

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

Girish Kamal



## **Presenter/Author Bios**



#### <u>Girish Kamal</u> Principal Rotating Equipment Engineer

Girish Kamal is working as Principal Rotating Equipment Engineer (Technical Authority 1) with the Centre of Excellence Division of PETRONAS Upstream in Kuala Lumpur. He has 32 years experience in the Oil and Gas Industry in the fields of rotating equipment management for onshore and offshore applications including specifications, design approvals, testing, inspection, commissioning, installation, maintenance and technical services.



### 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.



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- 1. Introduction and Background
- 2. Problem Statement
- 3. Pump Details
- 4. Pump Schematic/Process Flow Diagram/Pump Curve
- 5. Site Observations and activities conducted
- 6. Fault Tree Diagram with detailed Root Cause Analysis
- 7. Mitigation Solutions Analyzed/Implemented
- 8. Results
- 9. Lessons Learnt



## Introduction and Background

- O2 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<sup>3</sup>/hr flow and the minimum flow is 9 m<sup>3</sup>/hr. Normal flow rate through the pump is in the range of 15 m<sup>3</sup>/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°C and alarm is set at 80°C.

### Problem Statement

➡ High lube oil temperature (ranging between 82°C - 88°C) 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°C.

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



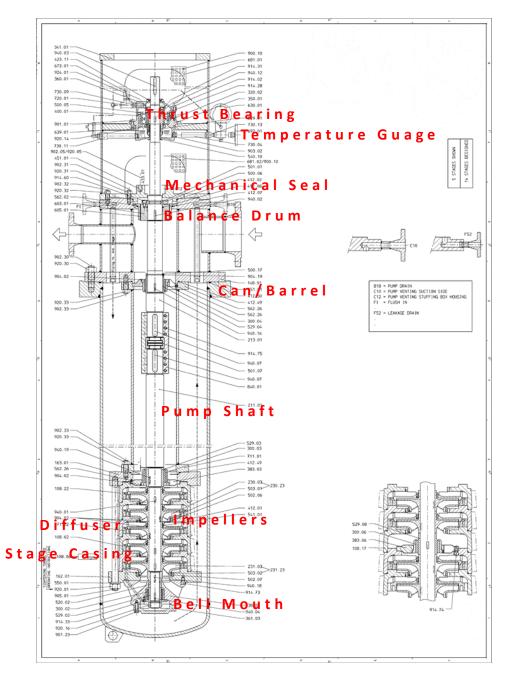
## Pump Details

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 <sup>0</sup> C				
Rated Capacity	30 m3/hr				
Specific Gravity of liquid	0.623 @ 57ºC (Normal) 0.663 @ 15ºC (Max)				
Pump Speed	2978 rpm				
Rated Power	47.8 KW				
Motor Rating	75 KW				

