SUNCOR 675 ESTSP R1
PUMP # 1 TEAR DOWN REPORT
Serial # 675UEFGHT100

CAN-K ARTIFICIAL LIFT SYSTEMS INC. CANADA

April 28, 2005 Revision-1

Pump Tear Down Report

CAN-K in the presence of Suncor's personnel Fernando Gavaria commenced the tear down of the ESTSP-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.

Tear Down Procedure:

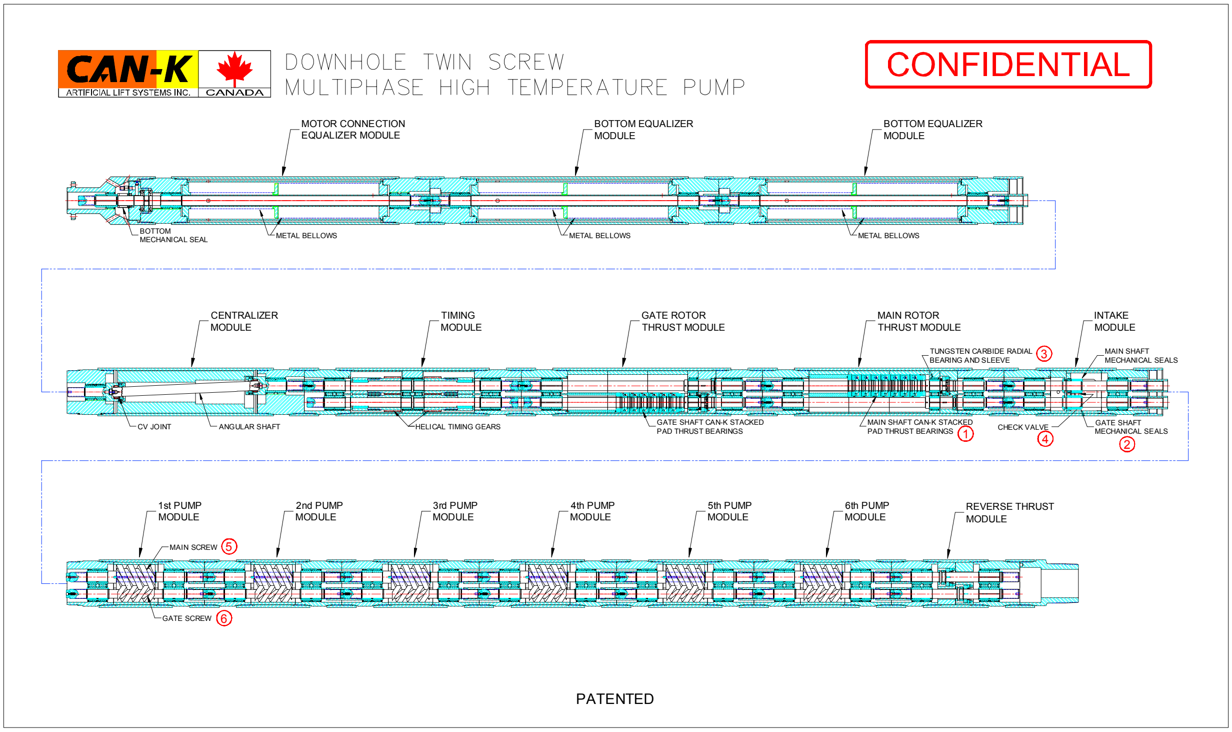
- Turn the pump manually and observe if it is turning
- If it is turning then install it on the test bench and run the pump and observe performance. If it did not turn, to start breaking up the connections from the top while the bottom barrier fluid section is pressure tested. The bottom flange will 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:

