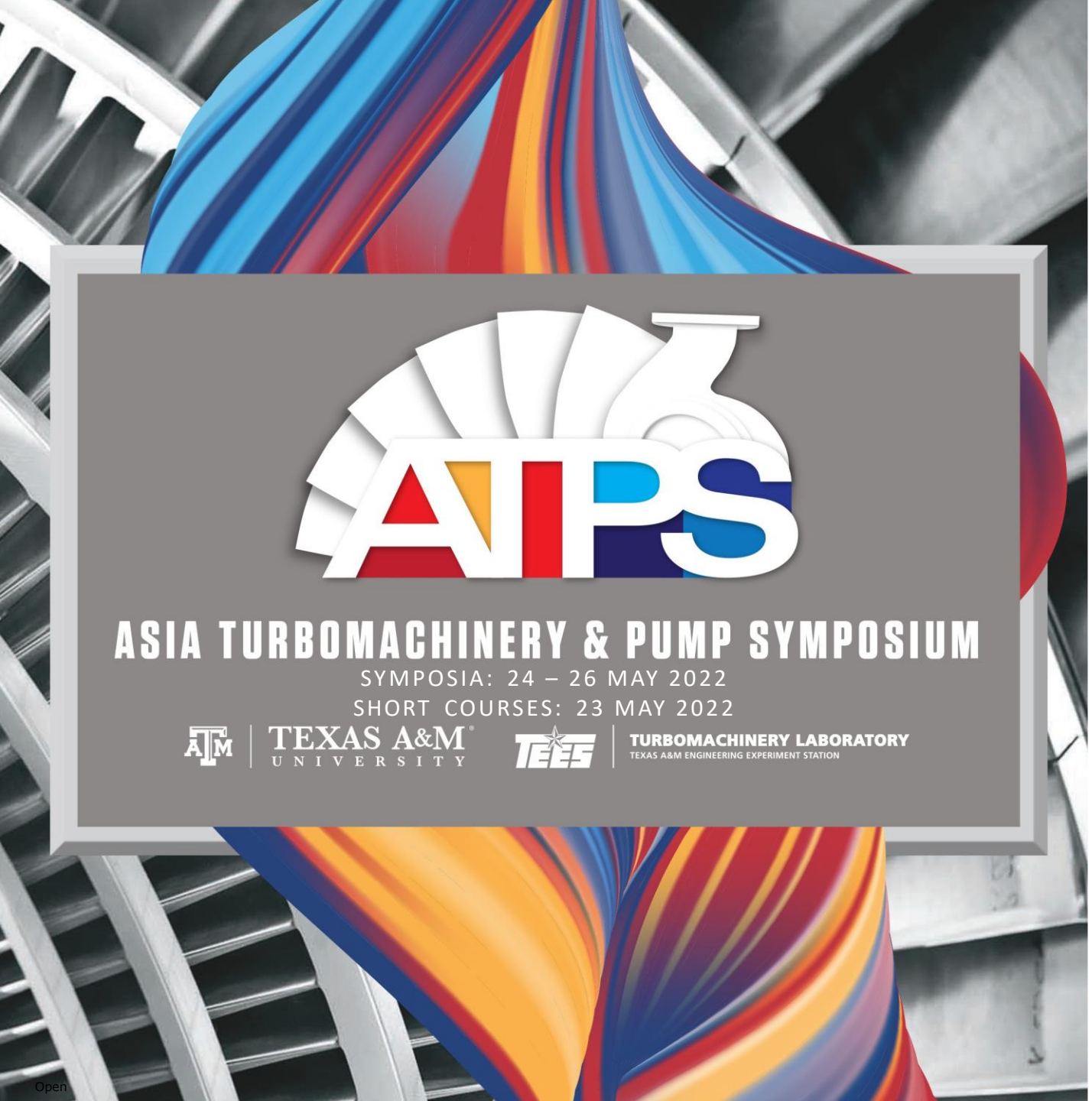

Case Study on Investigation and Resolution of High Lube Oil Pump Bearing Temperature for Off Spec. Condensate Recycle Pumps

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Presenter/Author Bios

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Abstract

Off Spec Condensate Recycle Pumps on an onshore gas production facility exhibited high lube oil temperature in pump bearing housing that exceeded the alert limits since commissioning. A Structured Root Cause Analysis was carried out to ascertain the cause of the high lube oil temperature that identified a large variation in pumping medium specific gravity as against the design data.

This case study will cover review of the pump design, problem history, structured root cause analysis conducted, solution implemented, along with results and lessons learnt.

Contents

Introduction and Background

- 02 units of Motor driven Vertical Can VS6 Type centrifugal pumps at an onshore gas production facility.
- Pump is 14 stage design with balance drum arrangement.
- Each Pump is rated for 30 m^3/hr flow and the minimum flow is 9 m^3/hr. Normal flow rate through the pump is in the range of 15 m^3/hr which is approximately the flow rate at which maximum loading of bearings occur.
- Each Pump is designed to operate with pumping medium specific gravity of 0.623 normal @ 57 deg C and 0.663 maximum @ 15 deg C.
- Existing balance drum diameter is 119.85 mm.
- Pumps are equipped with Ball type Thrust bearing (2X7214BECBJ).
- ISO VG 46 oil used for bearing lubrication with temperature gauge installed for oil temperature measurement.
- Allowable lube oil temperature in bearing housing for continuous operation is 70^0 C and alarm is set at 80^0 C.

