Presenter

Amr Mohamed Gad

Senior Machinery Engineer with RasGas company since 2007

- 13 years of experience in maintenance, retrofits, and upgrades of Gas Turbines, Compressors and Pumps in natural gas facilities.
- Previous publications at 5 major worldwide conferences

Boiler Feed Water Pumps Performance Loss

Amr Mohamed Gad– RasGas
Dr.Nicholas White – RasGas
Arbain Bin Mahmood– RasGas

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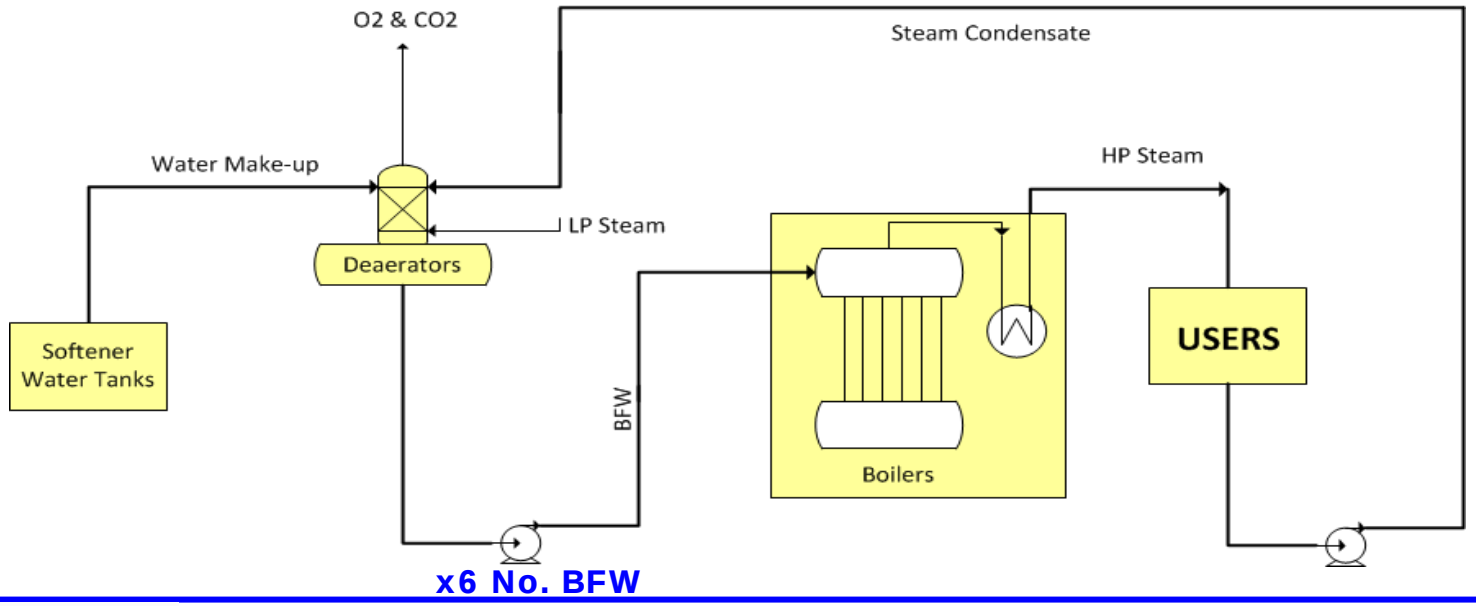
RGX2 Steam Condensate System

Steam condensate system set up at RGX2

- Total of x6 Boiler Feed Water Pumps (x4 steam driven pumps and x2 motor driven pumps).

Operating philosophy N+2:

- x4 in service and x2 Stand by operation.

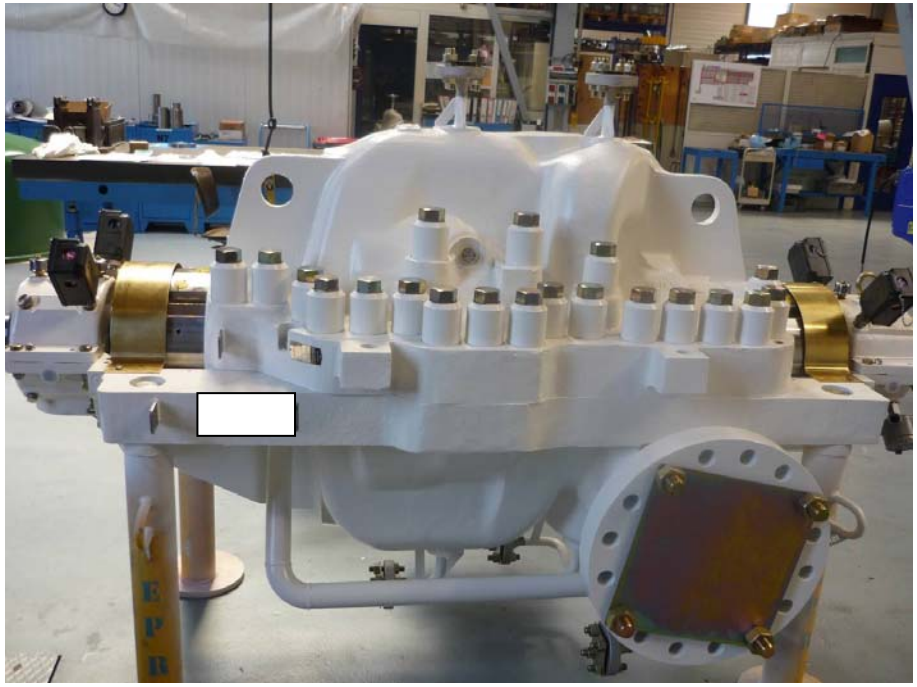


RGX2 Steam Condensate System

Pump specifications:

