WORLD-CLASS OUTSTANDING INTERNATIONAL

PROGRAM | EXHIBITION | NETWORKING

BOILER FEED WATER PUMPS PERFORMANCE LOSS

AMR MOHAMED GAD– RASGAS

DR.NICHOLAS WHITE – RASGAS

29TH INTERNATIONAL PUMP USERS SYMPOSIUM

HOUSTON SEPT.30TH -OCTOBER 3RD

RasGas

the power of the drop

THE ENERGY TO TRANSFORM

Texas A&M Engineering TEES Turbomachinery Laboratory

42nd Turbomachinery

29th Pump SYMPOSIA

GEORGE R. BROWN CONVENTION CENTER

9.30 – 10.3.2013

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 6 major worldwide conferences

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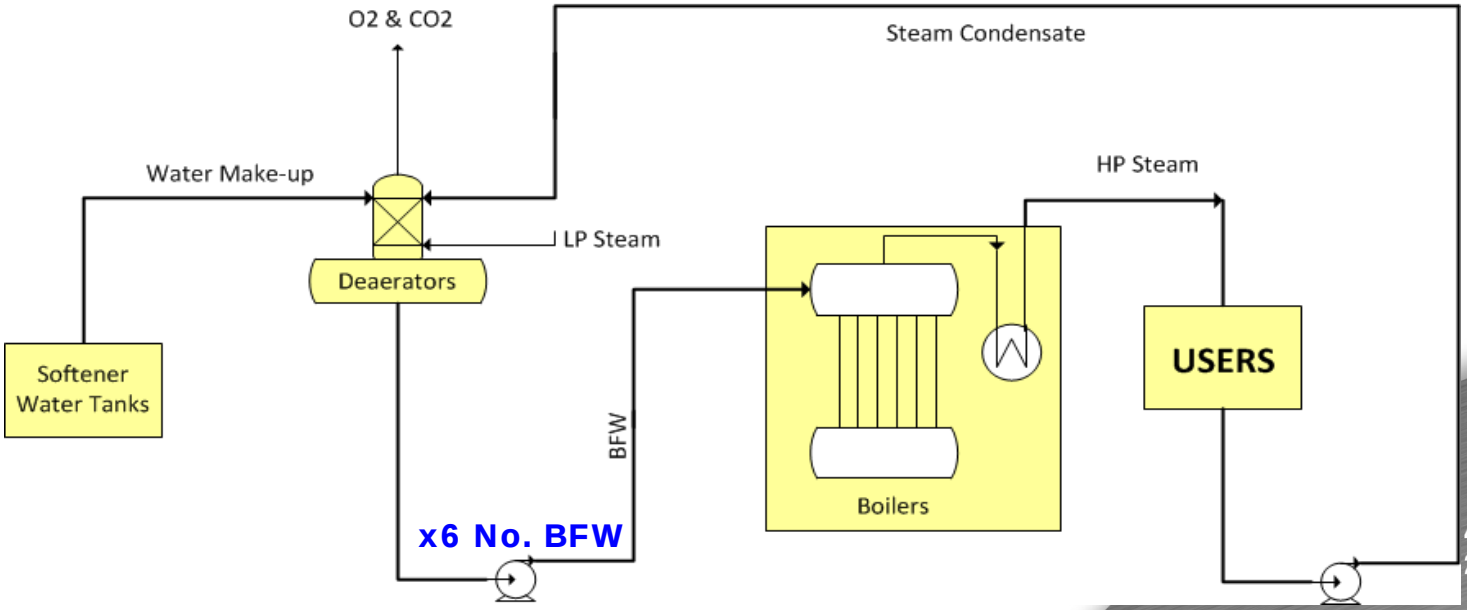
RGX2 Steam Condensate System

Steam condensate system set up at RGX2:

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

Operating philosophy N+2:

- x4 in service and x2 Stand by operation.