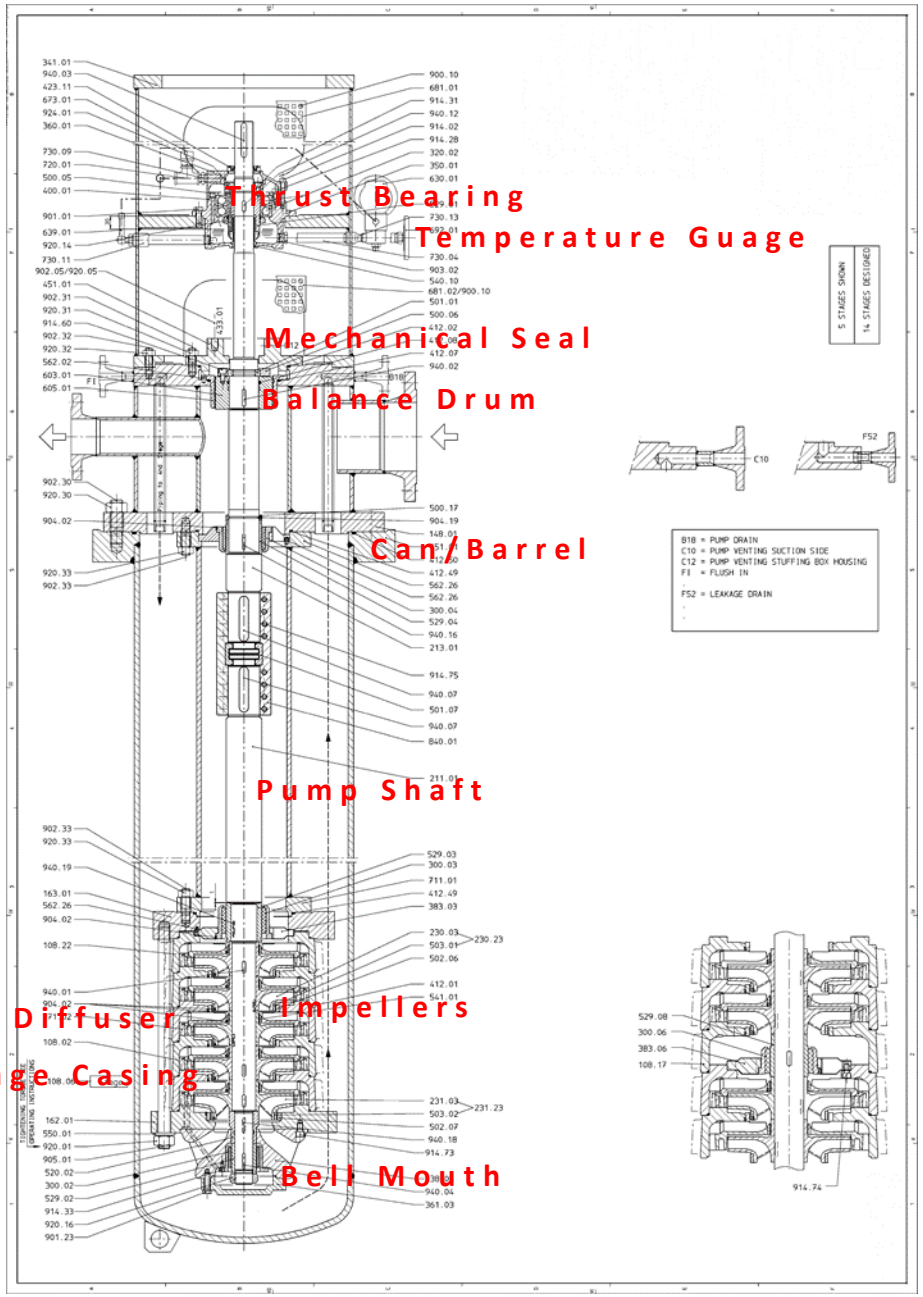
Problem Statement

- High lube oil temperature (ranging between 82^0C - 88^0C) in pump bearing housing since commissioning for both the pumps. The phenomenon was not consistently observed i.e., sometimes the pumps were observed to be running within allowable temperature limits of 70^0 C.

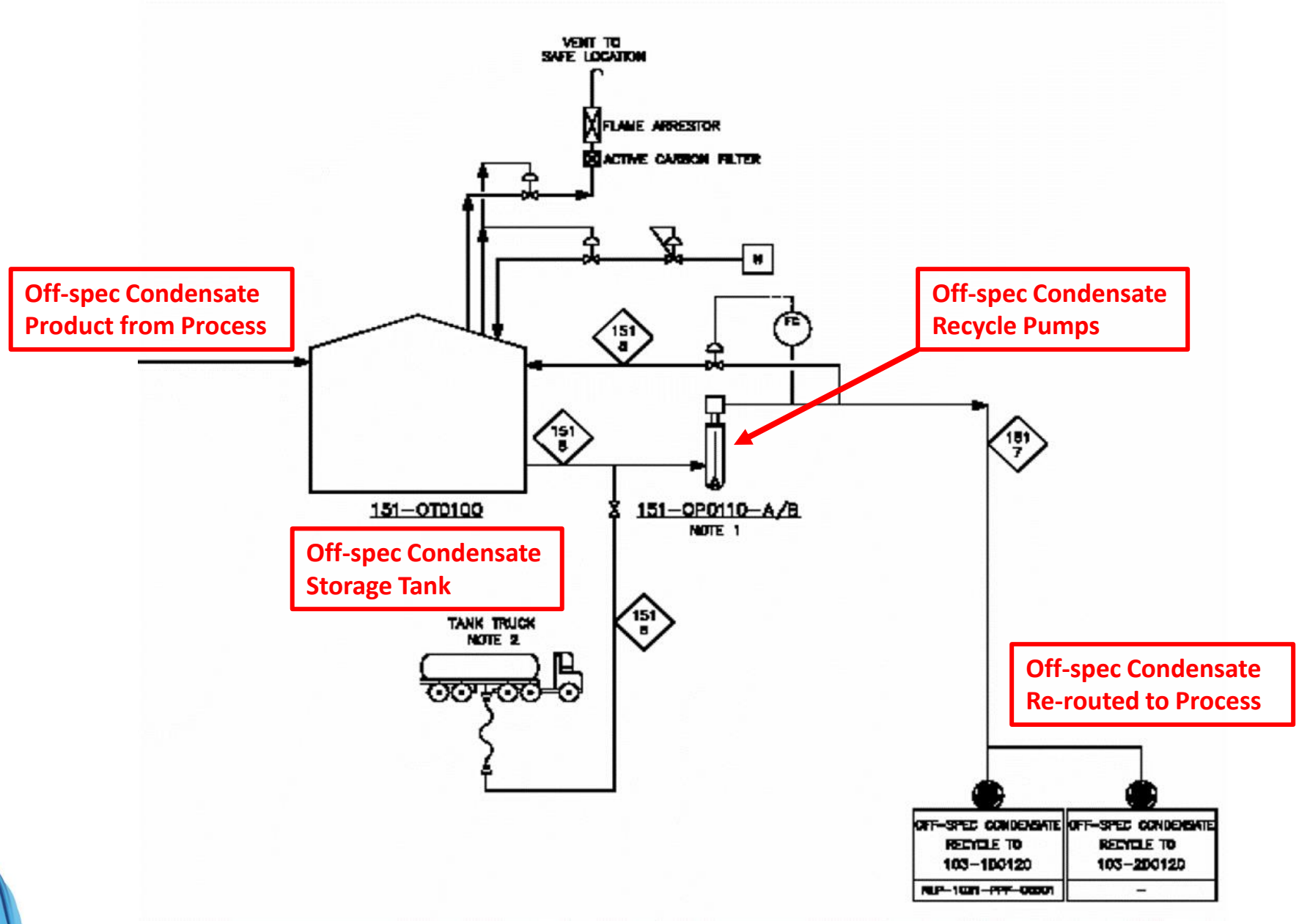
- Pumps were also seen operating at higher than maximum allowable working pressure of 40 bar g.