- Rated capacity 750 M3/hr
- Rated power 1.7 MW
- Differential head 680m
- Horizontally split casing
- 4 stage with double inlet impeller

RGX2 Steam Condensate System



New pump before installation

Old pump at skid in RGX2

Problem Summary

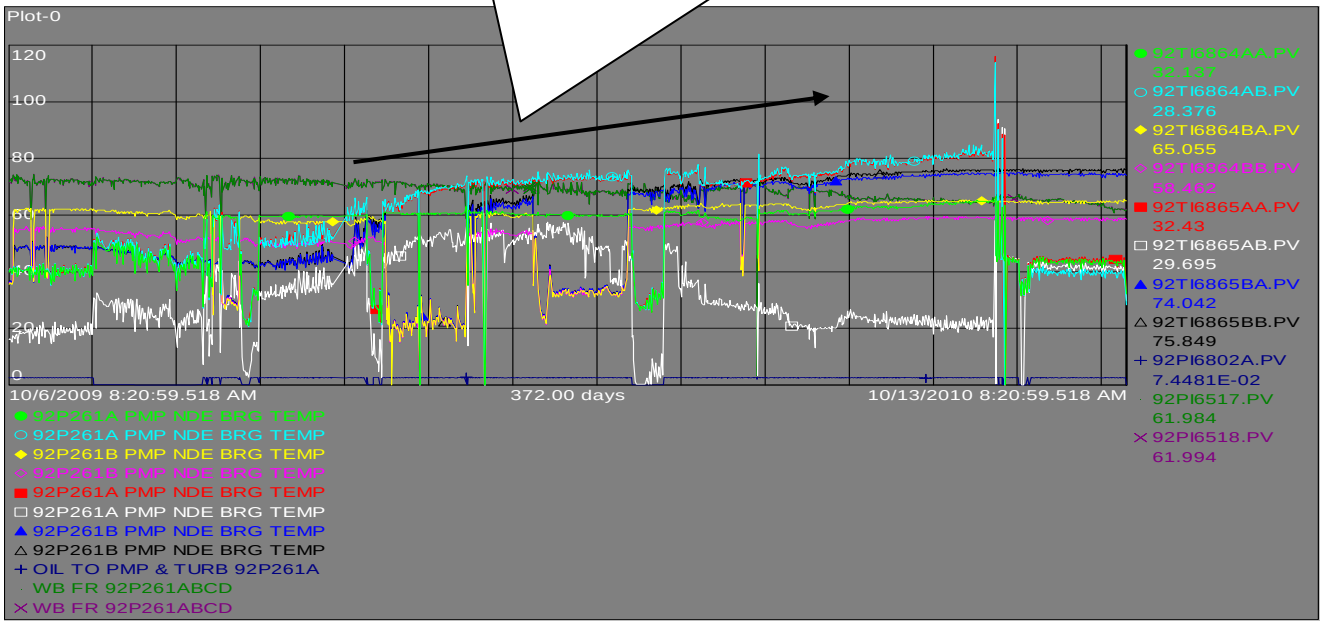
- One pump experienced high thrust bearing temperature alarm after 16 months of operation
- The thrust bearing was replaced twice during the following 6 months without identifying the root cause
- System operation indicated low pump performance (flow rate and head rise)
- During the 25 months of operation, thrust bearing temperature again reached high alarm level and pump was found seized upon inspection

Troubleshooting History

Historical Records

Unit 92-P261A historical events shown on a timeline

pump's thrust bearing temperature increase due to bearing degradation over one year – alarm level reach xx deg C