- CAN-K tried to turn the pump manually and it did not turn
- The bottom flange connection was removed to expose the bottom mechanical seal
- The top 5 ½ buttress thread connection was removed.
- The top reverse thrust bearing was removed and the reverse thrust was turning fine showing no signs of seizure. The pump was still not turning.
- The last pump stage (6th stage) was removed and the pump still did not turn.
- Similarly all the stages were removed up to the first stage. The pump still did not turn.
- The barrier fluid (clean section) was air tested. Air was pushed in at 25 psig with a gauge and the mechanicals seals, check valves, pump faces, ORB ports, equalizer seals were checked for leaks with soap water.
- We noticed that one of the mechanical seals at the intake was leaking as it showed bubbles.
- The check valve was not closing back and the air was leaking through the check valve at the intake too.
- Two ORB ports directly above the thrust bearings were showing bubbles confirming leaks.
- The bottom seal did not have any leaks at all, though the bottom and top mechanical seal design are of the same type in design.
- The intake section was removed and we saw crude oil and water in the barrier fluid (clean oil) section. This area is supposed to have only CAN-K 10 oil. We then tried to turn the pump and the pump was still not turning.
- The main thrust section was disconnected and the pump was manually turned and the pump turned with slight tightness due to cold crude oil in the system.
- The main thrust section was not turning. It was clear at this point that the final part of the pump that stopped it from turning was the main thrust bearing.
- The main thrust section was dismantled and we found that the shafts were completely heated up to extreme temperatures and turned black in areas where there were no tungsten bearings. One tungsten bearings appeared to be seized but we could push it out indicating that it was not welded on.
- We had to grind off some metal pieces to open the thrust section. The shaft at the thrust section was sheared. It was sheared due to intense heat at the thrust. All the thrust bearings were completely damaged and welded together. The other shaft at the thrust section, though turned black did not shear.
- The gate thrust section was removed. It was turning fine but filled with crude oil. The thrust bearings were completely filled with crude oil and on initial cleaning did not show any damage.
- The intake section was separately pressure tested on a jig. The same mechanical seal at the gate side was leaking and the check valve was not closing back.
- The mechanical seals were removed from the intake side. The path with graphalloy which is on the path of the shaft and the seal was clean and was not damaged. The faces were not cracked. The bellows of the mechanical seal did not show any leak when pressure tested meaning the bellows are good. The stationary seat when

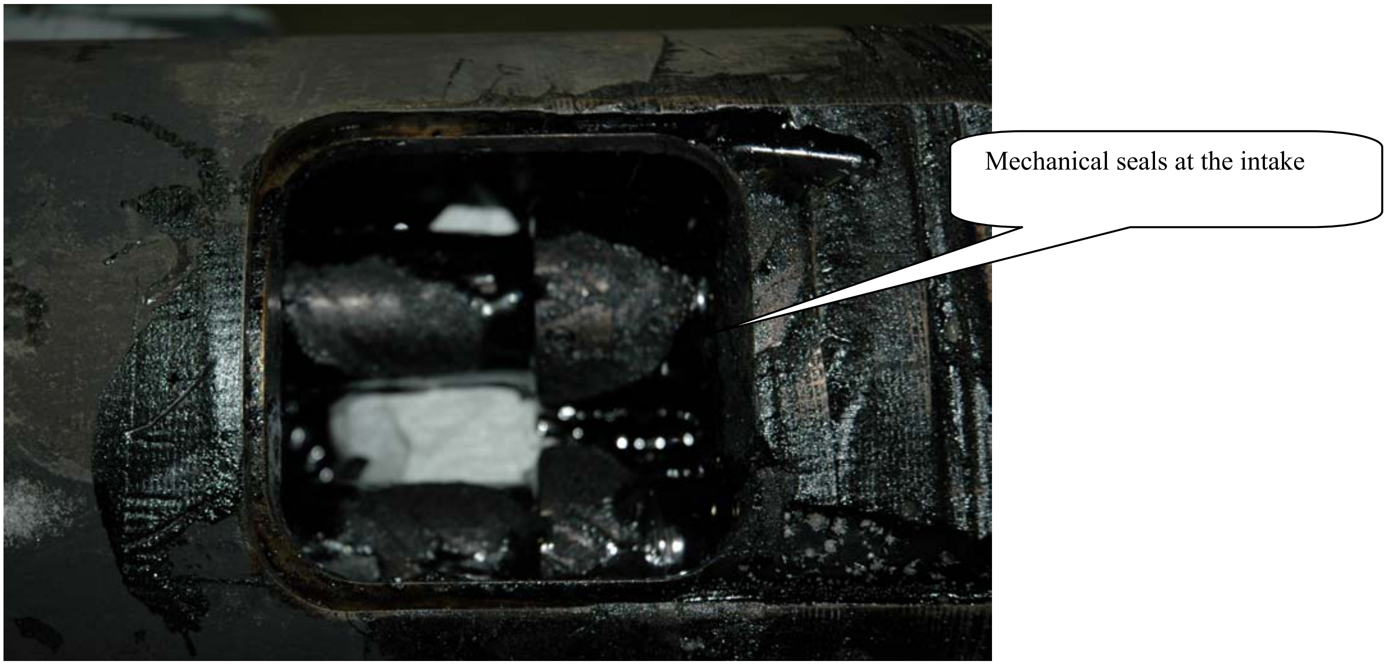
removed from the housing was completely deformed and appeared to be damaged or lost its properties.