Pump Details

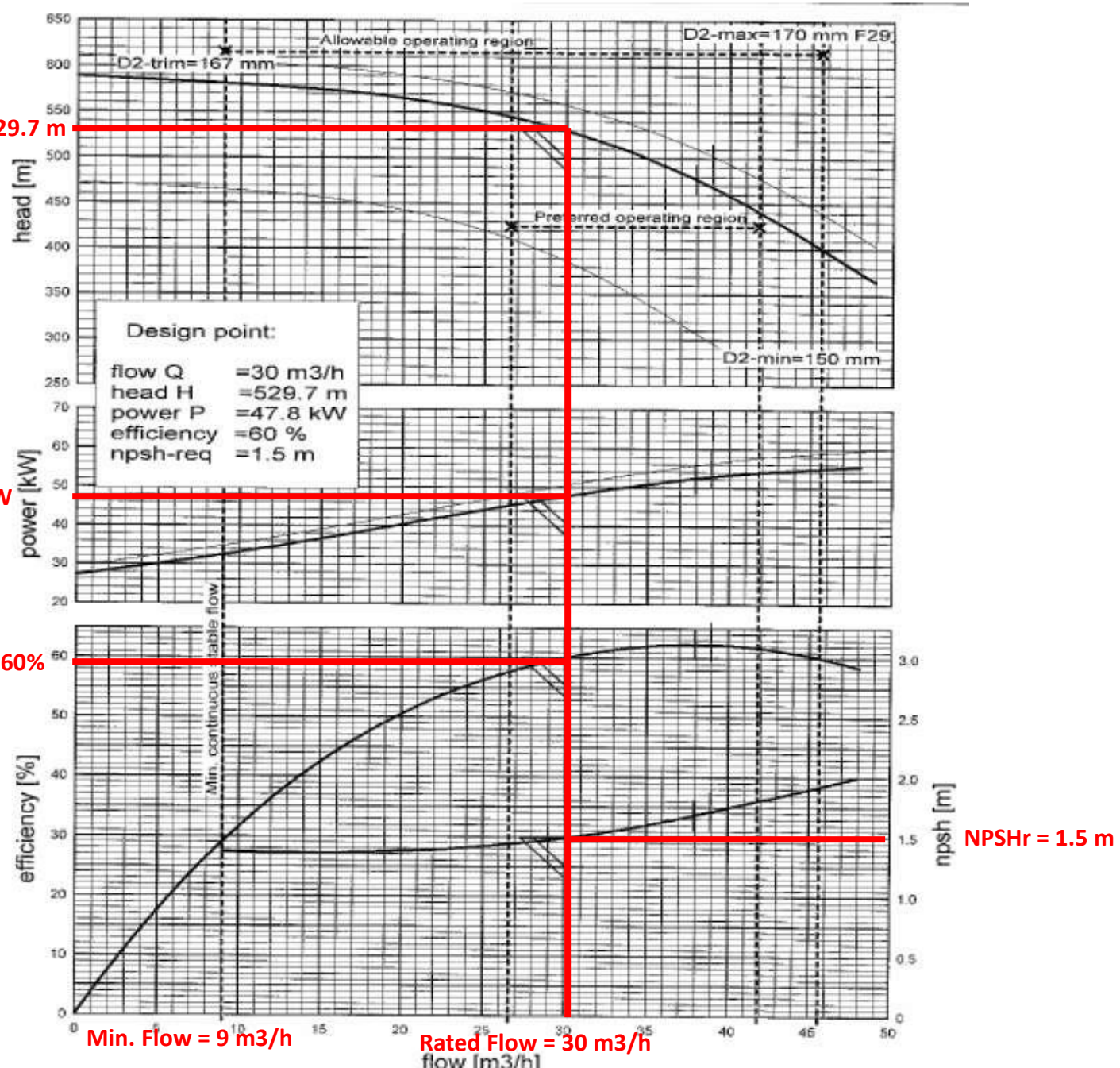
Design Data	
Pumping Liquid	Off-Spec HC Condensate
Suction Pressure (Rated)	0.0 barg
Discharge Pressure	32.1 barg
Differential Head	529.7 m
MAWP	40 barg
Pumping Temperature	57^0C
Rated Capacity	30 m3/hr
Specific Gravity of liquid	0.623 @ 57^0C (Normal) 0.663 @ 15^0C (Max)
Pump Speed	2978 rpm
Rated Power	47.8 KW
Motor Rating	75 KW