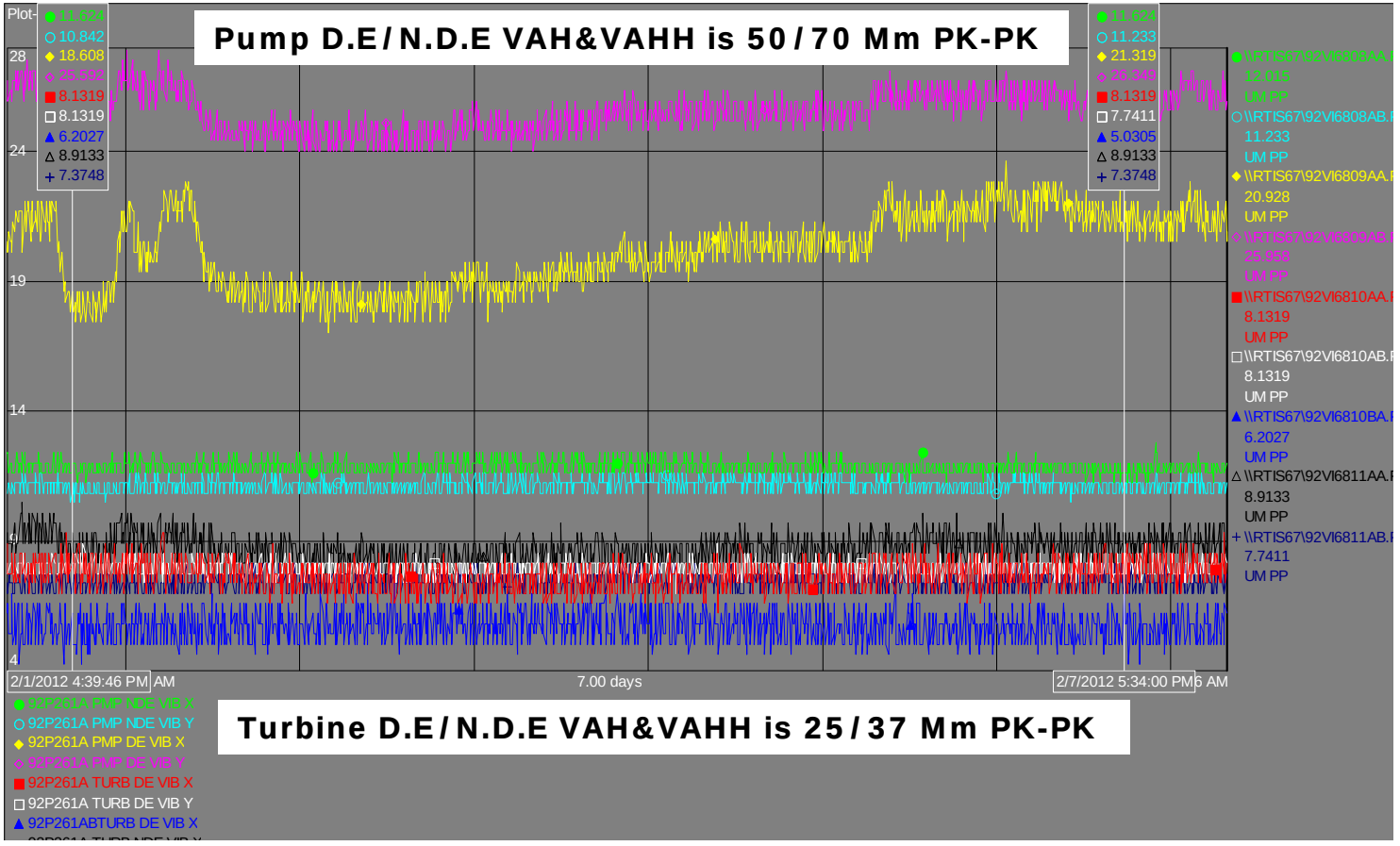
Troubleshooting History

Unit 92-P261A -Vibration readings

Pump D.E radial vibration

Pump N.D.E radial vibration

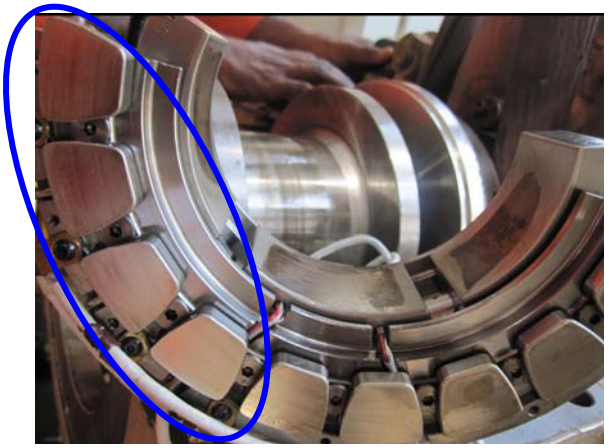
Turbine D.E & N.D.E radial vibration



Unit 92-A261A –Failure

Thrust Bearing failure signs:

Scoring and smear on thrust pads

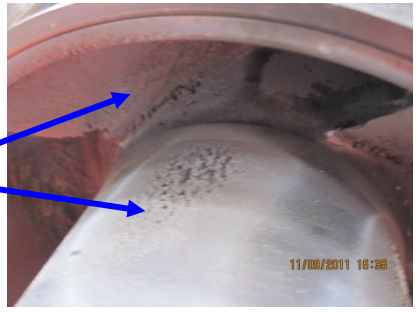


Smeared Journal pads

Unit 92-A261A –Failure

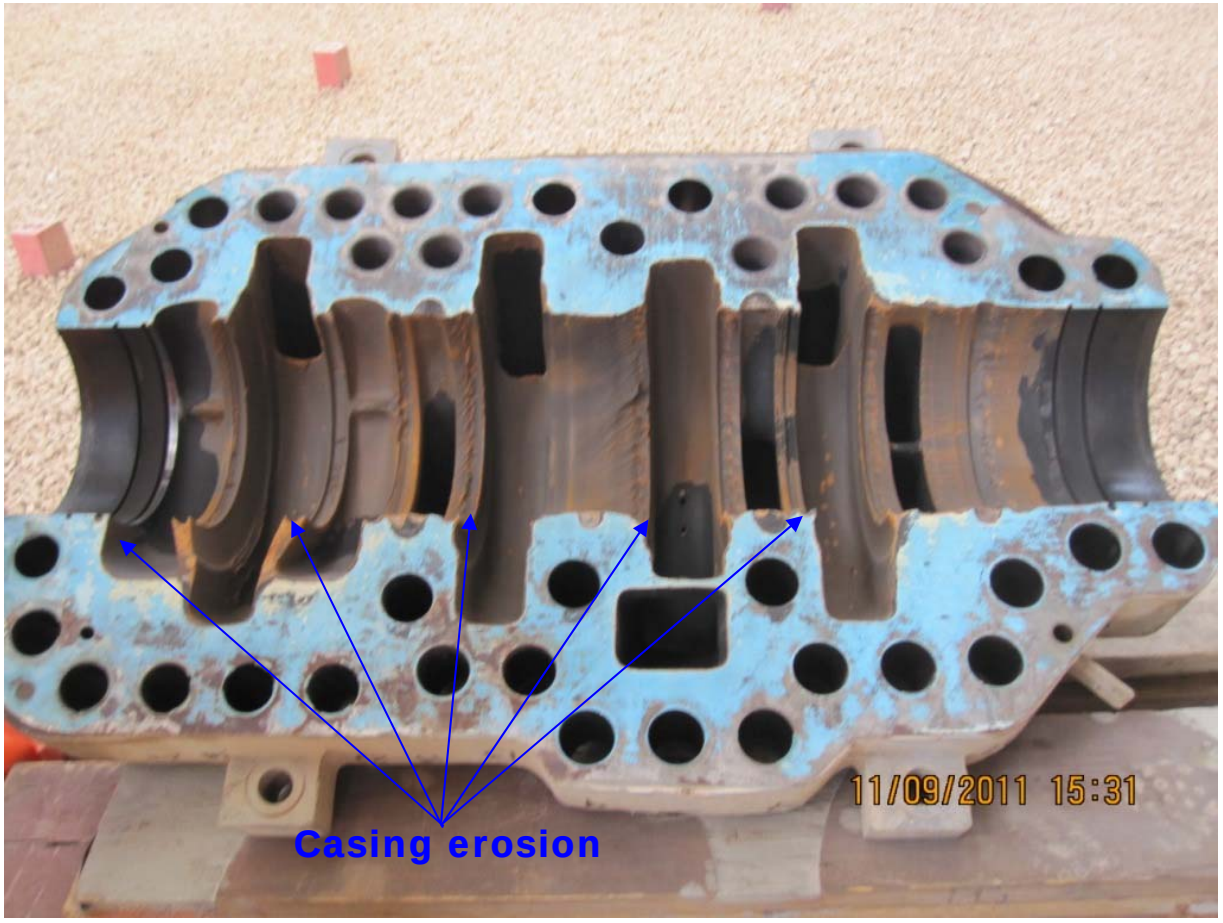
Casing erosion

Cavitation damage

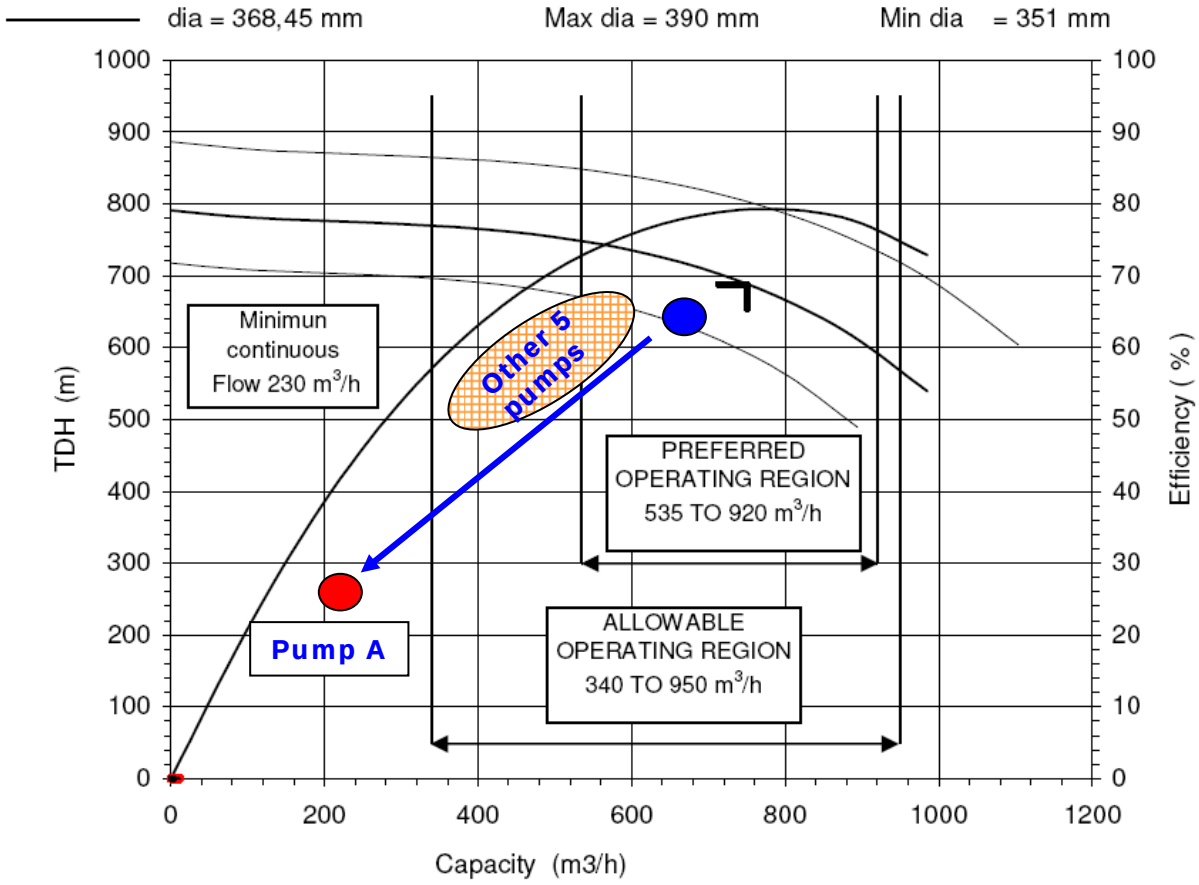


Unit 92-A261A –Failure

RCFA initiated August 2011 and completed October 2011

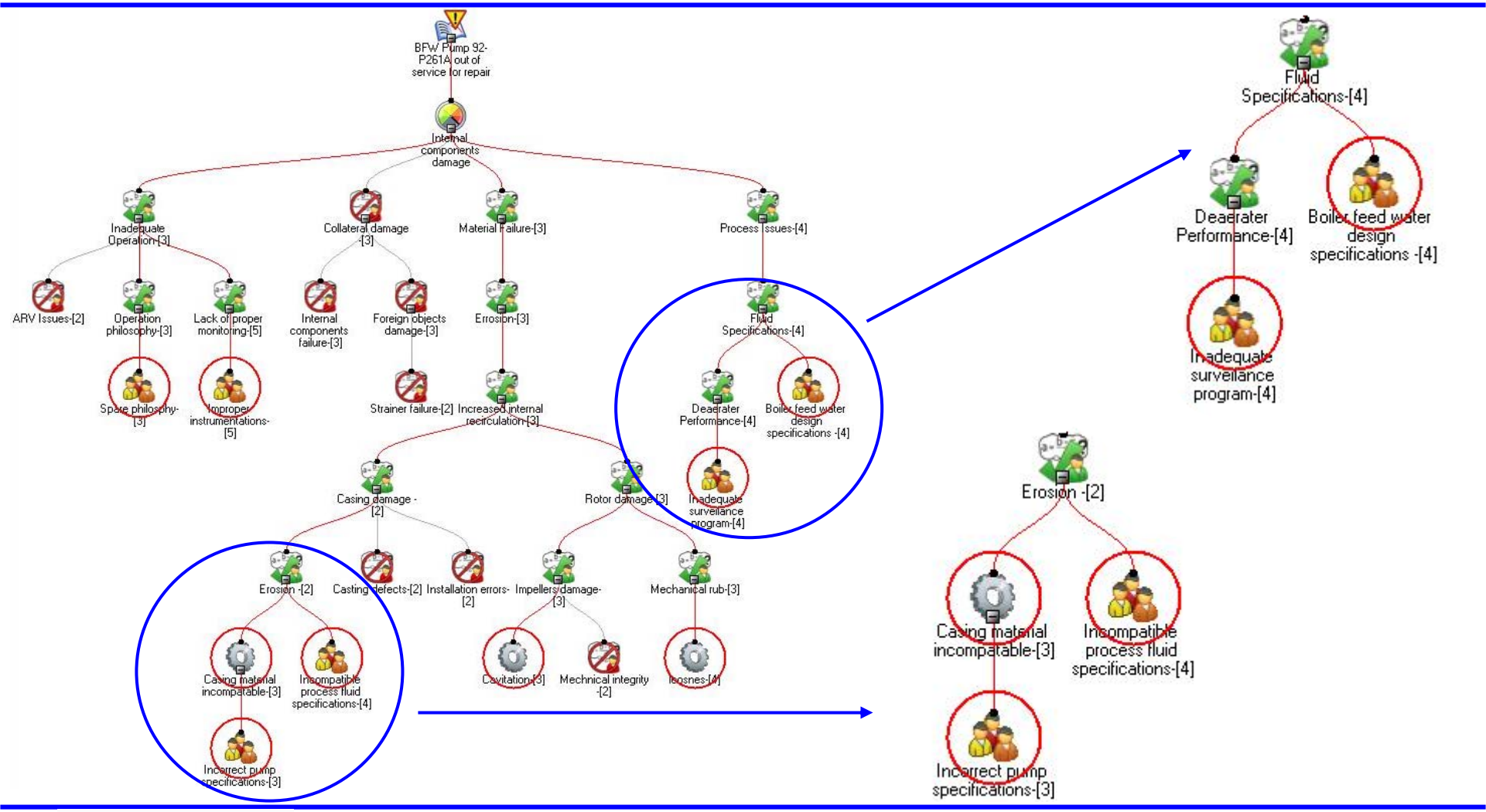


Performance Deterioration



Optimum performance **Deteriorated performance** **Other pumps performance**

RCFA-Unit 92-P261A



RCFA-Unit 92-P261A

RCFA – Findings