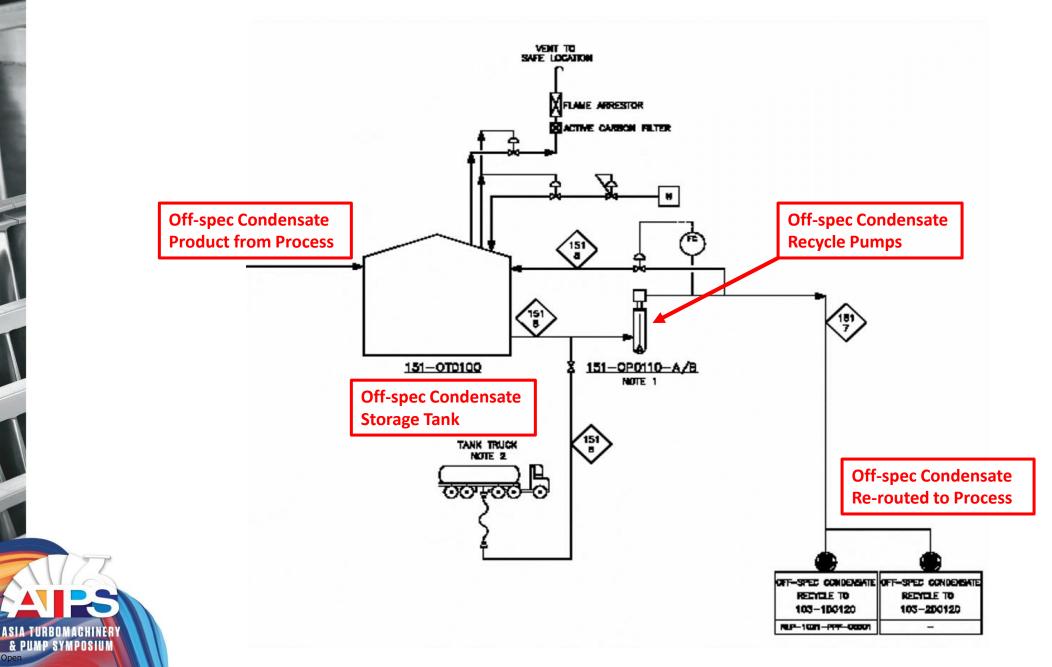
ASIA TURBOMACHINERY

& PUMP SYMPOSIUM

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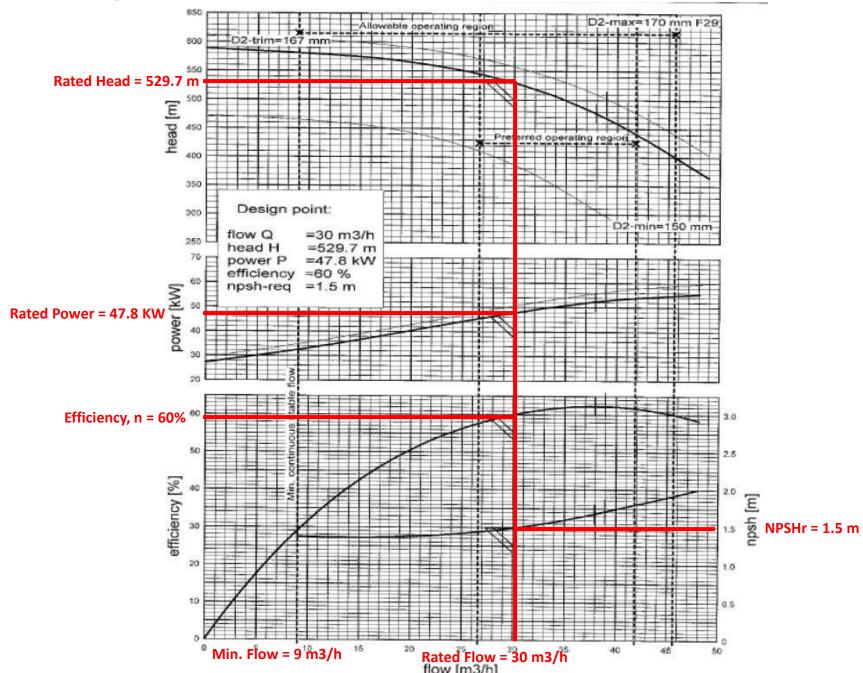


#### Pump Schematic Process Flow Diagram



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### Pump Performance Characteristic Curve