Pump Schematic Process Flow Diagram



Pump Performance Characteristic Curve



Rated Head = 529.7 m

Rated Power = 47.8 KW

Efficiency, n = 60%

NPSHr = 1.5 m

Min. Flow = 9 m3/h

Rated Flow = 30 m3/h

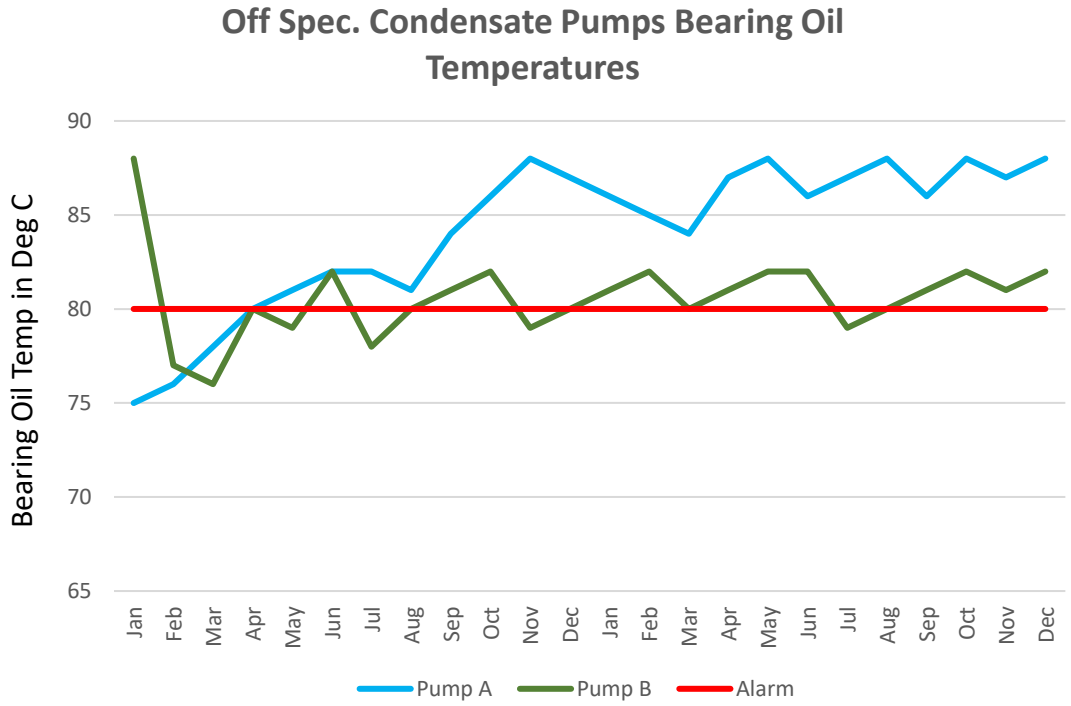
Site Observations and Activities conducted

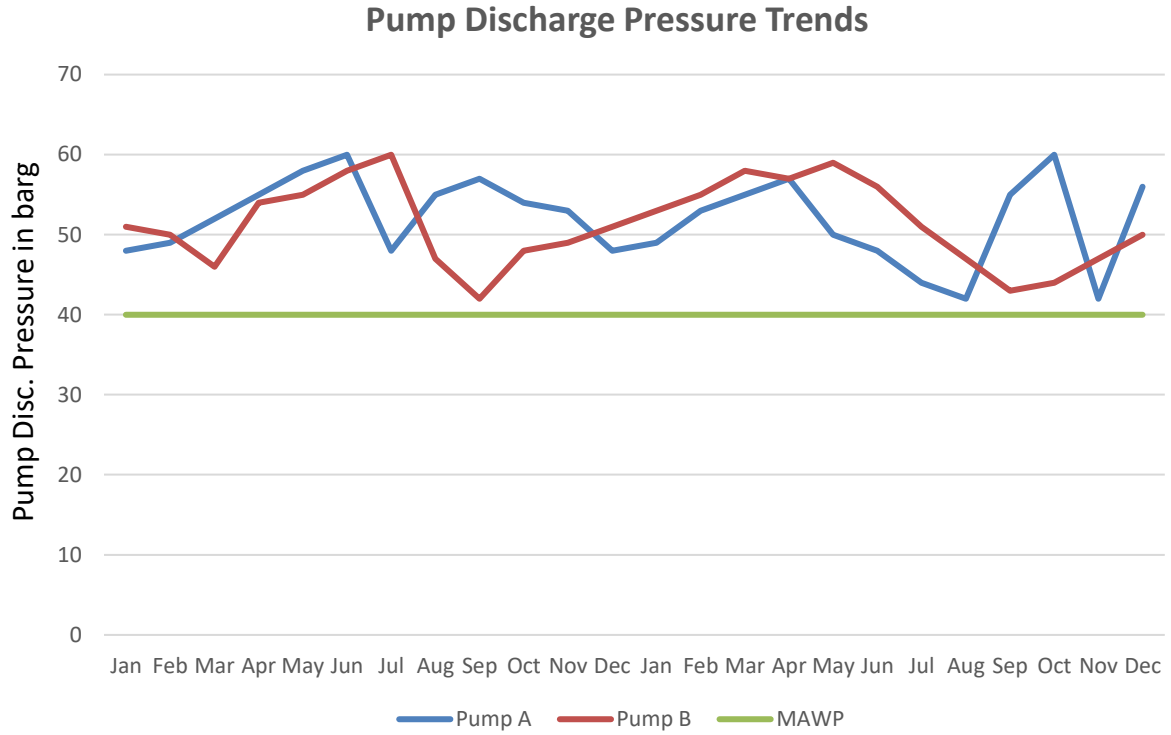
- Bearing inspection had been carried out and found to be in good condition.
- Bearing temperature gauges were suspected of faulty readings and the same was validated by infrared temperature measurements at different points on the bearing housing. This also confirmed that the temperatures were high.
- Bearing arrangement had been checked for correctness and verified to be as per design (Face to Face arrangement).
- Bearing preload data had been verified and found as per design.
- Shaft run out at bearing seating location had been checked and found to be within limits.
- No abnormal vibrations had been observed in the pump/motor system.
- Lube oil condition had been verified to be normal. As a fact even with new lube oil, the temperature still reached higher values.
- Pumps were being operated within allowable operating region as per the pump curve.
- Motor power was found adequate, but occasionally, during start-up high amps were noticed.