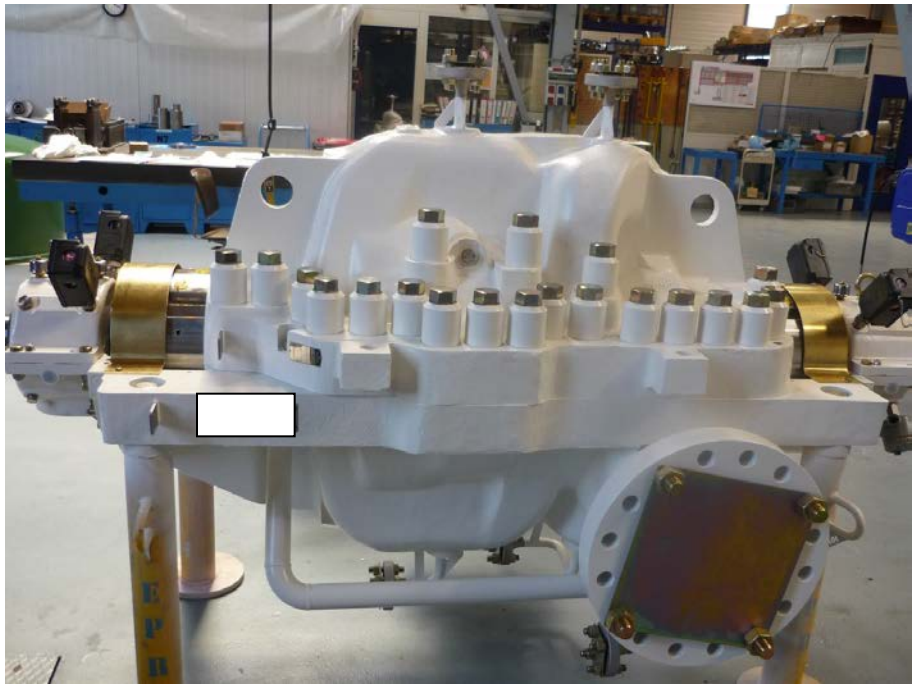


RGX2 Steam Condensate System

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

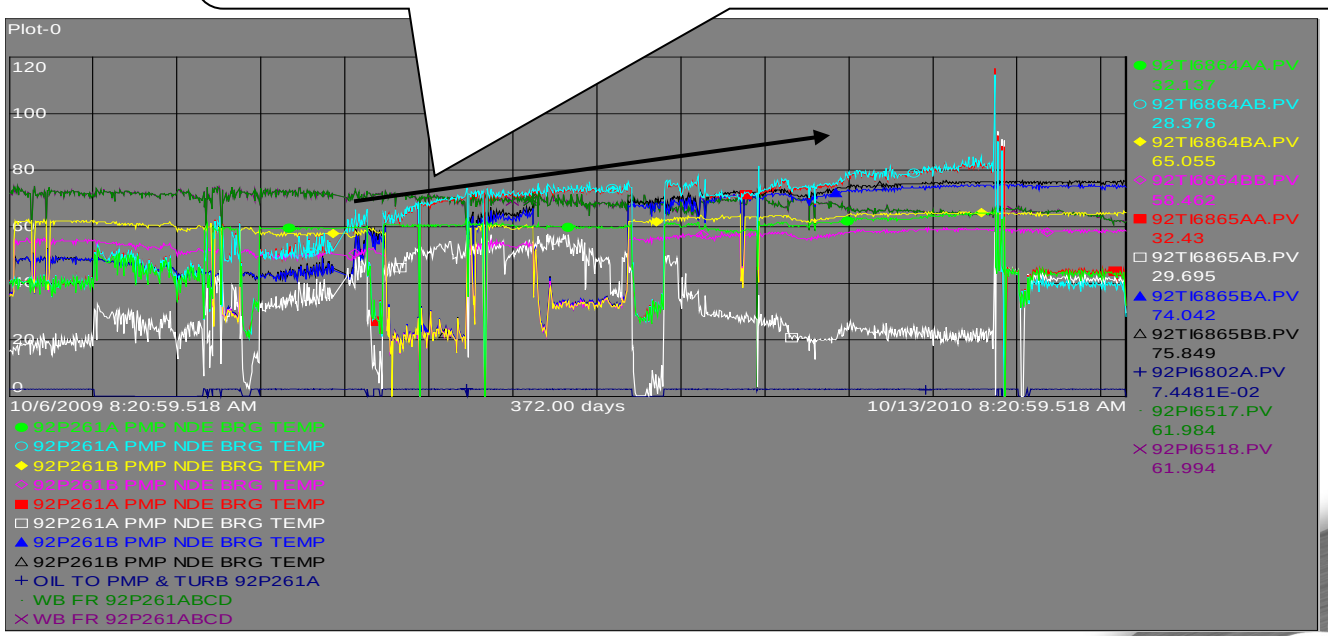
- One pump experienced high thrust bearing temperature alarm after 16 months of operation
- The thrust bearing was replaced twice during the following 6 months without identifying the root cause
- System operation indicated low pump performance
- During the 25 months of operation, thrust bearing temperature 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 reached (85 deg C)