## 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.

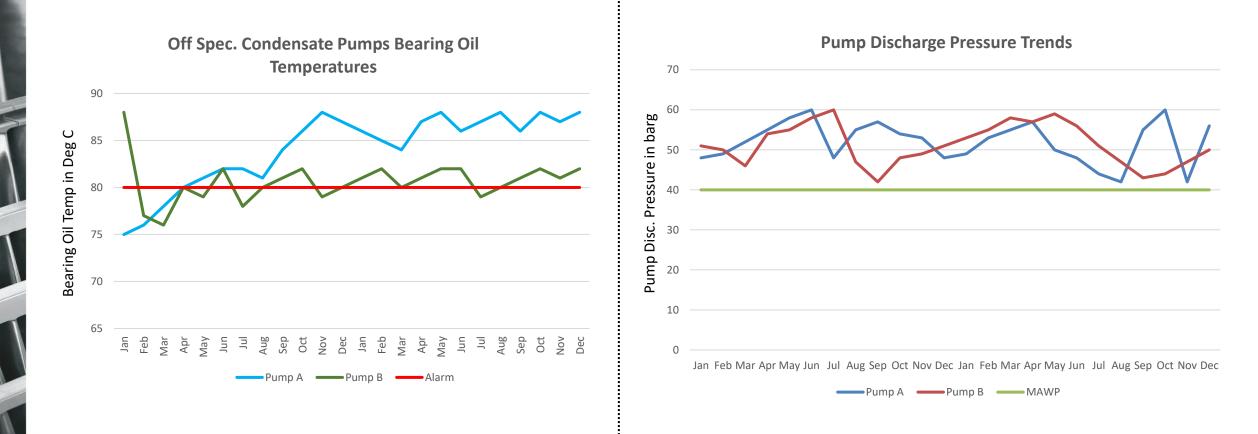
## Site Observations and Activities conducted

- 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.

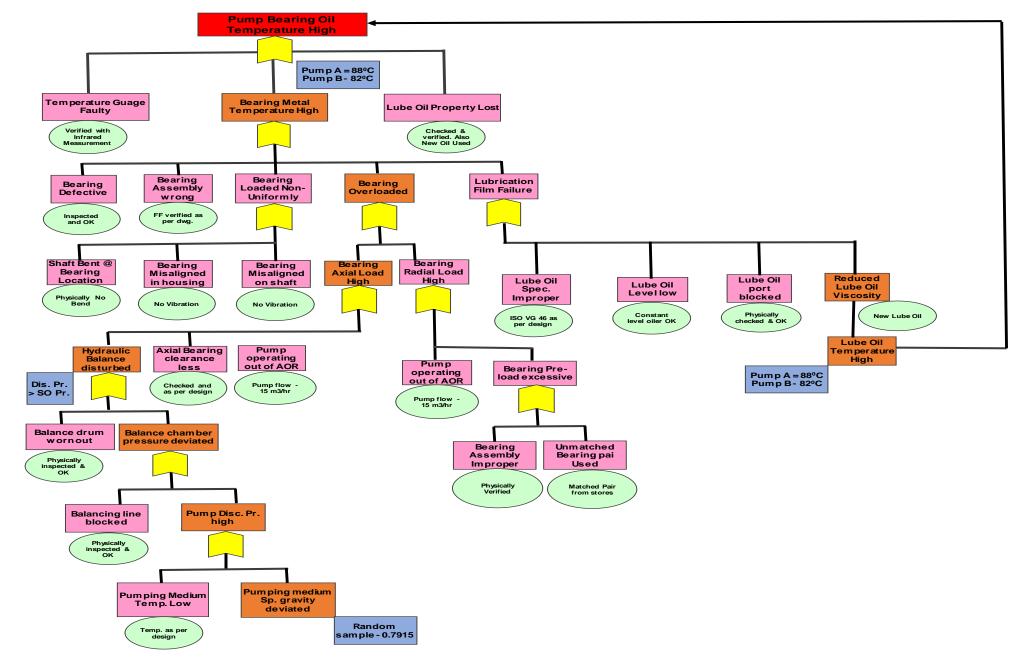
- Blockage of lube oil port in the pumping sleeve arrangement was suspected. The same has been verified and is found to be normal (no blockage).
- Lube oil specification was as per design ISO VG 46 as per pump manufacturers manual.
- □ Pumping medium specific gravity had been checked at random and was 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