- The check valve was removed and pressure tested and it was not closing or holding pressure.
- The timing gears module was removed and the gears though filled with crude oil did not show any visible damage with naked eye observation.
- The equalizers were removed and checked independently for leaks with pressure test and did not show any leaks.
- The bottom mechanical seal with the bottom equalizer was independently tested at 20 psig for leaks and did not show any leaks at all. This shows the bottom seal is in good condition.
- The first stage was dismantled to observe if there was any damage since the thrust was damaged. We noticed that the main screw ran on the gate screw, this was observed with curvature lines on the flanks of both the screws. The screws were damaged.
- At the time of preparing this report other pump stages (screw stages) have not been cleaned to observe for damage. It is common to have the first stage to have maximum damage in a situation of a thrust bearing failure. We expect to see similar damage in all screws.



Pump Schematic for easy reference.

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



Pump Intake showing the mechanical seals

Main thrust bearings stack

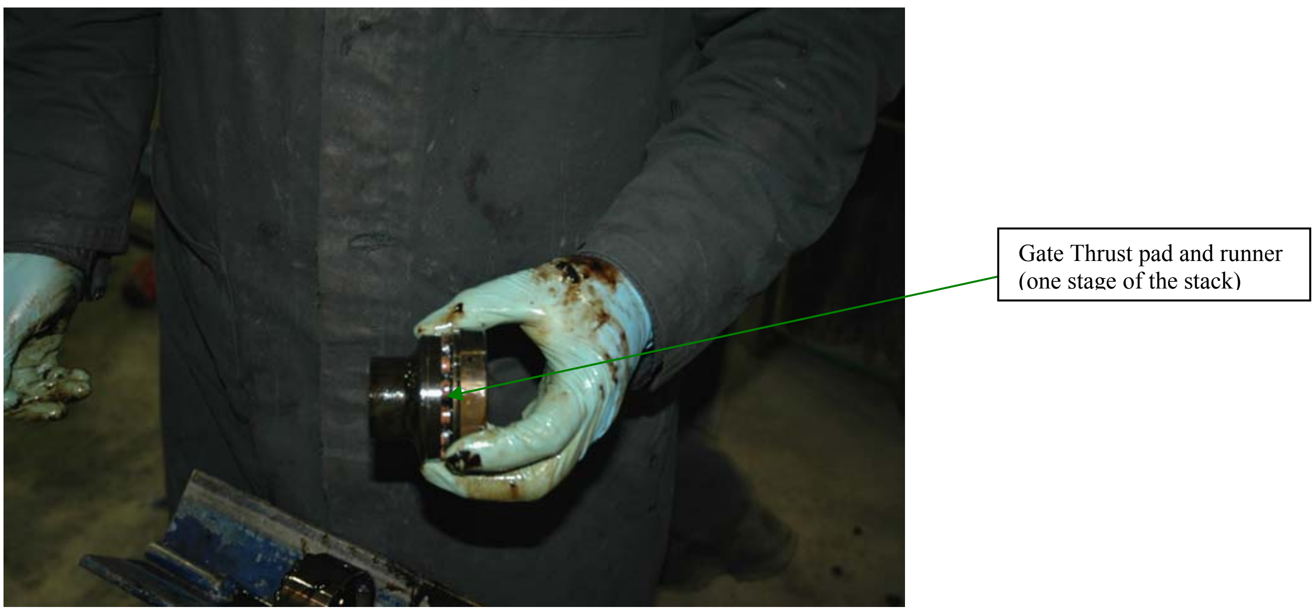
Main Thrust bearing shaft

Main shaft Sheared with thrust bearings damaged

Pressure Testing of the seals

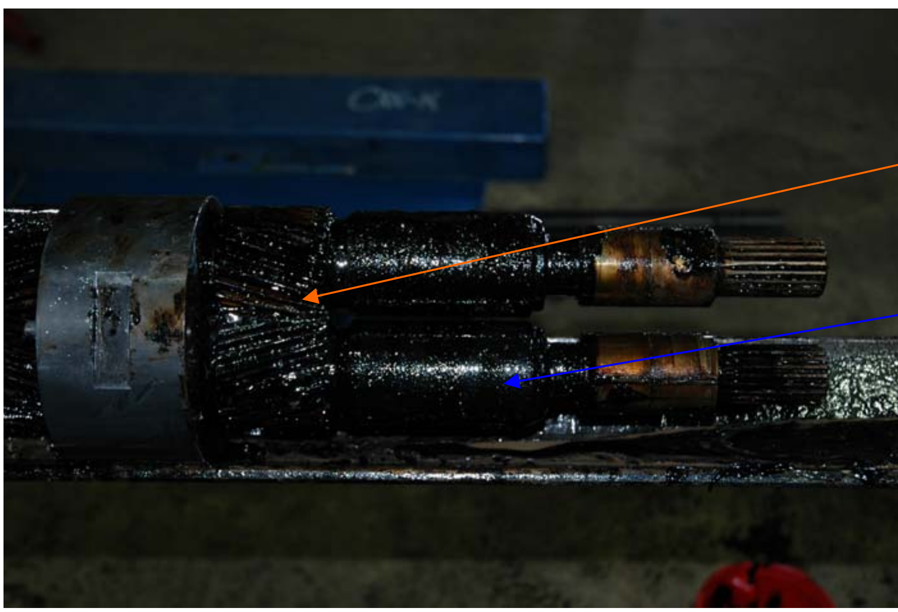
Independent Pressure Testing of Equalizers