Site Observations and Activities conducted

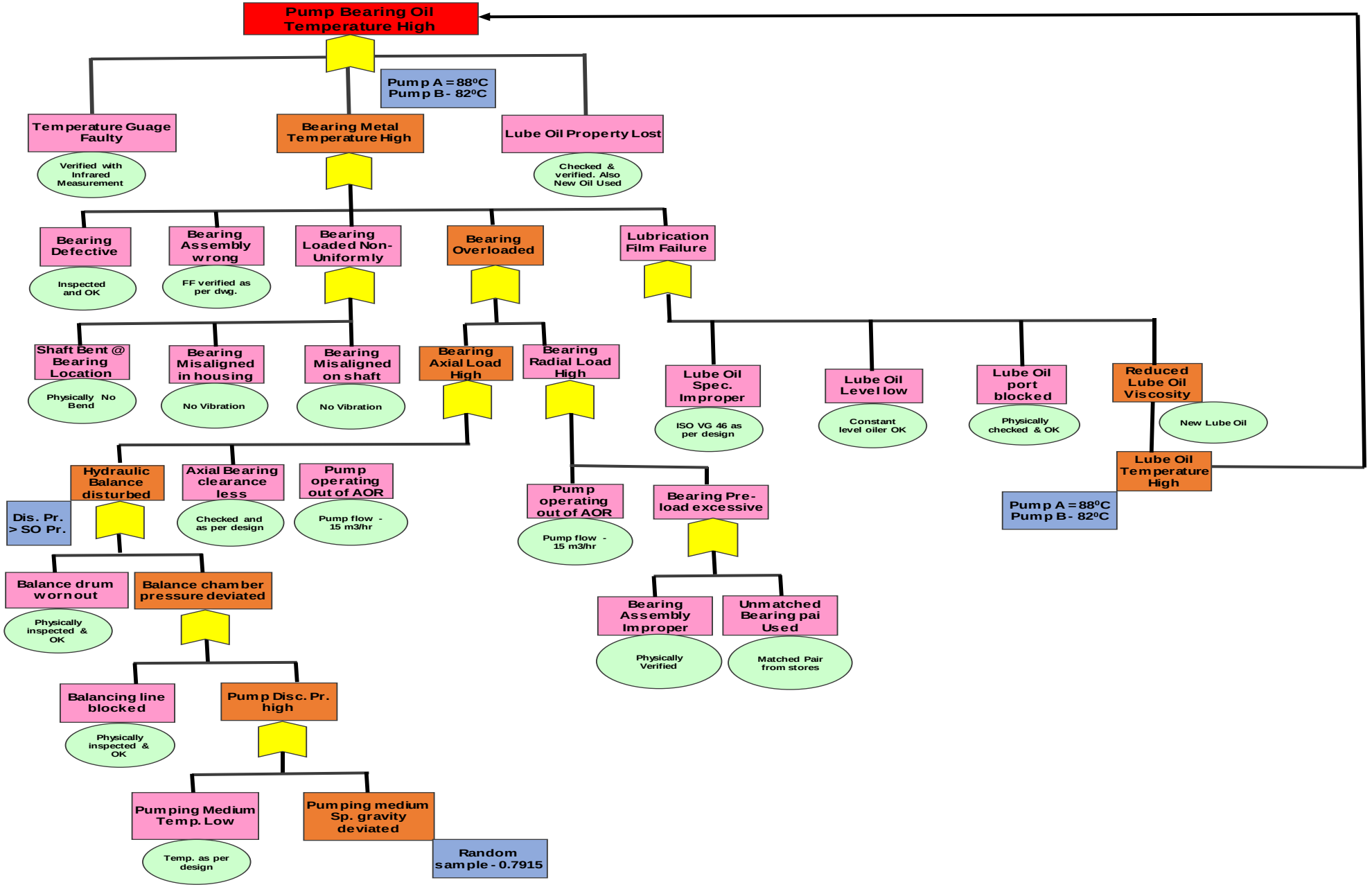
- Pump discharge pressure was higher than the shut off pressure of the pump as per characteristic curve.
- Pump operating pressure was higher than the Maximum Allowable Working Pressure of 40 bar g.
- Constant level oiler was checked and is found to be as per the design.
- Blockage of lube oil port in the pumping sleeve arrangement was suspected. The same has been verified and is found to be normal (no blockage).
- Lube oil specification was as per design ISO VG 46 as per pump manufacturers manual.
- Pumping medium specific gravity had been checked at random and was found varying between 0.7915 – 0.950.
- Pump bearing axial thrust load exceeded the allowable design thrust loads of bearing at flows between 15 – 20 m3/hr with a specific gravity of 0.950. However, the thrust load of the pump remained within limits with a specific gravity of 0.623 at all flow rates.

Site Observations- Pump Bearing Oil Temp. & Pump Discharge Pressure Trends





Detailed RCFA - Fault Tree Diagram



RCFA Analysis

- Higher specific gravity of the pumping medium resulted in disturbance in hydraulic balancing causing excessive pump bearing loading that also caused higher lube oil temperature in pump bearing housing.

- As a solution to the above issue, certain short-term mitigation solutions were analyzed and implemented.

- Additionally, change in hydraulic balancing (i.e. varying the balance drum size) was also sought from vendor to ensure that the pump bearing is not getting overloaded for the wider range of specific gravity of pumping medium. Also, validation of the efficacy of the solution was obtained by way of axial thrust & bearing load/life estimations for the new balancing drum which proved to be effective.

Axial Thrust Load Estimation- Existing Balance Drum – 119.85 mm

Input

Unit selection	ISO/Metric Units	Imperial Units

1- Pump data

Pump size	50-180		
Hydraulic	S	[-]	
Number of stages	1)	14	
Dimension "K"	2)	2065	mm
Pump power		71	kW

Notes: 1) Without dummy stages
2) Please refer to Product manual

2- Operating data

Rated flow	30	m3/h
Rated head	530	m
Minimum flow 3)	9	m3/h
Suction pressure	1,2	barg
Rated speed	2980	1/min
Fluid density	623	kg/m3

Notes: 3) If not known, 30% of Flow at BEP can be assumed

3- Mechanical seal

Mech. seal pressurized? 4)	yes	[-]	
Mech. seal press. with 5)	2	barg	
Chamber pressure	6,4	barg	
Buffer fluid pressure	8,4	barg	
Balance line returns to stage No. 6)	2	[-]	
NDE diam 7)=		DE diam 7)=	

Notes: 4) Mech. pressurized
YES: Plan 53,54,74
NO: API-Plan 52,62,72,76
5) Pressure diff. above Balance Pressure at Min. Flow
6) For design w/o Piston
enter Stage No.: 14 (=Last Stage)
7) In [mm]; If not known: let empty

4- With Balance drum (Piston) : YES

Available Std. diameter	119,85	[mm]
Custom diam.		[mm]
Taken for calculation	119,85	[mm]

Notes: For Design w/o Piston: Piston diam value will be:
→ 62 [mm] (shaft diam.)

5- Required bearing life time

Min. at rated flow	25000	[h]
Min. at min flow	16000	[h]

Notes: API recommendation at rated flow: 25000 [hours]
API recommendation at Min. flow: 16000 [hours]

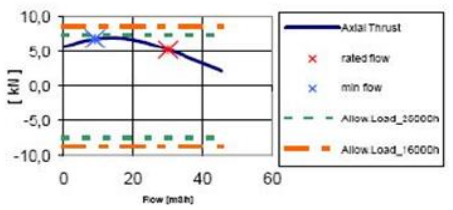
Output

Axial thrust

Axial thrust (rated)	5305	N	UP
(with +/- safety margins)	5305		UP
Axial thrust (min. flow)	6879		UP
(with +/- safety margins)	6879		UP

Bearing life

Angular contact ball bearing size:	7214	[-]
Bearing life L10h rated		[hours] OK
Bearing life L10h min. flow		[hours] OK
| Average Thrust load | > Min. load		
Verified	OK	[-]