ALPS ASIA TURBOMAGHINERY & PUMP SYMPOSIUM Open

# Detailed RCFA - Fault Tree Diagram



ALPS ASIA TURBOM ACHINERY & PUMP SYMPOSIUM

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## 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

			nput			
Unit	selection		ISO/Metric Units	O Imperial	Units	
1- Pump data			2- Operating data			
Pump size 50-180 👻		Rated flow 30		m3/h		
Hydraulic	-s •	[-]	Rated head	530	m	
Number of stages 1)	14	( )	Minimum flow 3)	9	m3/h	
Dimension "K" 2)	2065	mm	Suction pressure	1,2	barg	
Pump power 71 kW		Rated speed	2980	1/min		
Notes: 1) Without dummy stages		Fluid density	623	kg/m3		
2) Please refer	to Product manual		Notes: 3) If not known, 30%	of Flow at BE	P	
			can be assumed			
3- Mechanical seal			4- With Balance drum (F	Piston) :	YES	
Mech. seal pressurized? 4)	yes 🔻	[-]	Available Std. diameter	119,85	[mm]	
Mech. seal press. with 5)	2	barg	Custom diam.		[mm]	
Chamber pressure	6,4	barg	Taken for calculation	119,8	5 [mm]	
Buffer fluid pressure	8,4	barg	Notes: For Design w/o Pisto		value will be:	
Balance line returns	2	[-]		กากา]		
to stage No. 6)		2.0		shaft diam.)		
NDE diam 7)=	DE diam 7)=					
Notes: 4) Mech. pressuriz			5- Required bea			
YES: Plan 53,5			Min. at rated flow	25000	[h]	
NO: API-Plan 5	2,62,72,76 bove Balance Pressu		Min. at min flow Notes: API recommendation	16000	[h]	
at Min. Flow 6) For design w/o		(-l set Stage)	25000 (hours) API recommendation 16000 (hours)	n at Min. flow:		
	.: 14	(=Last Stage)	API recommendation 16000 [hours]	n at Min. flow:		
6) For design w/o enter Stage No. 7) In [mm]; If not I	.: 14 known: let empty	**************************************	API recommendation	n at Min. flow:		
6) For design w/o enter Stage No. 7) In [mm]; If not i Axia	.: 14	**************************************	API recommendation 16000 [hours]	n at Min. flow:		
6)For design w/o enter Stage No. 7) In [mm]; If not i Axial thrust (rated)	: 14 known: let empty al thrust	0	API recommendation 16000 [hours] utput	n at Min. flow:		
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6) For design w/o enter Stage No. 7) In [mm]; If not i Axial Ihrust (rated) with +/- safety margins) Axial thrust (min. flow) with +/- safety margins)	:: 14 known: let empty al thrust 5305 5305 6879	0	API recommendation 16000 [hours] utput UP UP UP	n at Min. flow:		
6) For design w/o enter Stage No. 7) In [mm]; If not i Axial Ihrust (rated) with +/- safety margins) Axial thrust (min. flow) with +/- safety margins)	14 known: let empty al thrust 5305 5305 6879 6879 aring life	0	API recommendation 16000 [hours] utput UP UP UP	n at Min. flow:		
6) For design w/o enter Stage No. 7) In [mm]; If not I Axial Ihrust (rated) with +/- safety margins) Axial Ihrust (min. flow) (with +/- safety margins) Bea	14 known: let empty al thrust 5305 5305 6879 6879	0	API recommendation 16000 [hours] UP UP UP UP 10,0	n at Min. flow:	-Axial Thrust	