Gate Thrust Shafts



Gate thrust

Gate Thrust Module disassembled

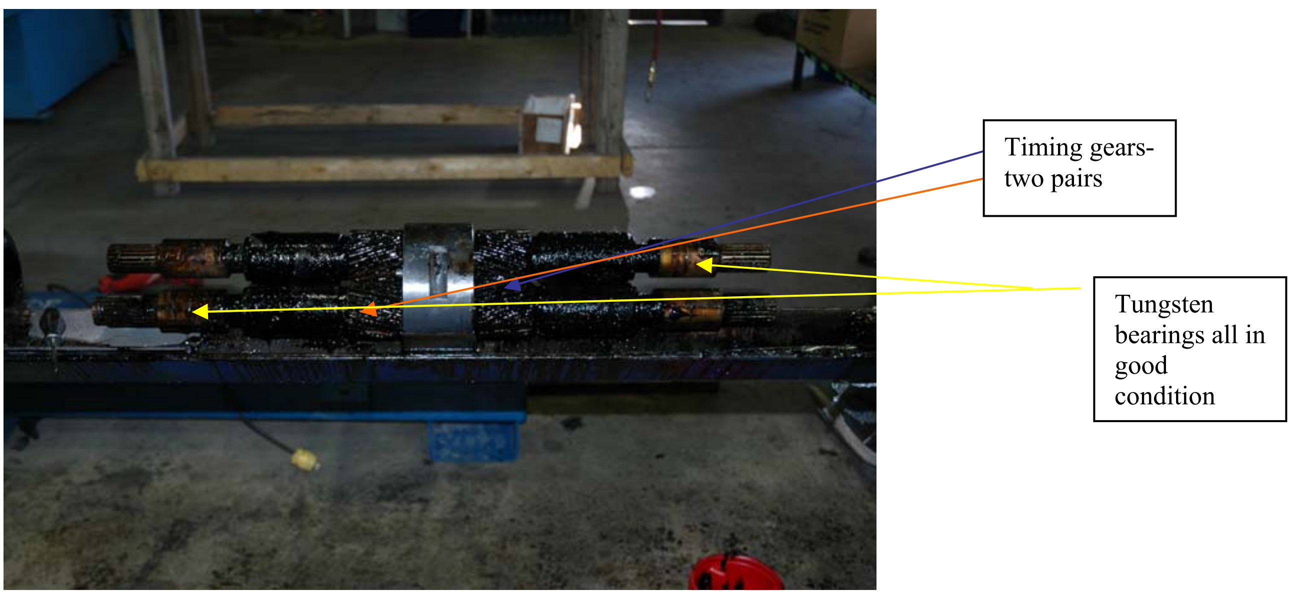


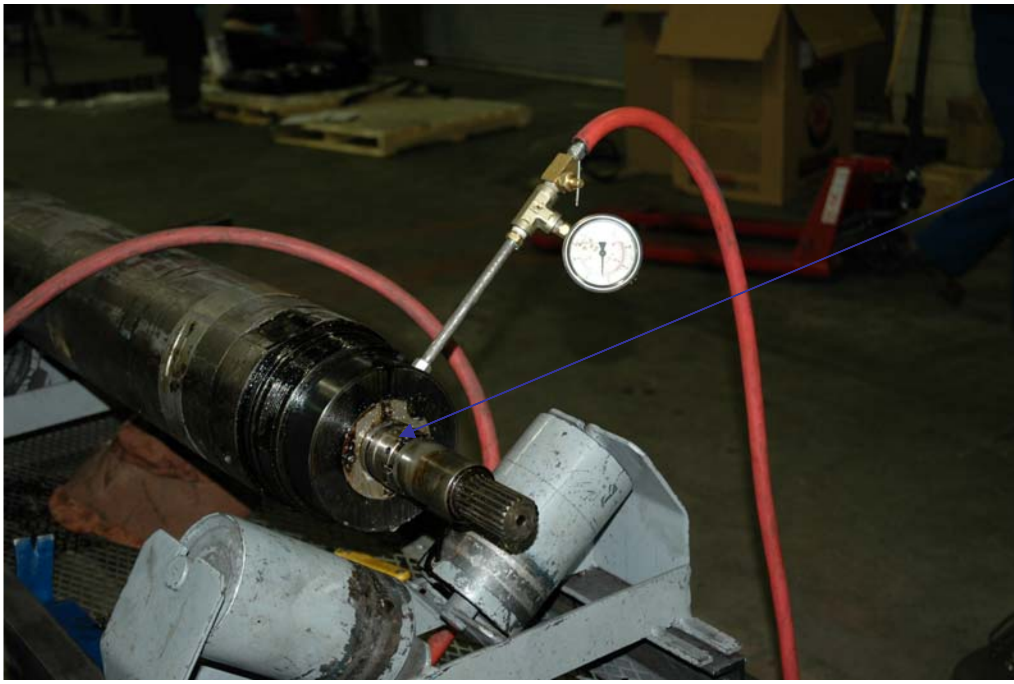
Timing gears- one pair shown. Filled with crude oil. No visible damage.