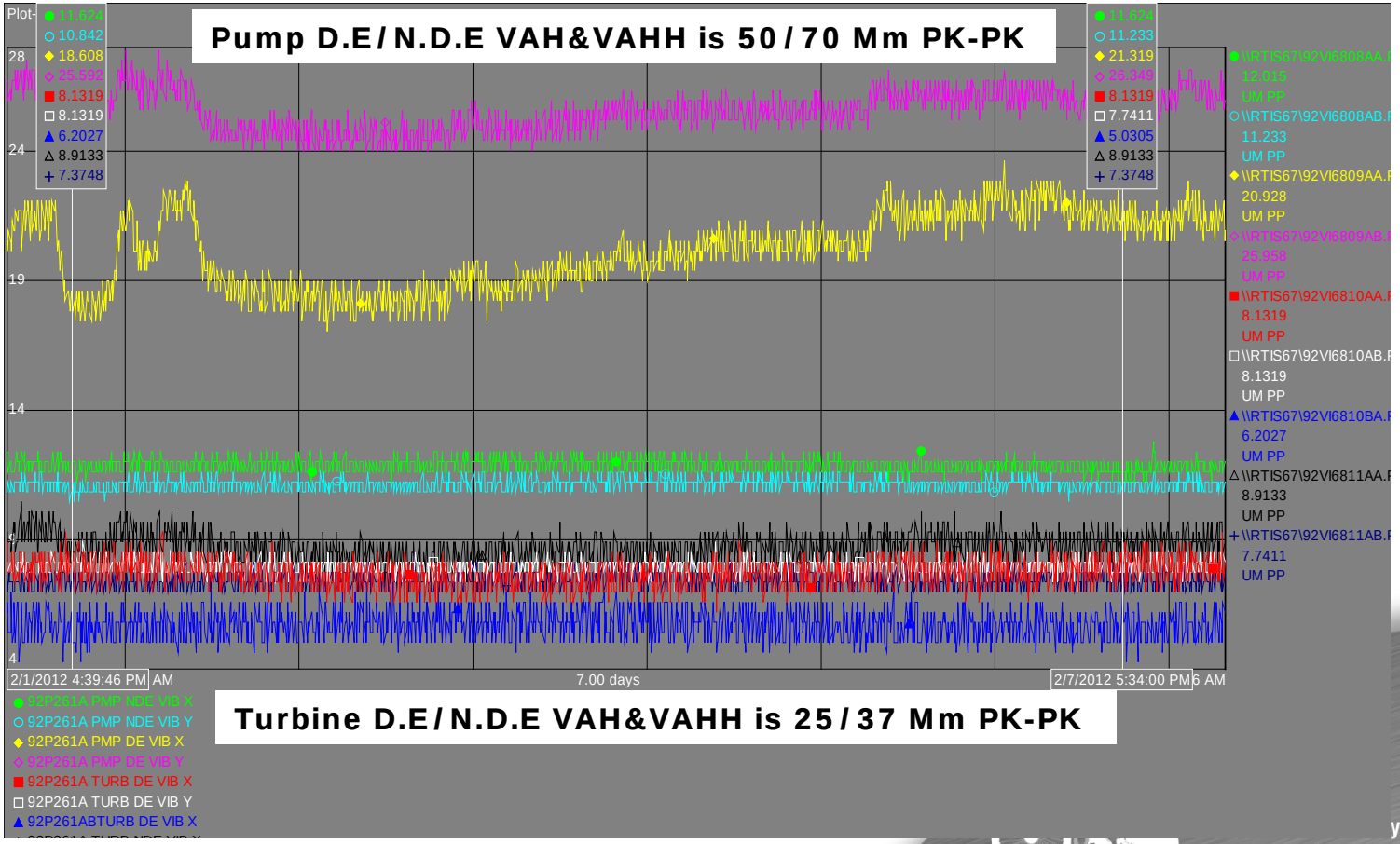
Troubleshooting History

Unit 92-P261A -Vibration readings:

Pump D.E radial vibration

Pump N.D.E radial vibration

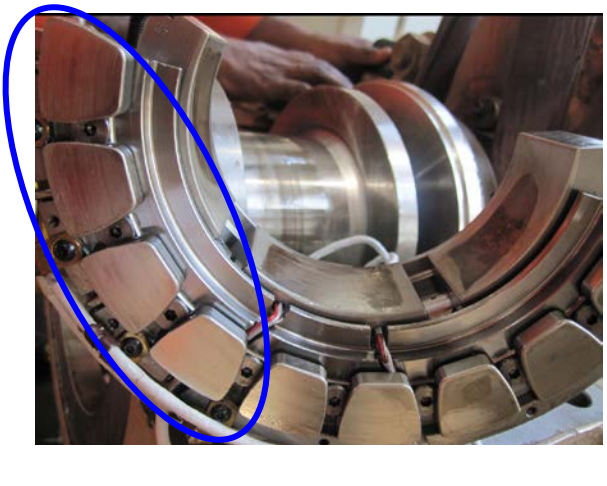
Turbine D.E & N.D.E radial vibration



Unit 92-P261A –Failure

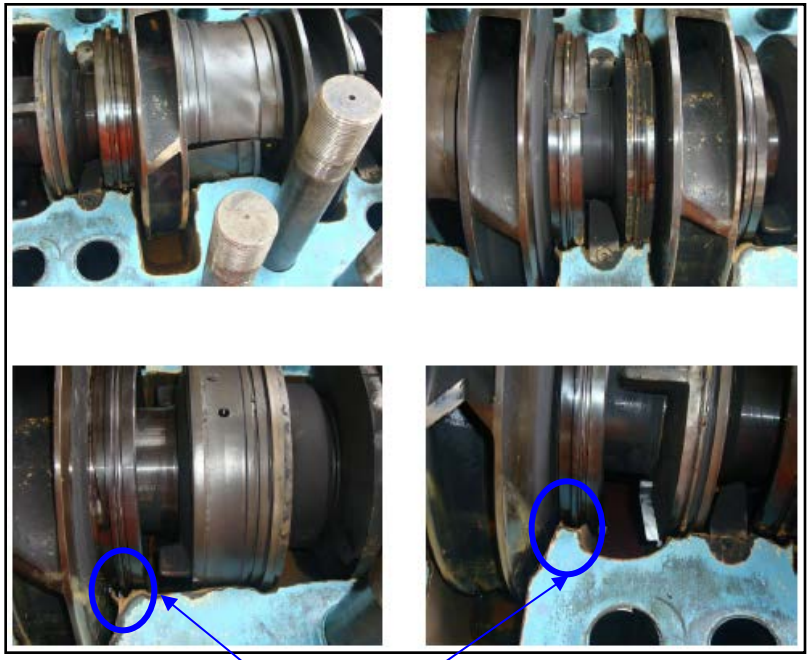
Thrust Bearing failure signs:

Scored and smeared thrust pads



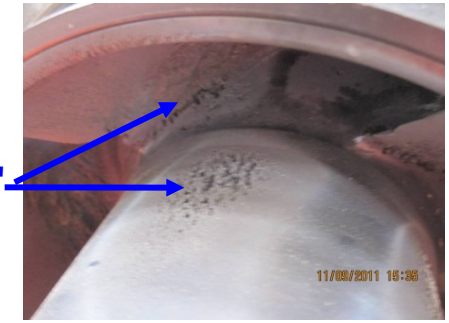
Smeared Journal pads

Unit 92-P261A –Failure



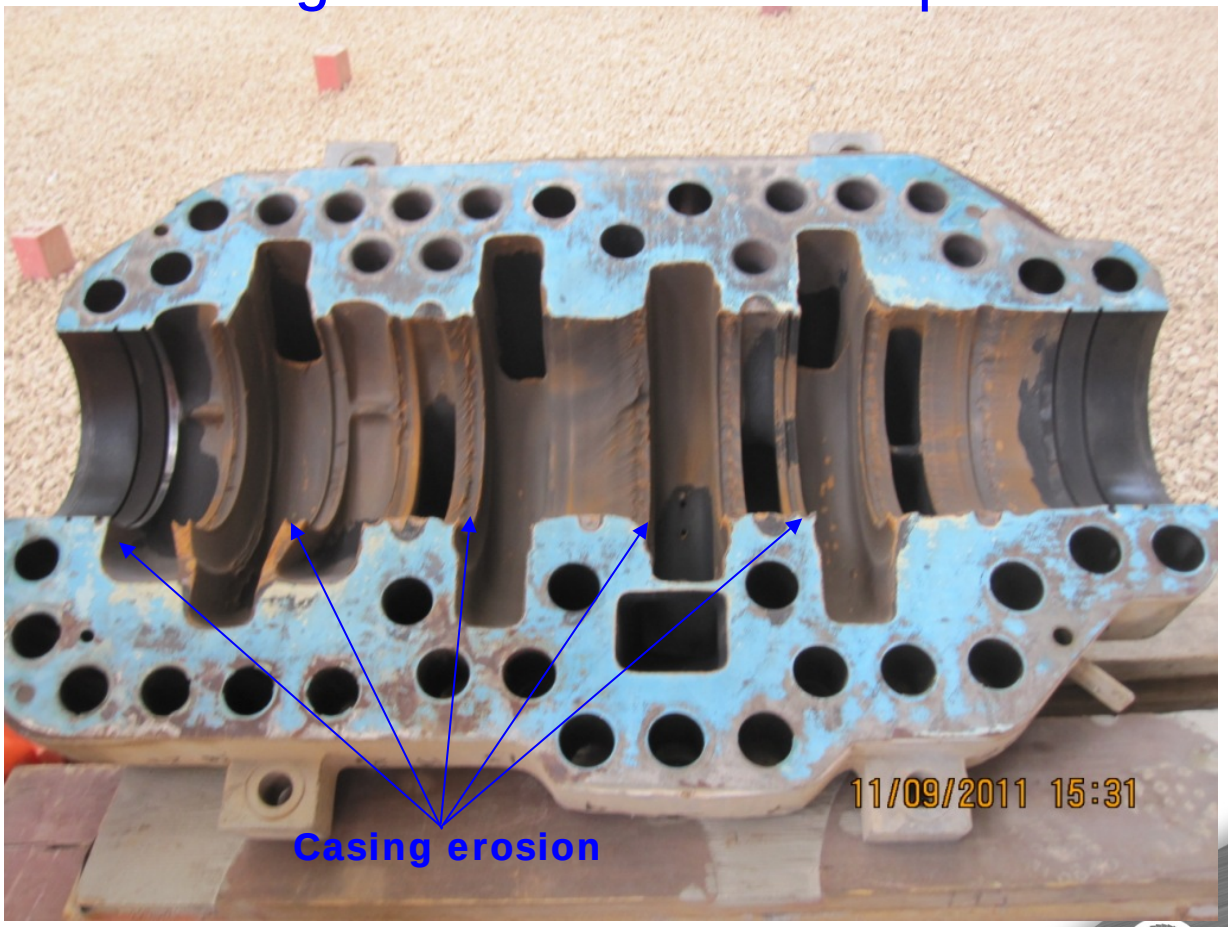
Casing erosion

Cavitations' damage

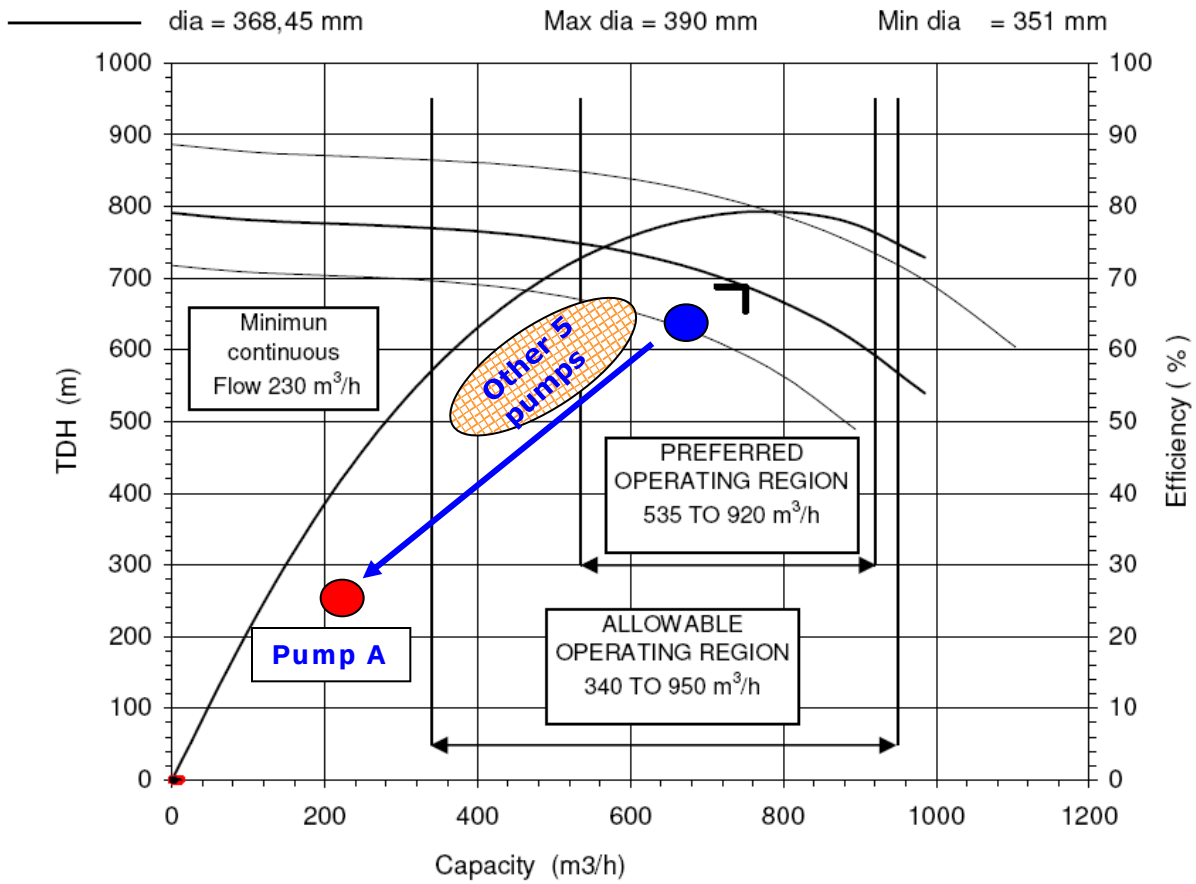