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6) For design w/o enter Stage No. 7) In [mm]; If not i Axial thrust (rated) with +/- safety margins) Axial thrust (rnin. flow) with +/- safety margins) Bearing size: Bearing life L10h rated Bearing life L10h rated Bearing life L10h min. flow Average Thru	14           known: let empty           al thrust           5305           6879           6879           aring life           7214           st load   > Min. lo	N [-] [hours] OK [hours] OK ad [-]	API recommendation 16000 [hours] utput UP UP UP UP UP 0 5,0 -10,0 0 20 40 Pow (man)	× ×	rated flow min flow Allow Load_25000h	
6) For design w/o enter Stage No. 7) In [mm]; If not i Axial thrust (rated) (with +/- safety margins) Axial thrust (rnin. flow) (with +/- safety margins) Bearing size: Angular contact ball bearing size: Bearing life L10h rated Bearing life L10h rated Bearing life L10h min. flow Average Thru Verified	:: 14 known: let empty al thrust 5305 6879 6879 aring life 7214 st load   > Min. lo OK	N [-] [hours] OK [hours] OK ad [-] Addition	API recommendation 16000 [hours] utput UP UP UP UP UP UP UP UP UP UP	× × 60	rated flow min flow Allow Load_20000h Allow Load_16000h	
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ι	Unit selection		ISO/Metric Units	Imperial	Units
1- Pump data			2- Operating data		
Pump size 50-180 V		Rated flow	30	m3/h	
Hydraulic s 🗸 [-]		Rated head	530	m	
Number of stages 1) 14		Minimum flow 3)	9	m3/h	
Dimension "K"	2) 2065	mm	Suction pressure	1,2	barg
Pump power 71 kW		Rated speed	2980	1/min	
Notes: 1) Without dummy stages		Fluid density	950	kg/m3	
2) Please r	efer to Product manual		Notes: 3) If not known, 30	0% of Flow at BE	P
			can be assume		NEG
	lechanical seal		4- With Balance drum		YES
Mech. seal pressurized		· [-]	Available Std. diameter	119,85	[mm]
Mech. seal press. with	5) 2	barg	Custom diam.		[mm]
Chamber pressure		1 barg	Taken for calculation		5 [mm]
Buffer fluid pressure	11,	1 barg	Notes: For Design w/o Pi		value will be:
Balance line returns	2	[-]		! [mm]	
to stage No.	6)		-	(shaft diam.)	
NDE diam 7)=	DE diam 7	)=[	E Dessuire d h	earing life th	
			5- Required b Min. at rated flow	25000	ne [h]
YES: Plan :			Min. at min flow	16000	[h]
NO: API-Plan 52,62,72,76					
		1100			
5) Pressure di	ff. above Balance Press	ure	Notes: API recommendat		
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<ol> <li>5) Pressure di at Min. Flov</li> <li>6) For design enter Stage</li> </ol>	iff. above Balance Press w w/o Piston	(=Last Stage)	Notes: API recommendat 25000 (hours) API recommendat 16000 (hours)	ion at rated flow:	
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Axial Thrust @rated (5305 N) & @ Min. Flow Condition (6879 N) @ SG = 623 kg/m3

