RELIABILITY IMPROVEMENT AT PETROTRIN REFINERY – PUMPS AT NO. 8 CDU. 1997 to 2003

Presented by : Stanley Deonarine
Head, Mechanical Eng.
Petrotrin Refinery
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PROBLEM – TO IMPROVE PUMP RELIABILITY ON TWELVE BAD ACTORS

- Program duration – 1997 Jan to 2003 Aug.
- Mean Time Between Overhauls (MTBO) was low at 13 months for pumps and 6 months for turbines (shop overhauls only).
- Plant production was occasionally disrupted by turbine breakdowns.
- Maintenance cost was high at US$ 9,380. per pump p.a. average.

IDENTIFY THE BAD ACTORS

- Survey the maintenance records and cost data in the CMMS (1997 & 1998) and the SAP (1999 – 2000) for the 49 pumps at No. 8 CDU. Look for the pumps with the worst record.

- Preliminary definition : "Bad actor" - any pump handling hydrocarbons with MTBO < 24 months or maintenance cost > US$ 7936 (TT$ 50,000) p.a. or MTBO < 15 months regardless of cost. Preliminary number of bad actors – 17.

- Five pumps within the MTBO and cost criteria above were improved purely by quality assurance repairs without any engineering upgrade.

- Final definition : "Bad actor" - any pump which must require some engineering upgrade to improve the above. Hence, final number of bad actors – 12.

IDENTIFY THE BAD ACTORS

	MTBO (months)	ANNUAL M'TCE COSTS (US $,000)	
Survey Maintenance Records, CMMS and SAP for all 49 Pumps over 1997 - 2000	> 24	< 7.9	Good Actors (32)
	< 24 OR	> 7.9	Bad Actors (17)
	< 15	Regardless of cost	Bad Actors (17)

For the 17 Bad Actors → Can Q.A. repair improve?

- YES – 5 Bad Actors resolved.
- NO – 12 Bad Actors require :
  1. Failure Analysis whenever dismantling/ repairs are done.
  2. Engineering upgrade to resolve.

ANALYSIS METHOD

- For all major incidents e.g. fire or equipment destruction, appoint a multi-disciplinary team to investigate and develop a detailed report.
- For routine failures on the bad actors, the mechanical engineer should carry out a failure analysis.
- The engineer obtains advice as required from other members of his asset team (Process Engineer, Operations Superintendent, Maintenance Supervisor, etc).

STEPS IN PROBLEM SOLVING – PROCESS RELATED

- What were the process conditions ? Adverse conditions will wreck mechanical seals
- Check suction tank for low level – problem !!
- Is NPSHA less than NPSHR ? – problem !!
- Are there light ends in the liquid ? Even small amounts can create havoc !!
- Compare actual operating conditions vs design conditions
- These causes affected one pump(TT-2407) seriously and contributed to problems on three others(TT-3100/01/58).

STEPS IN PROBLEM SOLVING – FAILURE ANALYSIS

- Examine machine before, during/after dismantling.
- Identify all damaged/worn parts and parts with highest frequency of failure.
- Identify parts likely to be associated with the root cause – packing/sleeves, mechanical seals (faces and o-rings) and bearings/cooling systems.
- Reconcile with previous historical findings and other steps in problem solving (slides 6, 8, 9)
- Establish a pattern/mechanism of failure.
- In developing a solution, dovetail - obtain inputs from other departments and seek out a solution which addresses other problems as well.

STEPS IN PROBLEM SOLVING – RELATED TO EQUIPMENT DESIGN

- Compare design of existing pump/turbine (40 years old) to modern design built to API standards.
- Particularly, look for design issues which lead to bearing overheating. Also, how is the bearing mounted to the shaft ? (refer to slide 13). Check for fretting & looseness of parts.
- These causes affected four pumps(TT-3134/36/38/40) and twelve turbines seriously.
- Can redesign be done in-house or should it be referred to the OEM ?
- Or should a new pump/turbine be bought ?

STEPS IN PROBLEM SOLVING – RELATED TO SHAFT SEAL DESIGN

- Examine seal faces and o-rings. Check for cracked/worn faces and embrittled o-rings. 40 year old seal designs (stellite vs carbon faces) were suffering rapid wear/overheating. These causes affected 2 LPG pumps(TT-3100/01) and a gasolene pump(TT-3158).
- On packed pumps, check for rapid grooving of sleeves. These causes affected 4 pumps (TT-3118/20/46/50). Cost of leakage – US$4,000. per pump p.a.

STEPS IN PROBLEM SOLVING

Process Related	Related To Shaft seal Design	Related To Equipment Design
1. Low suction tank levels. **2. NPSHA< NPSNR** **3. Presence of light hydrocarbons.** **4. Compare Operating vs. Design conditions.**	**1. Compare existing Design vs. Current API design.** **2. Examine Seal faces & O-rings. Over-heating & Wear.** **3. Replacement of Seals.**	**1. Compare existing Design vs. Current API design.** **2. Over-heating of Bearings. Fretting and looseness.** **3. Redesign – In-house or OEM or Replacement of equipment.**

RECOMMENDATIONS – PROCESS & SHAFT SEAL DESIGN

- At low suction pressure (2 psig), switch to another supply tank in order to avert onset of pump cavitation.
- For 4 pumps with packed glands, fit new mechanical seals (Silicon carbide vs carbon faces, alloy 718 bellows).
- For 2 LPG pumps and a gasolene pump, replace old seals by new tandem seals with outer seal in standby mode at atmospheric pressure. Multi-port flush. (Silicon carbide vs carbon faces - spring loaded).
- STATUS - All above completed except for the gasolene pump.