Additional checking

Bearing speed	290550	OK	mean bear. diam [mm]. x speed [1/min] < 500 000 refer to API 610 9th ed. 5.10.2 Table 9
Energy density	211580	OK	power [kW] x speed [1/min] < 4 000 000 refer to API 610 9th ed. 5.10.2 Table 9

Axial Thrust @rated (5305 N) & @ Min. Flow Condition (6879 N) @ SG = 623 kg/m3

Input

Unit selection	ISO/Metric Units	Imperial Units

1- Pump data

Pump size	50-180		
Hydraulic	S	[-]	
Number of stages	1)	14	
Dimension "K"	2)	2065	mm
Pump power		71	kW

Notes: 1) Without dummy stages
2) Please refer to Product manual

2- Operating data

Rated flow	30	m3/h
Rated head	530	m
Minimum flow 3)	9	m3/h
Suction pressure	1,2	barg
Rated speed	2980	1/min
Fluid density	950	kg/m3

Notes: 3) If not known, 30% of Flow at BEP can be assumed

3- Mechanical seal

Mech. seal pressurized? 4)	yes	[-]	
Mech. seal press. with 5)	2	barg	
Chamber pressure	9,1	barg	
Buffer fluid pressure	11,1	barg	
Balance line returns to stage No. 6)	2	[-]	
NDE diam 7)=		DE diam 7)=	

Notes: 4) Mech. pressurized
YES: Plan 53,54,74
NO: API-Plan 52,62,72,76
5) Pressure diff. above Balance Pressure at Min. Flow
6) For design w/o Piston
enter Stage No.: 14 (=Last Stage)
7) In [mm]; If not known: let empty

4- With Balance drum (Piston) : YES

Available Std. diameter	119,85	[mm]
Custom diam.		[mm]
Taken for calculation	119,85	[mm]

Notes: For Design w/o Piston: Piston diam value will be:
→ 62 [mm] (shaft diam.)

5- Required bearing life time

Min. at rated flow	25000	[h]
Min. at min flow	16000	[h]

Notes: API recommendation at rated flow: 25000 [hours]
API recommendation at Min. flow: 16000 [hours]

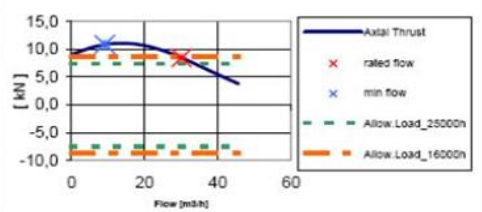
Output

Axial thrust

Axial thrust (rated)	8477	N	UP
(with +/- safety margins)	8477		UP
Axial thrust (min. flow)	10877		UP
(with +/- safety margins)	10877		UP

Bearing life

Angular contact ball bearing size:	7214	[-]
Bearing life L10h rated		[hours] OK
Bearing life L10h min. flow		[hours] OK
| Average Thrust load | > Min. load		
Verified	OK	[-]



Additional checking

Bearing speed	290550	OK	mean bear. diam [mm]. x speed [1/min] < 500 000 refer to API 610 9th ed. 5.10.2 Table 9
Energy density	211580	OK	power [kW] x speed [1/min] < 4 000 000 refer to API 610 9th ed. 5.10.2 Table 9

Axial Thrust @rated (8477 N) & @ Min. Flow Condition (10877 N) @ SG = 950 kg/m3

Axial Thrust Load Estimation-Proposed Balance Drum – 104.85 mm

Input

Unit selection: (●) ISO/Metric Units ( ) Imperial Units

1- Pump data

Pump size	50-180	
Hydraulic	S	[-]
Number of stages 1)	14	
Dimension "K" 2)	2065	mm
Pump power	71	kW

Notes: 1) Without dummy stages
2) Please refer to Product manual

2- Operating data

Rated flow	30	m3/h
Rated head	530	m
Minimum flow 3)	9	m3/h
Suction pressure	1,2	barg
Rated speed	2980	1/min
Fluid density	623	kg/m3

Notes: 3) If not known, 30% of Flow at BEP can be assumed

3- Mechanical seal

Mech. seal pressurized? 4)	yes	[-]
Mech. seal press. with 5)	2	barg
Chamber pressure	6,4	barg
Buffer fluid pressure	8,4	barg
Balance line returns to stage No. 6)	2	[-]
NDE diam 7)=	DE diam 7)=	

Notes: 4) Mech. pressurized
YES: Plan 53,54,74
NO: API-Plan 52,62,72,76
5) Pressure diff. above Balance Pressure at Min. Flow
6) For design w/o Piston enter Stage No.: 14 (=Last Stage)
7) In [mm]; If not known: let empty

4- With Balance drum (Piston) : YES

Available Std. diameter	104,85	[mm]
Custom diam.		[mm]
Taken for calculation	104,85	[mm]

Notes: For Design w/o Piston: Piston diam value will be:
→ 62 [mm] (shaft diam.)

5- Required bearing life time

Min. at rated flow	25000	[h]
Min. at min flow	16000	[h]

Notes: API recommendation at rated flow: 25000 [hours]
API recommendation at Min. flow: 16000 [hours]

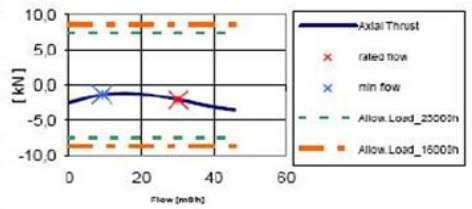
Output

Axial thrust

Axial thrust (rated)	-2044	N	DOWN
(with +/- safety margins)	-2044		DOWN
Axial thrust (min. flow)	-1314		DOWN
(with +/- safety margins)	-1314		DOWN

Bearing life

Angular contact ball bearing size:	7214	[-]
Bearing life L10h rated		[hours] OK
Bearing life L10h min. flow		[hours] OK
| Average Thrust load | > Min. load		
Verified	No	[-]



Additional checking

Bearing speed	290550	OK	mean bear. diam [mm]. x speed [1/min] < 500 000 refer to API 610 9th ed. 5.10.2 Table 9
Energy density	211580	OK	power [kW] x speed [1/min] < 4 000 000 refer to API 610 9th ed. 5.10.2 Table 9

Axial Thrust @rated (2044 N) & @ Min. Flow Condition (1314 N) @ SG = 623 kg/m3

Input

Unit selection: (●) ISO/Metric Units ( ) Imperial Units

1- Pump data

Pump size	50-180	
Hydraulic	S	[-]
Number of stages 1)	14	
Dimension "K" 2)	2065	mm
Pump power	71	kW