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

#### Axial Thrust Load Estimation-Proposed Balance Drum - 104.85 mm

		In	put		
Unit	selection		ISO/Metric Units	O Imperial	Units
1- Pi	ump data		2- Operation	ating data	
Pump size 50-180 🔻		Rated flow 30		m3/h	
Hydraulic	s 👻	[-]	Rated head	530	m
Number of stages 1)	14	(	Minimum flow 3)	9	m3/h
Dimension "K" 2)	2065	mm	Suction pressure	1,2	barg
Pump power 71 kW			Rated speed	2980	1/min
Notes: 1) Without dummy stages		Fluid density 623 kg/m3			
2) Please refer	to Product manual		Notes: 3) If not known, 3		<b>.</b>
			can be assume		
3- Mechanical seal			4- With Balance drum	1	YES
Mech. seal pressurized? 4)	-	[-]	Available Std. diameter	104.85	[mm]
Mech. seal press. with 5)	2	barg	Custom diam.	1	[mm]
Chamber pressure	6,4		Taken for calculation		5 [mm]
Buffer fluid pressure	8,4	barg	Notes: For Design w/o Pi		value will be:
Balance line returns	2	[-]		[mm]	
to stage No. 6)		2.5	-	(shaft dism.)	
NDE diam 7)=	DE diam 7)=		5 Demuined b	life tim	
Notes: 4) Mech. pressuriz YES: Plan 53,54			5- Required b Min. at rated flow	25000	[h]
NO: API-Plan 5			Min. at min flow	16000	[h]
	2,02,72,76 bove Balance Pressu	<b>r</b> e	Notes: API recommendation at rated flow:		
at Min. Flow	Jove Dalance Pressul	ic .	25000 [hours]		
6) For design w/o	Piston		API recommenda	ion at Min flow	
enter Stage No.		(=Last Stage)	16000 [hours]		
7) In [mm]; If not I		(			
		OL	tput		
Axia	al thrust				
Axial thrust (rated)	-2044		DOWN		
with +/- safety margins)	-2044	1 N	DOWN		
Axial thrust (min. flow)	-1314	1 1	DOWN		
with +/- safety margins)	-1314		DOWN		
Bea	Bearing life				
Angular contact	7214	[-]	10,0		Axial Thrust
ball bearing size:	12.14	1	5.0		
Bearing life		[hours]	100	×	rated flow
L10h rated	1	OK	₹ 0,0	×	min fow
			-		
Bearing life		[hours]	50	·	Allow Lord 25000h
L10h min. flow		OK	-5,0	·	Allow Load_20000h
L10h min. flow	st load   > Min. lo	OK	-5,0	·	Allow Load_2300th Allow Load_1600th
L10h min. flow	st load   > Min. Io No	OK		60	
L10h min. flow Average Thru	-	OK	-10,0 0 20 40	60	
L10h min. flow Average Thru	-	ок ad [-]	-10,0 0 20 40	60	
L10h min. flow Average Thru	-	ок ad [-]	-10,0 0 20 40	eed [1/min] < 0.2 Table 9	Allow Load_16000h

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

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		In	put			
Unit	selection		ISO/Metric Units	O Imperial	Units	
1- Pump data			2- Operating data			
Pump size 50-180 👻			Rated flow	30	m3/h	
Hydraulic	-s -	[-]	Rated head	530	m	
Number of stages 1)	14	1	Minimum flow 3)	9	m3/h	
Dimension "K" 2)	2065	mm	Suction pressure	1,2	barg	
Pump power	71	kW	Rated speed	2980	1/min	
Notes: 1) Without dummy stages		Fluid density	950	kg/m3		
2) Please refer t	o Product manual		Notes: 3) If not known, 30	% of Flow at BER	P	
			can be assumed			
	anical seal		4- With Balance drum (	Piston) :	YES	
Mech. seal pressurized? 4)	yes 🔻	[-]	Available Std. diameter	104,85	[mm]	
Mech. seal press. with 5)	2	barg	Custom diam.		[mm]	
Chamber pressure	and the second se	barg	Taken for calculation		5 [mm]	
Buffer fluid pressure	11,1	barg	Notes: For Design w/o Pist		value will be:	
Balance line returns	2	[-]		[mm]		
to stage No. 6)	0.5		-	(shaft diam.)	shaft diam.)	
NDE diam 7)=	DE diam 7)=	1				
Notes: 4) Mech. pressuriz			5- Required be			
YES: Plan 53,54			Min. at rated flow	25000	[h]	
NO: API-Plan 52	2,62,72,76 ove Balance Pressu		Min. at min flow 16000 [h] Notes: API recommendation at rated flow:			
at Min. Flow	ove balance Pressu	re.	Notes: API recommendation at rated flow: 25000 [hours] API recommendation at Min. flow:			
	Pieton					
6) For design w/o Piston enter Stage No.: 14 (=Last Stage)		16000 [hours]				
7) In [mm]; If not k		( Later stage/				
		Ou	tput			
Axia	al thrust					
Axial thrust (rated)	-2730	1	DOWN			
(with +/- safety margins)	-2730	N	DOWN			
Axial thrust (min. flow)	-1617		DOWN			
(with +/- safety margins)	-1617		DOWN			
	ring life					
Angular contact	7214	[-]	10,0		Axiai Thrust	
ball bearing size:		1	5.0			
Bearing life		[hours]		×	rated flow	
L10h rated		OK	₹ 0,0	×	min flow	
Bearing life		[hours]	-5.0		Allow Load_25000h	
L10h min. flow	tload Is Min 15	OK				
Average Thrus	st load   > Min. lo	l	-10,0		Allow.Load_16000h	
Verified	No	[-]	0 20 40 Ficw(m5/h)	60		
		Additiona	al checking			
Bearing speed	290550	OK	mean bear. diam [mm]. x spe refer to API 610 9th ed. 5.10.		500 000	
3 1			power [kW] x speed [1/min]			