Lock Nuts (No visible damage)

Timing Gears

Centralizer & Timing Gears as Modules ready for disassembly



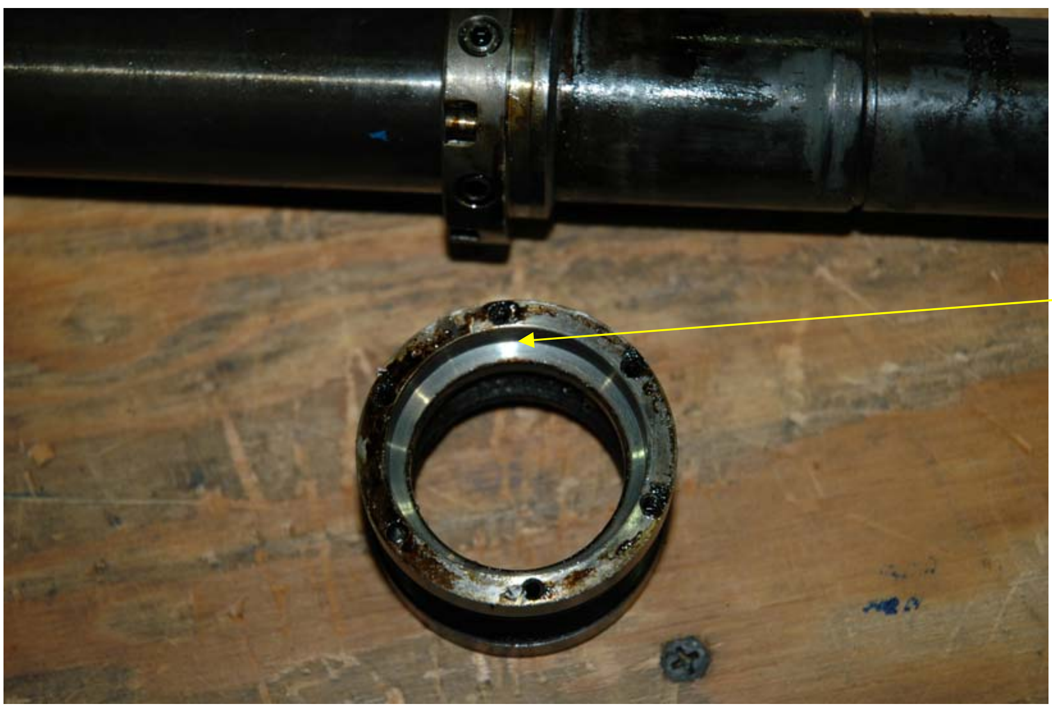


Bottom mechanical seal being pressure tested. No Leaks. Similar design to the top mechanical seals.

ORB pressure test on the thrust module. Showing Leaks on the ORB.

All thread connections between faces showed no leaks. Original thread dope is shown.

Cutting of metal pieces to remove main thrust bearings which are welded on due to high heat.



Mechanical seal (rotating) with graphalloy removed.

Gate and Main screws after cleaning

Mechanical seal housing


Mechanical Seal removed from the intake shaft

Bottom Mechanical seal tested for leaks under pressure.

Bottom flange section (this is the section that connects to the Schlumberger's protector) removed to expose the mechanical seals.

Conclusion Of Failure Mode:

Based on the tear down and further detailed study of the mechanical seals and the check / relief valve, it was concluded that the leakage path was through the check valve. Similar check valves were tested for resealing at high temperatures and it was not resealing. The screws could have turned back wards compressing the fluid on to the mechanical seal and the check valve while exiting through the intake. There were no spiking or other erratic running recordings on the amp chart prior to the last shut down.