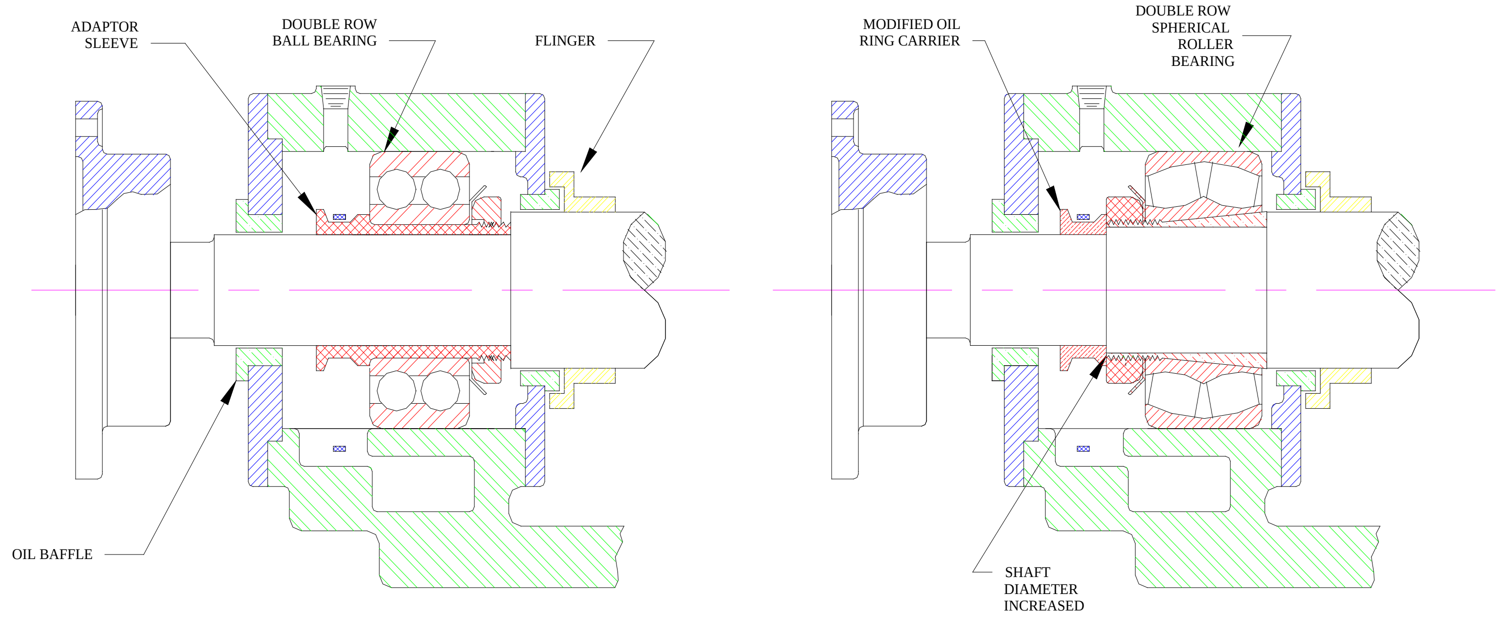
RECOMMENDATIONS – EQUIPMENT DESIGN

- Replace 12 turbines (40 years old) by new machines (API-611). Design new turbines to consume excess LP (65 psig) steam instead of 450 psig steam.
  STATUS – Completed.
  OPTION CONSIDERED – upgrade of old turbines by the OEM is technically sound but the cost is about the same as for a new turbine.

- Upgrade bearing/shaft design on 4 pumps to eliminate the adaptor which fitted as a sleeve between the radial ball bearing and the shaft.
  Refer to slide 13. STATUS – 2 pumps completed.
  OPTION CONSIDERED – Purchase of upgraded pump from the OEM is technically sound but the cost is much higher.

