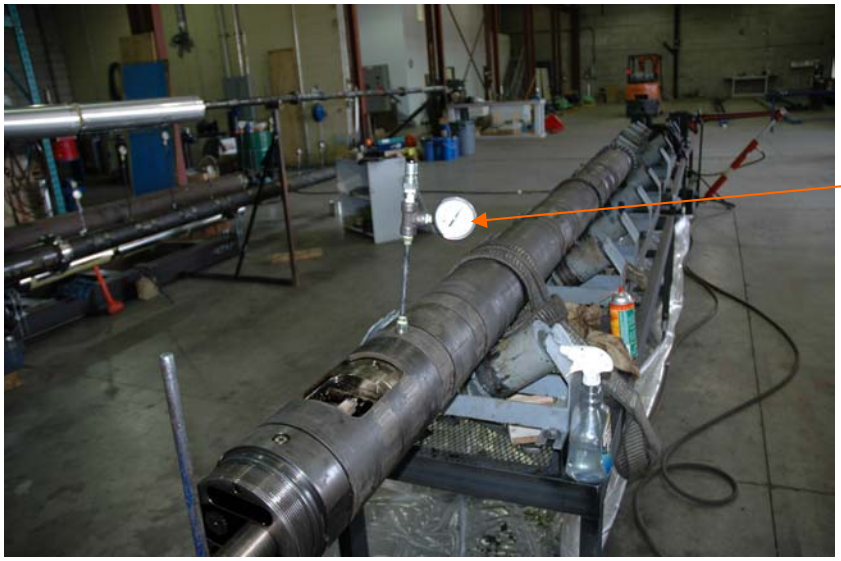
Gate thrust as being disassembled

Thrust Bearing stack after QC. Excellent condition. 100 % reusable



Pump stage # 2

Pump stage # 3

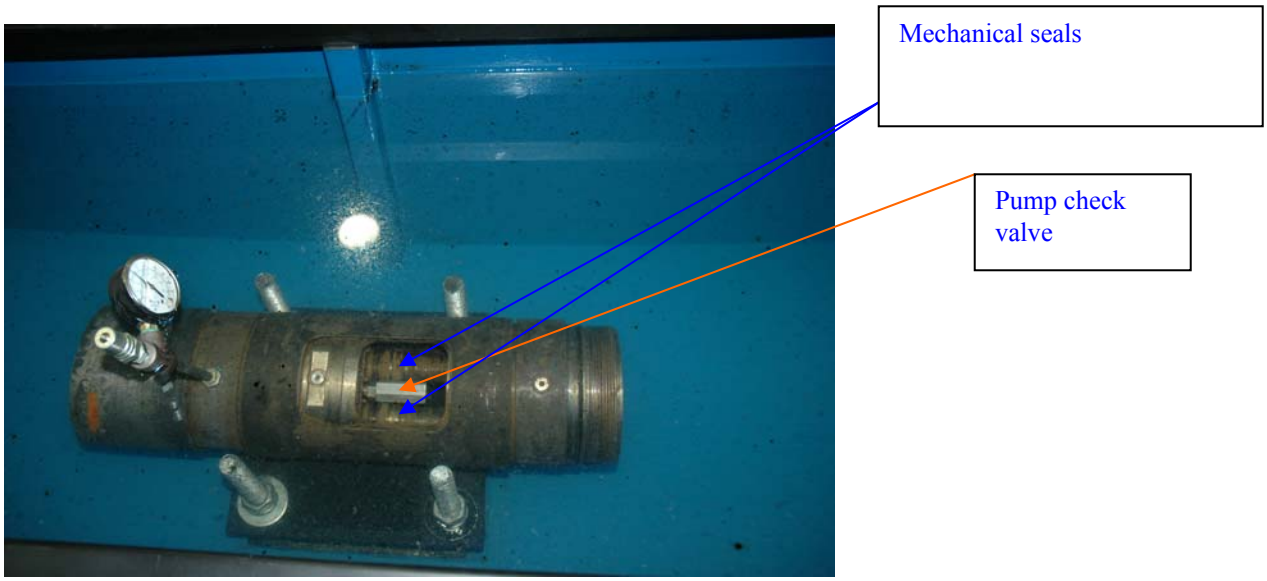


Bottom module tested for days after removing angular shaft

Timing Section being disengaged

Timing Gears in excellent condition

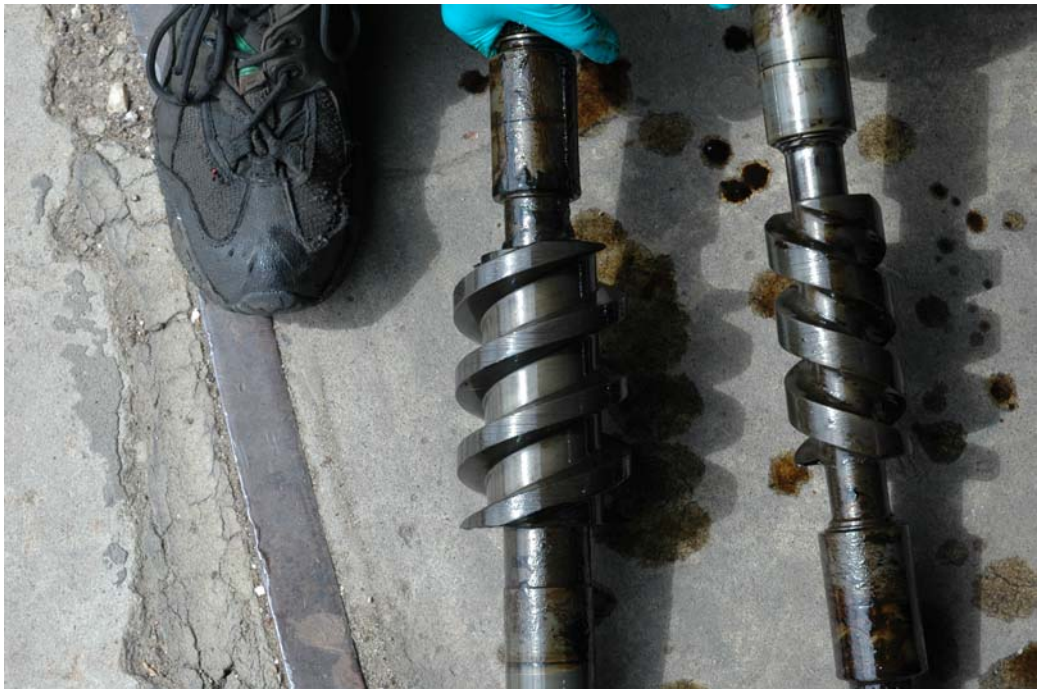
Intake section tested for days for resealing in water tank. Mechanical Seals and check valves in very good condition.



Foreign material which was provided to us by Suncor which came up with the pump. This has been given to Suncor for identification. No identification has been done at the time of preparing this report.

A pair of screw as removed.

A pair of screw shown with some deep grooves probably indicating some solid material that tried to enter the pump.



Conclusion Of Failure Mode:

The failure of the pump occurred due to the failure of angular shaft. After close scrutiny it was noticed that when the angular shaft was assembled the training provided to the assembly personnel was inadequate and the team did not know that the bullets though located by the split rings, must be set at a certain fixed distance to allow the free movement of the shaft while rotating. The split ring was completely pushed in not allowing the shaft to freely move while rotating. Due to this, severe heat was build up while the bullets where being pushed in into the split rings while rotating. The hardness of the location came down to close to around 50 HRC from the limit of 58 to 60HRC. Once this happened the wear pattern increased at extremely fast pace and completely damaged the joint. The bottom joint was damaged first as the torque is transferred from the bottom joint from the motor. Wear was setting in at the top too as this was also assembled by the same team and was incorrectly assembled.

Corrective and Preventive measures :

The assembly procedure was revisited. It is rewritten now. Stoppers are being provided in the new design so that there is no chance of error in future regardless of who will assemble it. Training has now been provided to all personnel on the assembly so that this will not repeat this error any more. Apart from this change, all refurbished pumps will have the larger angular shaft installed as we are manufacturing multiples of the new design for the larger pump which are being manufactured for Suncor.

Assembly Procedures in General:

As a standard CAN-K has gone through all assembly procedures and changed some for more clarity. We have even incorporated new "GO and "NO GO" assembly limitations to the new designed pumps to avoid such problems in future.

Some Additional lessons learned by this tear down:

Though this failure has brought unnecessary losses to Suncor and CAN-K, we now know that the pump check valve worked very well, the mechanical seals worked very well and the CAN-K 10 oil was not contaminated with the well bore fluid. We also learned that the tubing check valve possibly worked too.