Notes: 1) Without dummy stages
2) Please refer to Product manual

2- Operating data

Rated flow	30	m3/h
Rated head	530	m
Minimum flow 3)	9	m3/h
Suction pressure	1,2	barg
Rated speed	2980	1/min
Fluid density	950	kg/m3

Notes: 3) If not known, 30% of Flow at BEP can be assumed

3- Mechanical seal

Mech. seal pressurized? 4)	yes	[-]
Mech. seal press. with 5)	2	barg
Chamber pressure	9,1	barg
Buffer fluid pressure	11,1	barg
Balance line returns to stage No. 6)	2	[-]
NDE diam 7)=	DE diam 7)=	

Notes: 4) Mech. pressurized
YES: Plan 53,54,74
NO: API-Plan 52,62,72,76
5) Pressure diff. above Balance Pressure at Min. Flow
6) For design w/o Piston enter Stage No.: 14 (=Last Stage)
7) In [mm]; If not known: let empty

4- With Balance drum (Piston) : YES

Available Std. diameter	104,85	[mm]
Custom diam.		[mm]
Taken for calculation	104,85	[mm]

Notes: For Design w/o Piston: Piston diam value will be:
→ 62 [mm] (shaft diam.)

5- Required bearing life time

Min. at rated flow	25000	[h]
Min. at min flow	16000	[h]

Notes: API recommendation at rated flow: 25000 [hours]
API recommendation at Min. flow: 16000 [hours]

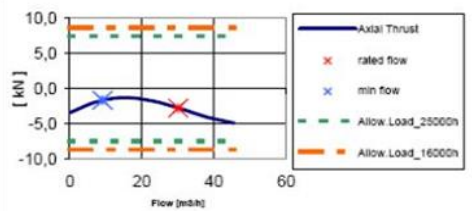
Output

Axial thrust

Axial thrust (rated)	-2730	N	DOWN
(with +/- safety margins)	-2730		DOWN
Axial thrust (min. flow)	-1617		DOWN
(with +/- safety margins)	-1617		DOWN

Bearing life

Angular contact ball bearing size:	7214	[-]
Bearing life L10h rated		[hours] OK
Bearing life L10h min. flow		[hours] OK
| Average Thrust load | > Min. load		
Verified	No	[-]

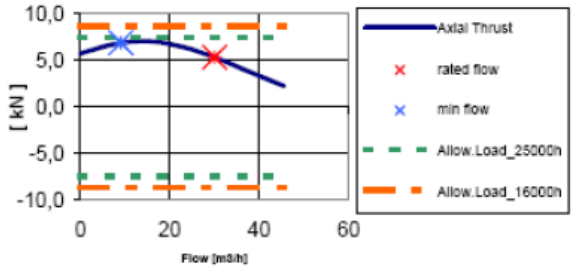
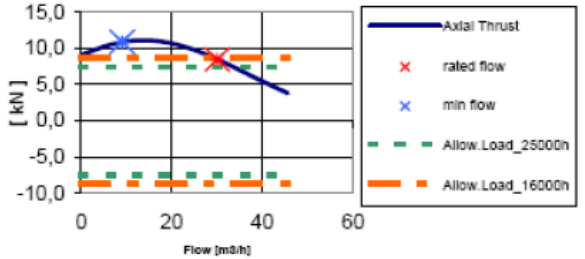
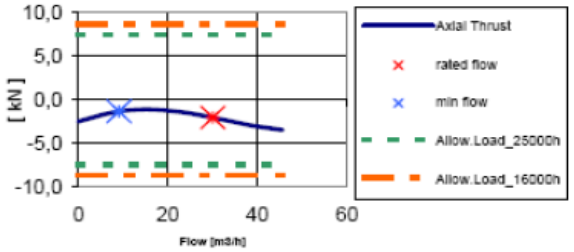
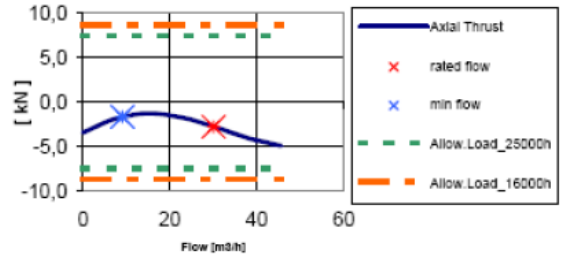


Additional checking

Bearing speed	290550	OK	mean bear. diam [mm]. x speed [1/min] < 500 000 refer to API 610 9th ed. 5.10.2 Table 9
Energy density	211580	OK	power [kW] x speed [1/min] < 4 000 000 refer to API 610 9th ed. 5.10.2 Table 9

Axial Thrust @rated (2730 N) & @ Min. Flow Condition (1617 N) @ SG = 950 kg/m3

Axial Thrust Load Estimation Comparison

Fluid Density	Balance Drum Size	Axial Thrust Load Estimation	Result
0.623 Kg/m3	119.85 mm		
0.950 Kg/m3	119.85 mm		
0.623 Kg/m3	104.85 mm		
0.950 Kg/m3	104.85 mm		

Mitigation Solutions Implemented

After evaluating various options, the following short-term mitigation solutions were implemented for handling the higher specific gravity off-Spec condensate from the storage tank:

Short Term Mitigation Solutions:

- ✓ Carry out piping modifications, including isolation valves, to drain Off-Spec Condensate from the Off-Spec Condensate Storage Tank to DSO Storage Tank to the DSO Sump drum.
- ✓ Install an on-line Density Analyzer to monitor the density of hydrocarbon condensate while draining the fluid from the Off-Spec Condensate Storage Tank to DSO Storage Tank.
- ✓ Update the Operating Procedure to mandate starting Off-Spec Condensate Recycle Pump with open discharge and to drain any fluid with specific gravity higher than 0.70.
- ✓ Configure a high pump discharge pressure alarm (PAH) with a set point of 38 barg.
- ✓ Change the set point of pump high high discharge pressure trip (PAHH) from the present value of 58 barg to 40 barg.
- ✓ Change the protection settings of the Off-Spec Condensate Recycle Pump Motors as below:

	Present Setting	Recommended Setting
Motor Start-up time	1 sec	5 sec
Motor Stall Trip Delay	5 sec	8 sec