Unit 92-P261A –Failure

RCFA initiated August 2011 and completed Oct. 2011

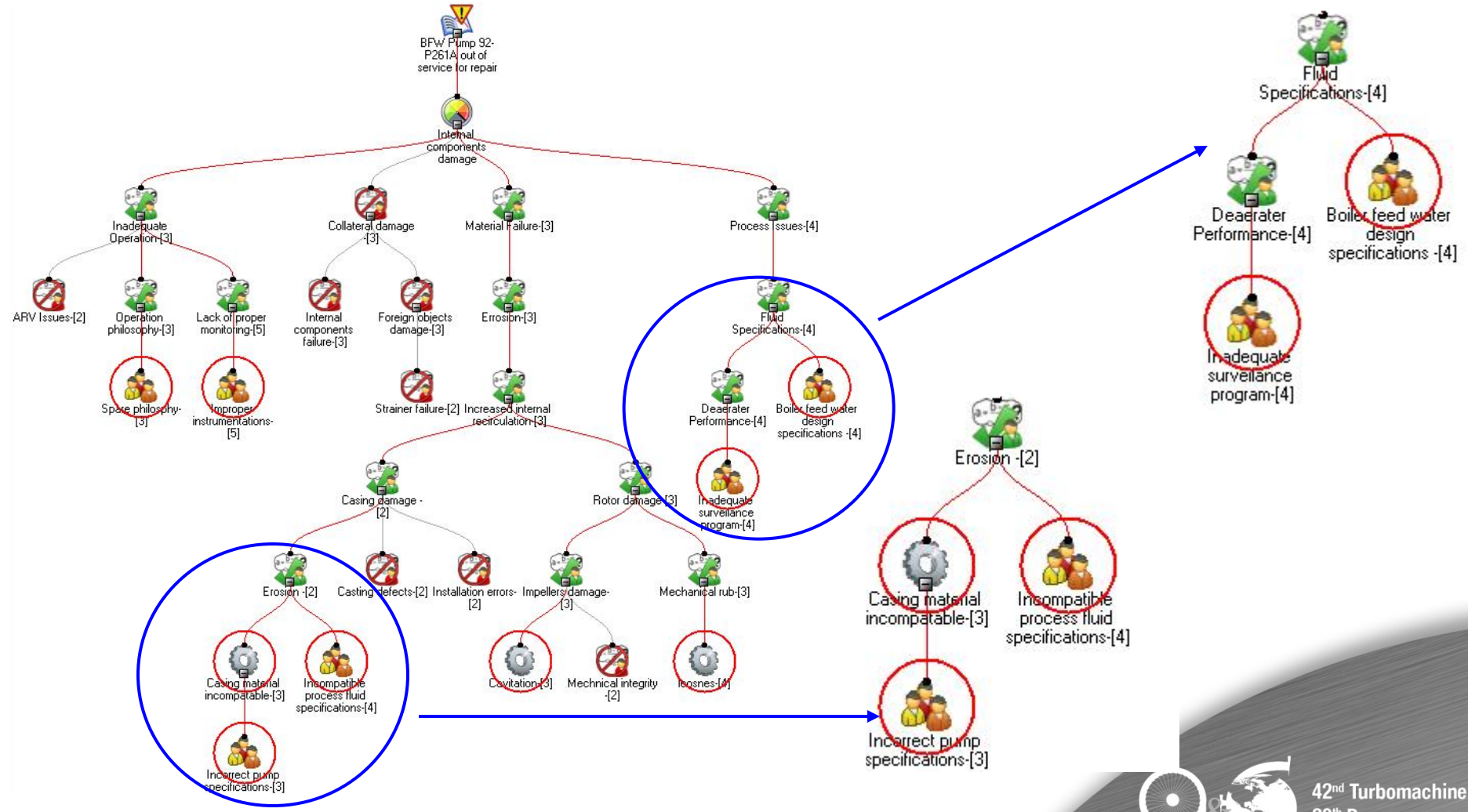


Performance Deterioration



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

RCFA-Unit 92-P261A



RCFA-Unit 92-P261A

RCFA – Findings:

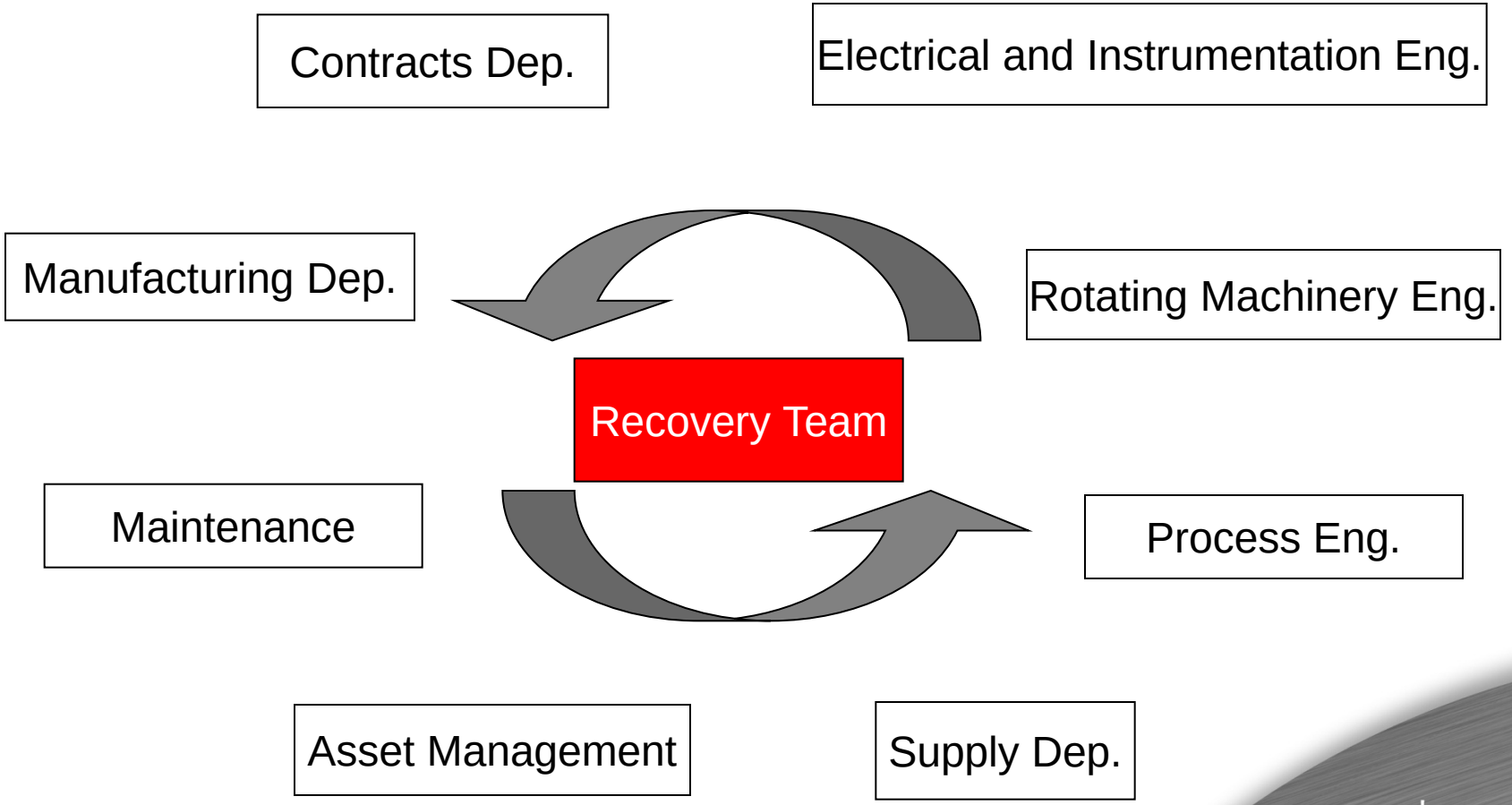
- Root Cause (Human) - Incorrect material specification of the pump casing for boiler feed water service led to major damage of casing inner walls and rotor parts
- Contributing Factor 1 (Latent) – Insufficient online monitoring of pump performance due to inadequate instrumentation prevented effective 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 (A487CA6NM) and replace the existing pumps with carbon steel casing (A216 WCB)
- Medium action: Revise Equipment Strategy to perform bi-monthly online performance monitoring task including steam condensate dissolved oxygen and PH levels to ensure remaining within specification
- Long term action: Improve online monitoring:
  -Digital discharge pressure transmitter
  -Install flow measurement devices on the discharge and recirculation line

Operational Risk Mitigation



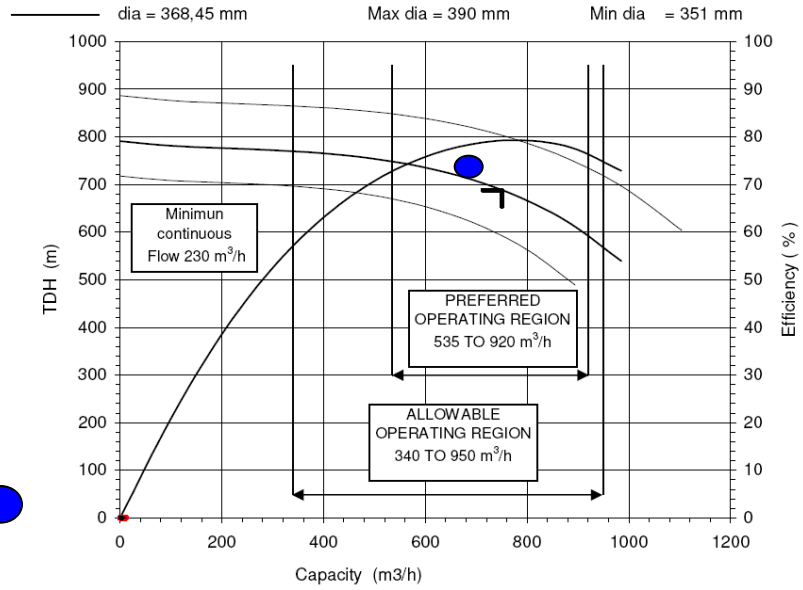
Operational Risk Mitigation

Integrated Repair plan:

- x3 pumps repaired between Oct. 2011 and March 2012
- x2 pumps were repaired used spare parts supplied from third party as fast repair.
- System reviewed for equipment reliability (Turbines, Motors, Automatic Recycle Valves, Instruments etc.) and corrective actions taken as appropriate
- Frequent measurement of discharge and recycle flow using clamp flow meter to assess pump performance
- Long term - Installation of x6 new pumps with stainless steel casing (procurement and installation time-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.



Optimum performance

Lessons Learned

- Follow API610 guidelines during 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?

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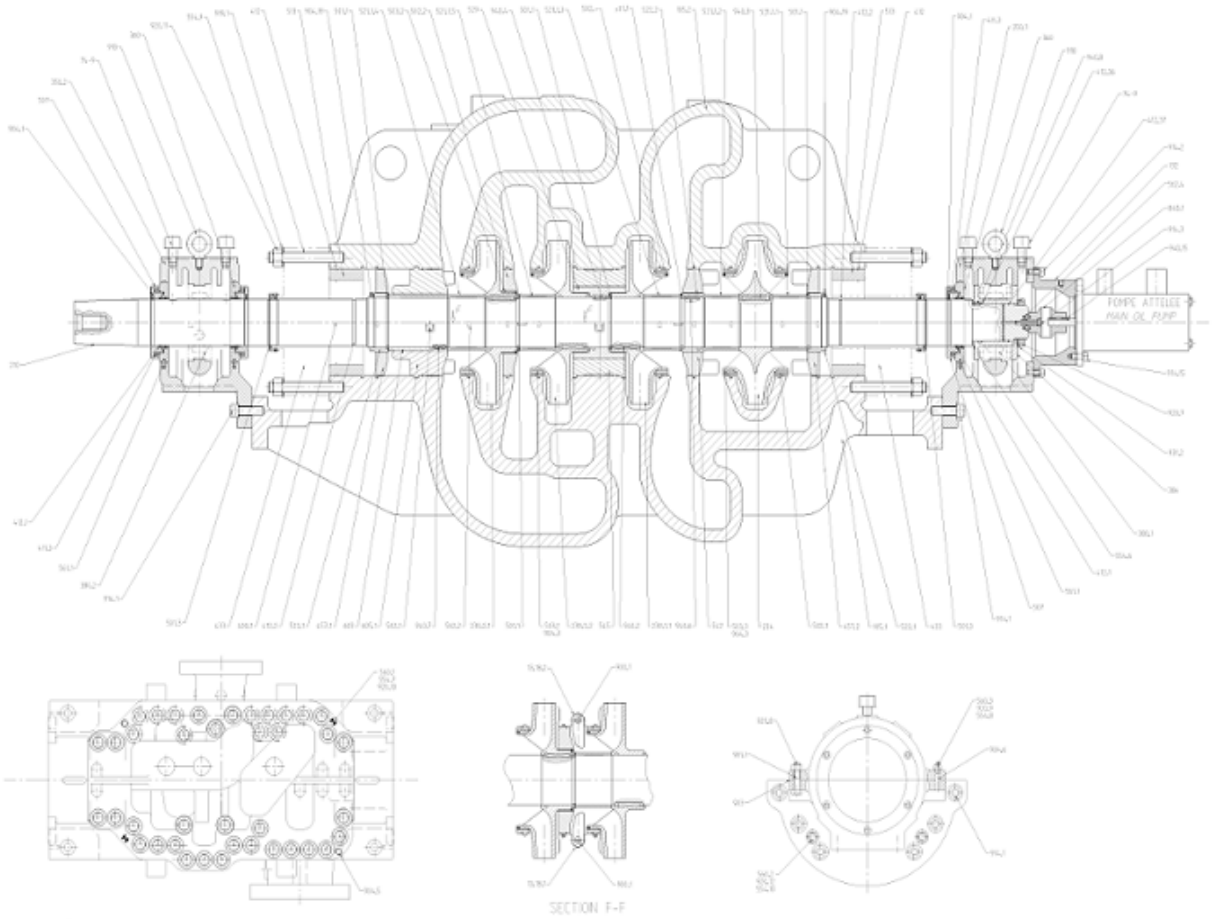
Backup


POMPE ATTELEE
MAIN OIL PUMP
SECTION F-F

APPLICABLE TO: ○ PROPOSALS ● PURCHASE ☒ AS BUILT

FOR	Ras Laffan Liquefied Natural Gas Company Limited (3)			UNIT	92 Steam and Condensate System		
SITE	RAS LAFFAN, QATAR			SERVICE	Boiler Feed Water Pump		
NO. REQ	5	PUMP SIZE	8x10x14.5 H/Y	TYPE	Centrifugal	NO. STAGES	4
MANUFACTURER	UNION PUMP S.A.S.			MODEL	DVMX	SERIAL NO.	P350 to P354