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	10,0 5,0 5,0 -5,0 -5,0 -0,0 -0,0 0 20 40 60 Fixed flow X min flow Axial Thrust X rated flow X min flow Axial Thrust X min flow Axial Thrust Axial Thrust X min flow Axial Thrust Axial Thrust X min flow Axial Thrust Axial	
0.950 Kg/m3	119.85 mm	15,0 $10,0$ $5,0$ $-5,0$ $-10,0$ $20$ $40$ $60$ Fixer (md/h)	
0.623 Kg/m3	104.85 mm	10,0 5,0 -5,0 -10,0 0 20 40 60 Fixed math Axial Thrust x rated flow X min flow Allow:Load_25000h 60	
0.950 Kg/m3	104.85 mm	10,0 5,0 -5,0 -10,0 0 20 40 60 Flow [main]	

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## 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.
- $\checkmark$  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	<b>Recommended Setting</b>
Motor Start-up time	1 sec	5 sec
Motor Stall Trip Delay	5 sec	8 sec

## Modifications Implemented

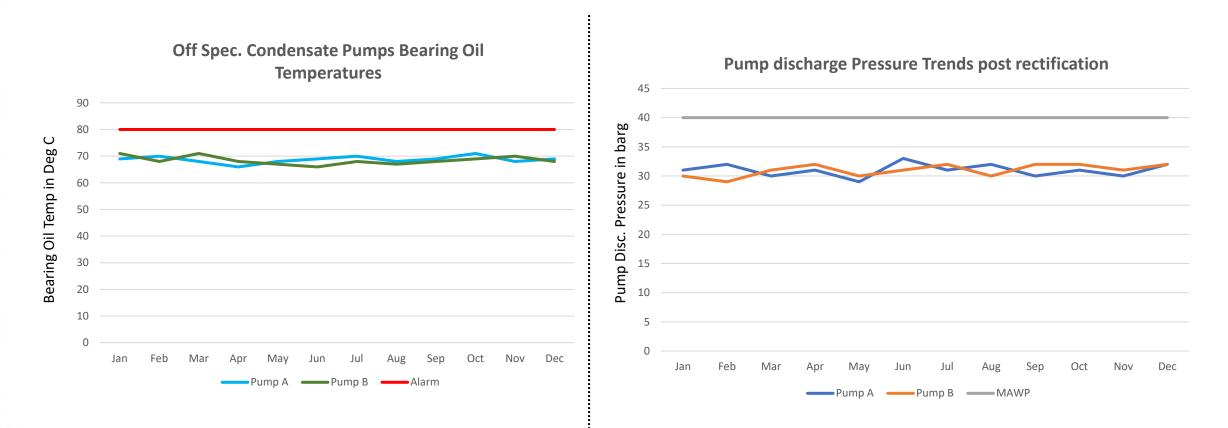
Further, as a permanent solution to the issue, the following long-term modifications were implemented:

#### 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



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### 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**