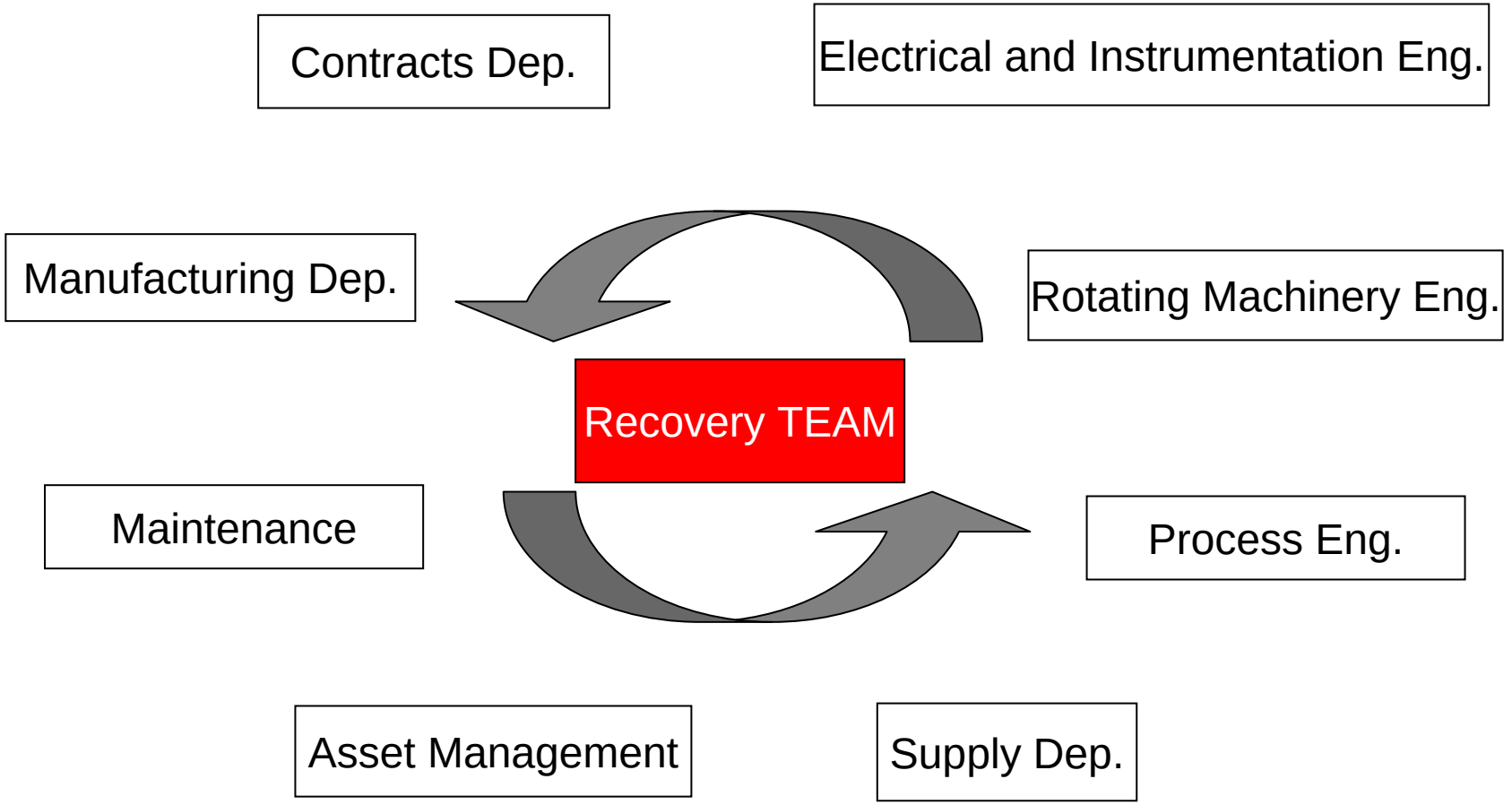
- Root Cause (Human) - Incorrect material specification of the pump casing for boiler feed water service led to major damage of casing inner walls and rotor parts
- Contributing Factor 1 (Latent) – Insufficient online monitoring of pump performance due to inadequate instrumentation prevented effective pump health monitoring
- Contributing Factor 2 (Latent) – Inadequate surveillance program for boiler feed water conditions led to a possible corrosive environment within pump flow path