NOTES: INFORMATION BELOW TO BE COMPLETED: ○ BY PURCHASER ☐ BY MANUFACTURER ◯ BY MANUFACTURER OR PURCHASER

○ GENERAL (3.1.1)

PUMPS TO OPERATE IN (PARALLEL)		NO. MOTOR DRIVEN	2	NO. TURBINE DRIVEN	3 (2+1)
~~(SERIES)~~ WITH	92-P261A/B/C/D	PUMP ITEM NO.	92-P261C/D	PUMP ITEM NO.	92-P261A/B , 92-P271A
GEAR ITEM NO.		MOTOR ITEM NO.	92-PM261C/D	TURBINE ITEM NO.	92-PT261A/B , 92-PT271A
GEAR PROVIDED BY		MOTOR PROVIDED BY	Pump Vendor	TURBINE PROVIDED BY	Pump Vendor
GEAR MOUNTED BY		MOTOR MOUNTED BY	Pump Vendor	TURBINE MOUNTED BY	Pump Vendor
GEAR DATA SHT. NO.		MOTOR DATA SHT. NO.		TURBINE DATA SHT. NO.	

OPERATING CONDITIONS

- ● CAPACITY, NORMAL 630.0 (m3/h) RATED 750.0 (m3/h)
- OTHER
- ● SUCTION PRESSURE MAX./RATED 5.10 / 2.30 (BARG)
- ● DISCHARGE PRESSURE 65.20 *1.7 (BARG)
- ● DIFFERENTIAL PRESSURE 62.90 *1.7 (BAR)
- ● DIFF. HEAD *1.8 680.4 (m) NPSHA 13.6 (m) *1.1
- ○ PROCESS VARIATIONS (3.1.2)
- ● STARTING CONDITIONS Auto Start/Stop *1.5 (3.1.3)
- SERVICE: ● CONT. ○ INTERMITTENT (STARTS/DAY)
- ● PARALLEL OPERATION REQ'D (2.1.11) *1.6

○ SITE AND UTILITY DATA *1.2

LOCATION: (2.1.29)

- ○ INDOOR ○ HEATED ○ UNDER ROOF
- ● OUTDOOR ● UNHEATED ○ PARTIAL SIDES
- ● GRADE ○ MEZZANINE ○
- ○ ELECTRIC AREA CLASSIFICATION (2.1.22 / 3.1.5)

*1.4

- ○ WINTERIZATION REQ'D ● TROPICALIZATION REQ'D.

SITE DATA (2.1.29)

- ● ALTITUDE (m) BAROMETER 1.013 (BAR abs)
- ● RANGE OF AMBIENT TEMPS: MIN/MAX. 4 / 49 (°C)
- ● RELATIVE HUMIDITY: MIN / MAX 35 / 80 (%)

UNUSUAL CONDITIONS: (2.1.23) ● DUST ○ FUMES

- ● OTHER Salty and dusty (Sand Storm)
- ○ UTILITY CONDITIONS:

STEAM:	DRIVERS		HEATING	
MIN	39.5 (BARG)	366 (°C)	(BARG)	(°C)
MAX	41.3 (BARG)	376 (°C)	(BARG)	(°C)

ELECTRICITY	DRIVERS	HEATING	CONTROL	SHUTDOWN
VOLTAGE	6600	240	120	24
HERTZ	50	50	50	
PHASE	3	1	1	

SITE AND UTILITY DATA (CONT'D)

- WATER SOURCE Fresh Water
- CHLORIDE CONCENTRATION (PPM) (3.5.2.6)
- INSTRUMENT AIR: MAX/MIN PRESS 7 / 4.5 (BARG)

LIQUID

- ● TYPE OR NAME OF LIQUID Boiler Feed Water *1.3
- ● PUMPING TEMPERATURE: NORMAL 120 (°C) MAX. 150 (°C) MIN. 43 (°C)
- ● VAPOR PRESSURE 2 (BAR abs) @ 120 (°C)
- ● RELATIVE DENSITY (SPECIFIC GRAVITY): NORMAL 0.943 MAX MIN
- ○ SPECIFIC HEAT, Cp (kJ/kg °C)
- ● VISCOSITY 0.232 (cP) @ 120 (°C)
- ○ MAX. VISCOSITY (cP)
- ○ CORROSIVE/EROSIVE AGENT (2.11.1.8)
- ○ CHLORIDE CONCENTRATION (PPM) (3.5.2.6)
- ○ H_2S CONCENTRATION (PPM) (2.11.1.11)

LIQUID (2.1.3) ○ HAZARDOUS ○ FLAMMABLE

- ○ OTHER

PERFORMANCE

- PROPOSAL CURVE NO. 620319A/B/C/D RPM 2980
- ■ IMPELLER DIA. RATED 368.45 MAX. 390 MIN. 351 (mm)
- ■ RATED POWER 1673.2 (BHP) EFFICIENCY 79.2 (%)
- ■ MINIMUM CONTINUOUS FLOW: THERMAL (m3/h) STABLE 230 (m3/h)
- ■ PREFERRED OPERATING REGION 535 TO 920 (m3/h)
- ■ ALLOWABLE OPERATING REGION 340 TO 950 (m3/h)
- ■ MAX HEAD @ RATED IMPELLER *1.3 792 *1.9 (m)
- ■ MAX POWER @ RATED IMPELLER 1900 (kW)
- ■ NPSHR AT RATED CAPACITY 7.4 (m) (2.1.8)
- ■ SUCTION SPECIFIC SPEED 11820 (m³/hr - m) (2.1.9)
- ○ MAX. SOUND PRESS. LEVEL REQ'D <85 (dBA) (2.1.14)
- ■ 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