On observing the main thrust bearings and areas in the thrust areas it shows that the temperature in that area has gone up. The check /relief valve's seals were damaged as the check valve was not closing. The ORB seals at the main thrust location were leaking near the main thrust but was not leaking at any other locations. Du Pont concluded that the stationary Kalrez we used could fail with hot water and or steam though it has high temperature capability of 316 deg C. The bottom mechanical seal which is of the same design of the top mechanical seal did not fail and appears to be in very good condition. This lead us to study as to why the top seal showed signs of failure but the bottom seal did not have any damage at all, though both are the same type of mechanical seals.

Testing of two new check/relief valves were done at the shop to see if it would reseal as certified by the suppliers of these relief/check valves. To our surprise, we found that the two new check valves were faulty too and did not reseal as certified by the suppliers.

All the areas of the tungsten bearings seem to be in good condition. The keys are all in good condition too.

The start of failure is now concluded as the failure of the check /relief valve at the intake.

The following areas had failed prior to final failure of the pump:

1. The check/relief valve (refers to intake pump check valve) did not reseal at high temperatures. When the pump stopped there was a rush of fluid back to the intake. At this time fluid started entering the barrier fluid section (clean area) and damaged the main thrust bearings.

Future Design changes and recommendations for any New Pumps.

1. Install spring loaded low coefficient of friction horizontal landing check valve (refers to discharge end) at the discharge to avoid reverse flow. CAN-K will supply this system as a package in future. Check valve (discharge side) must be landed close to the discharge as possible unlike an ESP. This is a "MUST" for all future installations.
2. Locate the mechanical seals in a protected area at the intake.
3. Add extra equalizers at the top and bottom to push the main and gate thrust as far as possible from the well bore fluid as possible. Build extra fluid areas at the top even if we have to bring most of the equalizers to the top.
4. Use high temperature Kalrez hot water, steam and crude oil compatible seals of 316 deg C. Replace existing ones though rated for high temperatures.
5. Use high temperature Kalrez based check/relief valves designed and manufactured by CAN-K and away from direct flow of the suction line.
6. Provide provisions of extra cooling areas on the thrust sections instead of using Aluminum and or Copper sheets to reduce thermos type heat containment at the thrust areas. The present failed pump had aluminum sheets rolled around the main thrust and gate thrust to conduct heat to the external shroud. New designs could have slots for direct contact with the well bore fluid. At the present time we have already changed it to copper for better heat dissipation.
7. Explore ways to balance thrust loading in larger casings style pumps. This system is not generally suitable for down hole pumps but will explore if it is possible.

Second Pump modifications (assembled):

1. Replace the check valve with 220 deg C working temperature rating. Seal rated for 316 deg C. <u>Replaced with alternative supplier of check /relief valve.</u>
2. Replaced ORB with Kalrez with hot water, steam and crude oil compatible "O"rings-316 deg Celsius.
3. Replaced the "O" rings on the stationary of the mechanical seals to Kalrez "O" rings of 316 deg C with hot water, steam and hydrocarbon compatibility. This would mean we have to dismantle part of the pump.

Conclusion:

The failure occurred due to the failure of a single check valve which was supposed to reseal but it did not reseal. When the pump was stopped, the back flow pushed fluid into the barrier fluid section (clean area), damaging the main thrust bearings.

The recommended modifications and changes will increase the life of the pump approaching towards the target of MTBF to 25,000 hours. CAN-K will strive to the best of its capability to achieve 25,000 hours.

We think this failure has given us immense knowledge to make modifications when our pump is landed at high temperatures and areas of weak points of the pump we must revisit. All these are now mainly focused on the check/ relief valve at the intake, locate mechanical seals preferably away from the direct reverse flow and keeping the CAN-K 10 oil IN and the crude oil and water OUT. However, the thrust chamber cooling, more scrutiny in QC and very close multiple checking while assembly must be revisited as a precautionary measure.