RCFA-Unit 92-P261A

RCFA – Recommendations

- Immediate action: Purchase x6 new BFWPs with 12%Cr Stainless Steel casings and replace the existing pumps with carbon steel casing
- Medium action: Revise the Equipment Strategy to perform a bi-monthly online performance monitoring task including steam condensate dissolved oxygen and pH levels to ensure they remain within specification
- Long term action: Improve online monitoring by installation of the following:
  -Digital discharge pressure transmitter
  -Install flow measurement devices on the discharge and recirculation line

Operational Risk Mitigation



Operational Risk Mitigation

Integrated Repair plan

- x3 pumps repaired between October 2011 and March 2012
- x2 pumps were repaired used spare parts manufactured by third party as fast track repair to save time

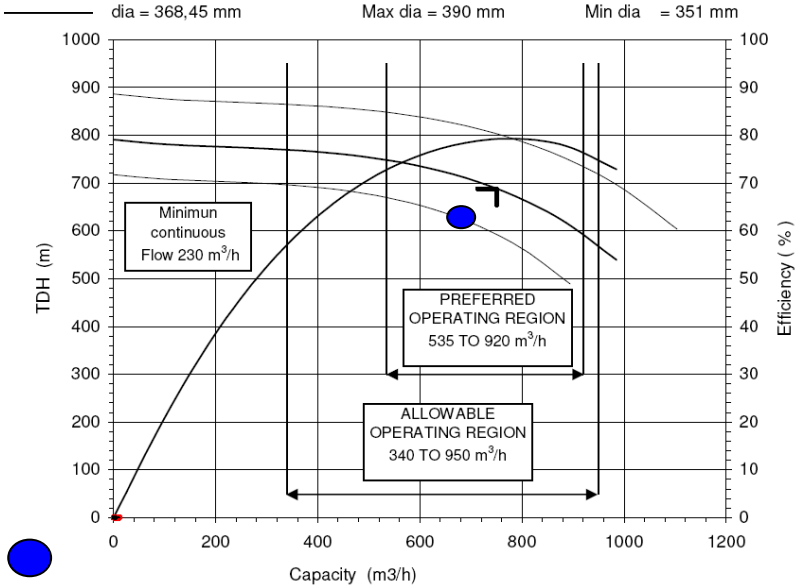
- System reviewed for equipment reliability
  (Turbines, Automatic Recycle Valves, Instruments etc.) and corrective actions taken as appropriate

- Close monitoring and measurement of discharge and recycle flow using clamp flow meter to assess pump performance

- Long term - Installation of x6 new BFW pumps with stainless steel casing (procurement and installation during 14 months)

Recommendations Results

- Performance for the repaired 3 units as interim solution was similar to OEM design.
- Ultimate replacement of all pumps by new stainless steel casing's units results in operating the BFW system with reliable units as per OEM design.



Lessons Learned

- Follow API610 guidelines during equipment procurement (material specifications versus fluid service)
- Improve datasheet and specification review during project FEED and procurement
- Improve online monitoring instruments required during plant design

Questions?

Authors:

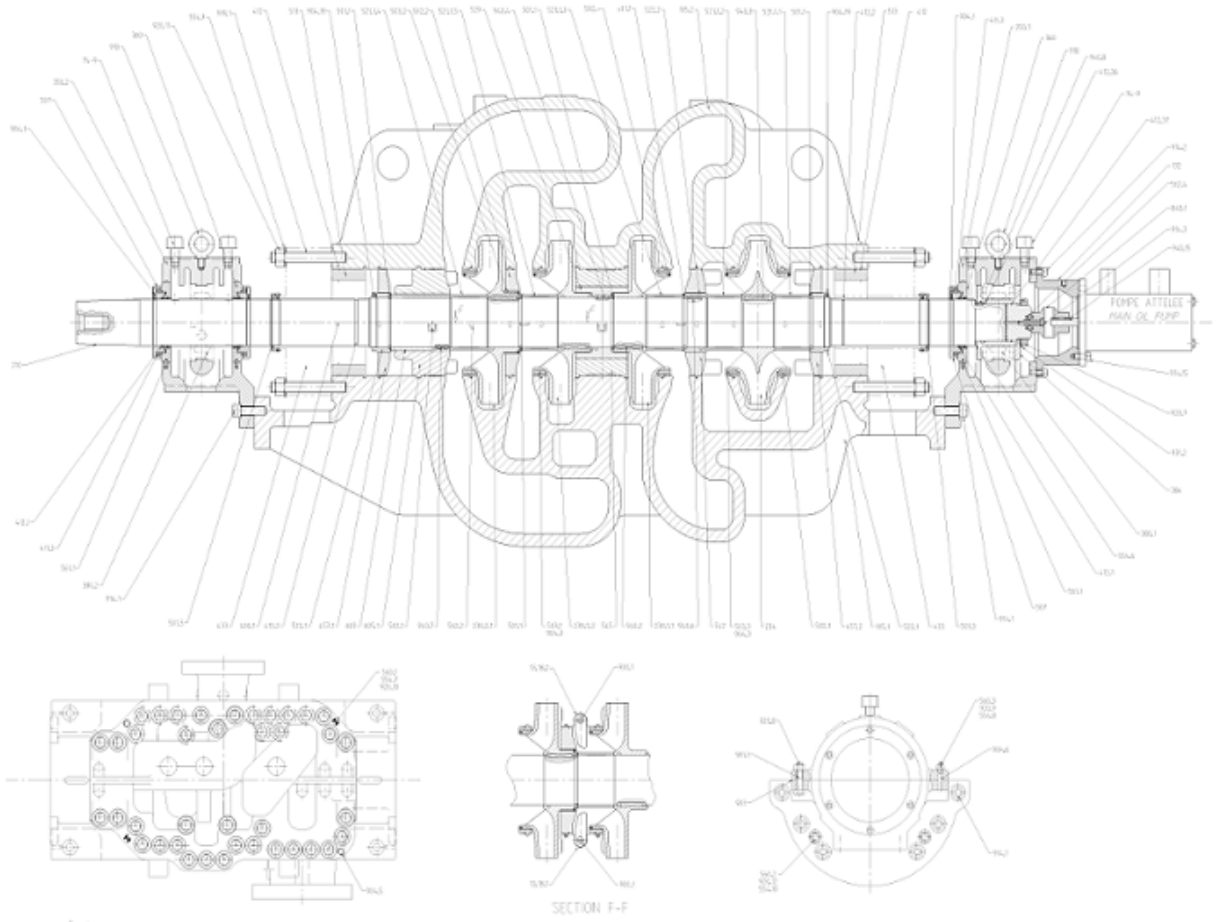
Amr Mohamed Gad – RasGas

Dr. Nicholas White - RasGas

Arbain Mahmood – RasGas

asmohamedgad@rasgas.com.qa

Backup


POMPE ATTELEE
MAIN OIL PUMP
SECTION F-F

0	1	APPLICABLE TO:	○ PROPOSALS	● PURCHASE	◯ AS BUILT						
	2	FOR	Ras Laffan Liquefied Natural Gas Company Limited (3)			UNIT	92 Steam and Condensate System				
	3	SITE	RAS LAFFAN, QATAR			SERVICE	Boiler Feed Water Pump				
1	4	NO. REQ	5	PUMP SIZE	8x10x14.5 H/Y	TYPE	Centrifugal	NO. STAGES	4		
1	5	MANUFACTURER	UNION PUMP S.A.S.			MODEL	DVMX	SERIAL NO.	P350 to P354		
	6	NOTES: INFORMATION BELOW TO BE COMPLETED:	○ BY PURCHASER	☐ BY MANUFACTURER	◯ BY MANUFACTURER OR PURCHASER						
	7	○ GENERAL (3.1.1)									
0	8	PUMPS TO OPERATE IN (PARALLEL)		NO. MOTOR DRIVEN	2	NO. TURBINE DRIVEN	3 (2+1)				
1	9	~~(SERIES)~~ WITH	92-P261A/B/C/D	PUMP ITEM NO.	92-P261C/D	PUMP ITEM NO.	92-P261A/B , 92-P271A				
1	10	GEAR ITEM NO.		MOTOR ITEM NO.	92-PM261C/D	TURBINE ITEM NO.	92-PT261A/B , 92-PT271A				
	11	GEAR PROVIDED BY		MOTOR PROVIDED BY	Pump Vendor	TURBINE PROVIDED BY	Pump Vendor				
	12	GEAR MOUNTED BY		MOTOR MOUNTED BY	Pump Vendor	TURBINE MOUNTED BY	Pump Vendor				
	13	GEAR DATA SHT. NO.		MOTOR DATA SHT. NO.		TURBINE DATA SHT. NO.					
	14	**OPERATING CONDITIONS**				**SITE AND UTILITY DATA (CONT'D)**					
E	15	● CAPACITY, NORMAL	630.0 (m3/h)	RATED	750.0 (m3/h)	WATER SOURCE	Fresh Water				
	16	OTHER				CHLORIDE CONCENTRATION (PPM)		(3.5.2.6)			
E	17	● SUCTION PRESSURE MAX./RATED	5.10 /	2.30 (BARG)		INSTRUMENT AIR: MAX/MIN PRESS	7 /	4.5 (BARG)			
0	18	● DISCHARGE PRESSURE	65.20	*1.7 (BARG)		**LIQUID**					
0	19	● DIFFERENTIAL PRESSURE	62.90	*1.7 (BAR)		● TYPE OR NAME OF LIQUID	Boiler Feed Water *1.3				
0	20	● DIFF. HEAD *1.8	680.4 (m)	NPSHA	13.6 (m) *1.1	● PUMPING TEMPERATURE:					
E	21	○ PROCESS VARIATIONS			(3.1.2)	NORMAL	120 (°C)	MAX.	150 (°C)	MIN.	43 (°C)
	22	● STARTING CONDITIONS	Auto Start/Stop *1.5		(3.1.3)	● VAPOR PRESSURE	2 (BAR abs) @	120 (°C)			
	23	SERVICE: ● CONT. ○ INTERMITTENT (STARTS/DAY)				● RELATIVE DENSITY (SPECIFIC GRAVITY):					
	24	● PARALLEL OPERATION REQ'D (2.1.11) *1.6				NORMAL	0.943	MAX		MIN	
	25	○ SITE AND UTILITY DATA *1.2				○ SPECIFIC HEAT, Cp		(kJ/kg °C)			
	26	**LOCATION: (2.1.29)**				● VISCOSITY	0.232 (cP) @	120 (°C)			
	27	○ INDOOR ○ HEATED ○ UNDER ROOF				○ MAX. VISCOSITY		(cP)			
	28	● OUTDOOR ● UNHEATED ○ PARTIAL SIDES				○ CORROSIVE/EROSIVE AGENT		(2.11.1.8)			
	29	● GRADE ○ MEZZANINE ○				○ CHLORIDE CONCENTRATION (PPM)		(3.5.2.6)			
	30	○ ELECTRIC AREA CLASSIFICATION (2.1.22 / 3.1.5)				○ H_2S CONCENTRATION (PPM)		(2.11.1.11)			
	31	*1.4				LIQUID (2.1.3) ○ HAZARDOUS ○ FLAMMABLE					
	32	○ WINTERIZATION REQ'D ● TROPICALIZATION REQ'D.				○ OTHER					
	33	**SITE DATA (2.1.29)**				**PERFORMANCE**					
0	34	● ALTITUDE (m)	BAROMETER	1.013 (BAR abs)		PROPOSAL CURVE NO.	620319A/B/C/D	RPM	2980		
0	35	● RANGE OF AMBIENT TEMPS: MIN/MAX.	4 /	49 (°C)		■ IMPELLER DIA. RATED	368.45 MAX.	390 MIN.	351 (mm)		
0	36	● RELATIVE HUMIDITY: MIN / MAX	35 /	80 (%)		■ RATED POWER	1673.2 (BHP)	EFFICIENCY	79.2 (%)		
	37	**UNUSUAL CONDITIONS: (2.1.23)** ● DUST ○ FUMES				■ MINIMUM CONTINUOUS FLOW:					
0	38	● OTHER	Salty and dusty (Sand Storm)			THERMAL (m3/h)		STABLE	230 (m3/h)		
0	39	○ UTILITY CONDITIONS:				■ PREFERRED OPERATING REGION	535 TO	920 (m3/h)			
0	40	**STEAM:**	DRIVERS		HEATING	■ ALLOWABLE OPERATING REGION	340 TO	950 (m3/h)			
0	41	MIN	39.5 (BARG)	366 (°C)	(BARG) (°C)	■ MAX HEAD @ RATED IMPELLER *1.3	792	*1.9 (m)			
0	42	MAX	41.3 (BARG)	376 (°C)	(BARG) (°C)	■ MAX POWER @ RATED IMPELLER	1900 (kW)				
0	43	ELECTRICITY	DRIVERS	HEATING	CONTROL SHUTDOWN	■ NPSHR AT RATED CAPACITY	7.4 (m) (2.1.8)				
0	44	VOLTAGE	6600	240	120 24	■ SUCTION SPECIFIC SPEED	11820 (m³/hr - m) (2.1.9)				
1	45	HERTZ	50	50	50	○ MAX. SOUND PRESS. LEVEL REQ'D	<85 (dBA) (2.1.14)				
0	46	PHASE	3	1	1	■ EST MAX SOUND PRESS. LEVEL	84 (dBA) (2.1.14)				