Modifications Implemented

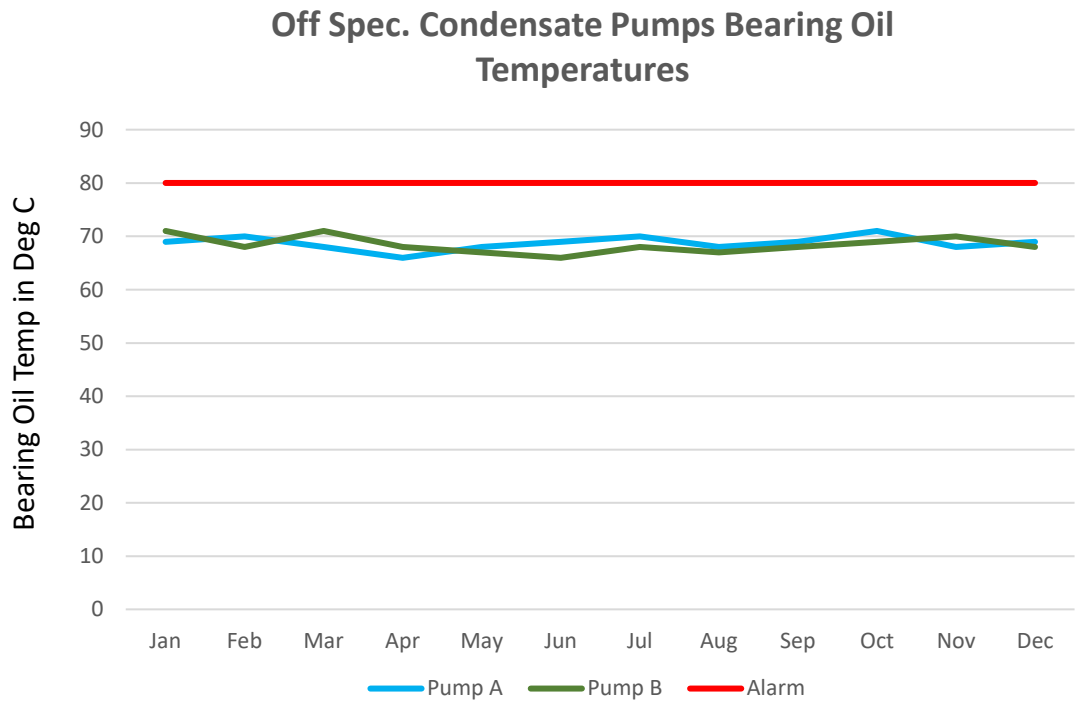
Further, as a permanent solution to the issue, the following long-term modifications were implemented:

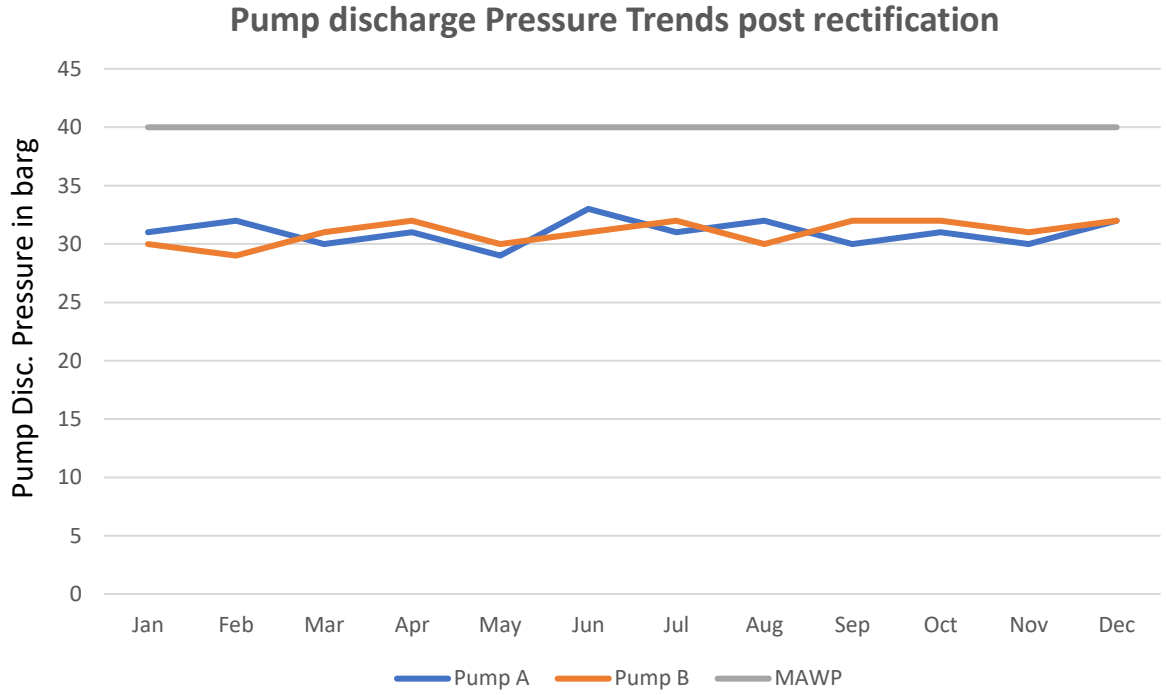
Long Term Modifications:

- ✓ The balance drum size was modified from the existing diameter of 119.85 mm to the reduced diameter of 104.85 in order to reduce the high load to the bearings causing high bearing oil temperatures.

- ✓ Additionally, the pressure parts (inlet/outlet casing & can/barrel) were also modified to suit the new operating conditions (high working pressures).

Site Observations Post Modifications- Pump Bearing Oil Temp. & Pump Discharge Pressure Trends





Results

- ✓ **The short terms mitigation solutions as well as the implementation of permanent modifications ensured continuous safe operation of the pump within allowable pump bearing lube oil temperatures as well as pump discharge pressures.**

Lessons Learnt

- Amongst the processing fluid characteristics, the specific gravity of the pumping fluid versus the pump design/component selection represents one of the most critical fluid dynamic parameters to be considered.
- Changes in pumping fluid specific gravity can affect pump performance in a way that may force the pump off its curve.
- It can also affect BHP as seen from the pump horsepower equation.
- Especially, an unpredicted increase in specific gravity of the pumping medium would disturb the hydraulic balance causing excessive pump bearing loading that would eventually affect the bearing life. This would also result in increase in pump discharge pressure.
- This case study also highlights the significance of conducting a structured Root Cause Failure Analysis (RCFA) to resolve the pain points through implementation of short-term mitigation actions followed by long-term modifications.

Thank You