Operational Risk Mitigation

Integrated Repair plan

Task Name	Duration	Start	Finish	Resource Names
1 Mitigation Plan for exposure without healthy spare BFWP	16 days	10/26/11	11/16/11	Team 1
2 Procurement of x6 new BFWPs	53 days	10/26/11	1/5/12	Team 1
3 Procurement of consumable spares (x1 set) from CU	120 days	11/7/11	4/12/12	Team 1
4 Procument for consumable spares (x2 sets) from WG	64 days	11/1/11	1/22/12	Team 1
5 eMWO for CU Service Engineer	**1 day**	**11/3/11**	**11/4/11**	**Team 1**
6 Write QA/QC check list for vendor BFWP repairs	3 days	11/13/11	11/15/11	Team 1
7 Award CU contract for repair services	13 days?	12/2/11	12/19/11	Team 1
8 Locally manufacture replacement ST guide rod assembley	7 days	12/21/11	12/29/11	Team 1
9 Procure spare ST guide rod assembley (x2 sets) from DR (USA)	29 days	12/19/11	1/22/12	Team 1
10 Procure spare ST guide rod assembley (x1 set) from DR (UAE)	18 days	12/22/11	1/14/12	
11 92-P261A repair and installation	50 days	11/4/11	1/11/12	CU/Team 1
12 Repair of original 92-P261A rotor	116 days	12/13/11	5/14/12	CU/Team 1
13 92-P261B repair and installation	35 days	11/3/11	12/20/11	WG/Team 1
14 92-P271 repair and installation	49 days	12/21/11	2/20/12	WG/Team 1
15 92-P261C repair and installation	37 days	2/21/12	4/11/12	WG/Other/Team 1
16 92-P261D repair and installation	37 days	4/12/12	6/1/12	WG/Other/Team 1
17 ARV replacement and surveillence	76 days?	8/1/11	11/15/11	Team 2
18 Troubleshooting Instrumentation & Controls	5 days	10/30/11	11/4/11	Team 3
19 Enhanced monitoring program	21 days	10/26/11	11/23/11	Team 1/ Team 2
20 Failure Analysis for ARV's	**177 days**	**3/2/11**	**11/4/11**	**Team 2**
21 Failure Analysis for Pumps	**23 days**	**11/3/11**	**12/5/11**	**Team 1**
22 Failure Analysis for Instrumentation & Controls	24 days	10/30/11	12/1/11	Team 3
23 Manufacture of x 6 BFWPs at CU	141 days	1/2/12	7/6/12	CU/Team 1