EXAMPLE OF EQUIPMENT REDESIGN

UPGRADE OF PUMP BEARING/SHAFT



OLD DESIGN

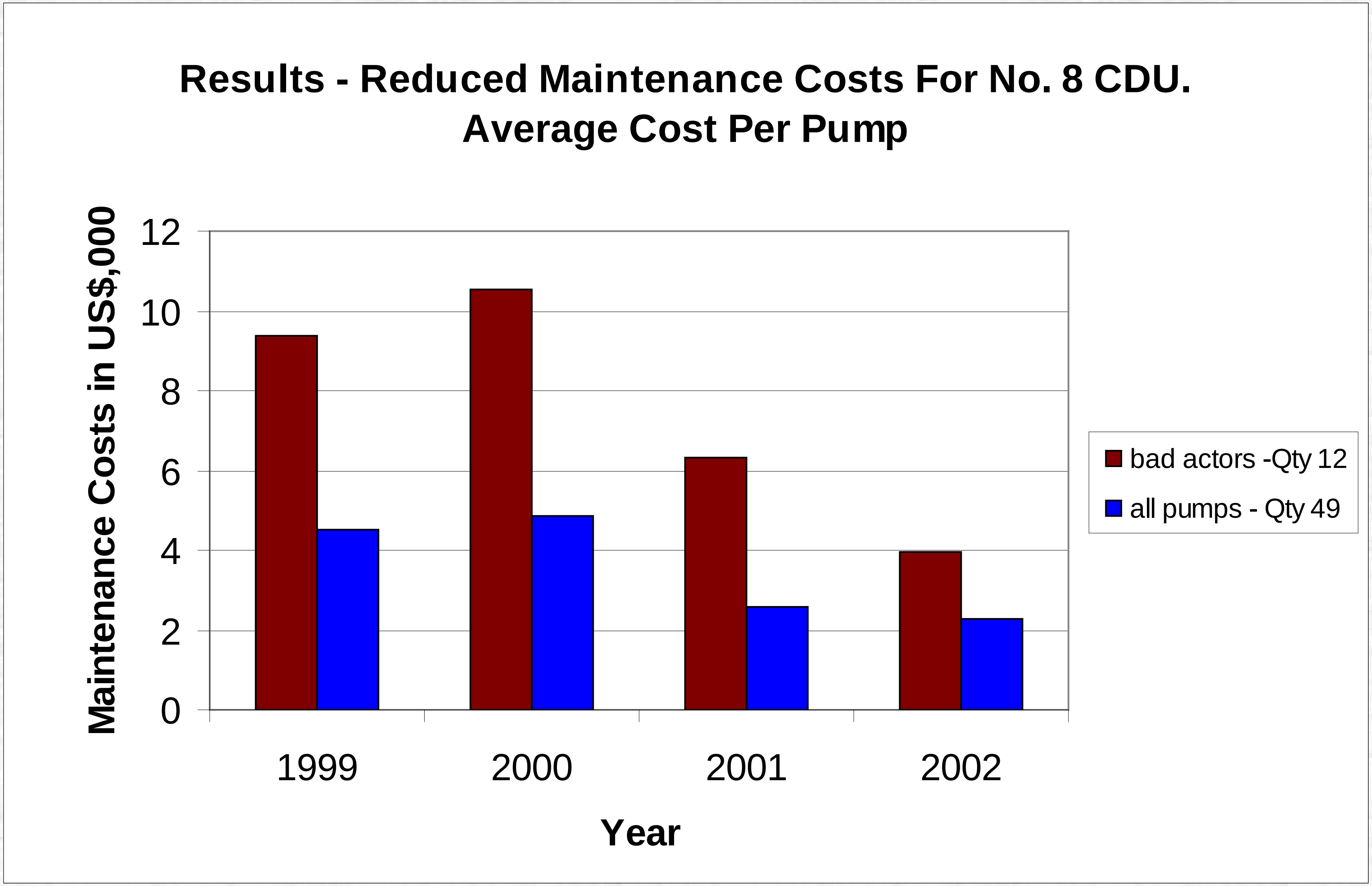
MODIFIED DESIGN

NOTE: SHAFT WITH ENLARGED BEARING SEAT. ADAPTOR SLEEVE ELIMINATED. BEARING HOUSING IS THE SAME

NO. 8 CDU – 12 BAD ACTOR PUMPS

TT NO.	SERVICE	MTBO (MONTHS)		MTCE COSTS TT$, 000			
		JAN '97 - AUG '00	SEPT '00 - AUG '03	1999	2000	2001	2002
2407	Charge Booster West	11	36	164	35	0	27
3140	Heater Charge North	22	36	32	117	0	182
3138	Common Spare for Cold Crude Charge/ Heater Charge	22	18	63	249	121	26
3136	Cold Crude Charge South	14.7	36	100	93	10	0
3134	Cold Crude Charge North	14.7	36	28	3	28	41
3120	Reduced Crude South	14.7	36	39	48	157	0
3118	Reduced Crude North	14.7	36	0	84	5	7
3150	Kerosene to Storage South	14.7	36	106	0	37	0
3146	Light Gas Oil South	11	36	16	0	37	0
3158	Common Spare for Splitter Charge/ Main Reflux	11	18	0	24	40	0
3100	Depropaniser Reflux North	4.4	* 12	52	101	41	0
3101	Depropaniser Reflux South	5.5	* 12	109	40	3	17
AVERAGE MTBO		**13.4 MTHS**	**29 MTHS**				
AVERAGE MAINTENANCE COST PER PUMP US$,000				**9.38**	**10.52**	**6.34**	**3.97**
INCULDE FOR INFLATION, 5% P.A. US$,000				**10.88**	**11.57**	**6.66**	**3.97**

*** Overhauls were done early in the period. Since then, MTBO has improved to over 24 months.**

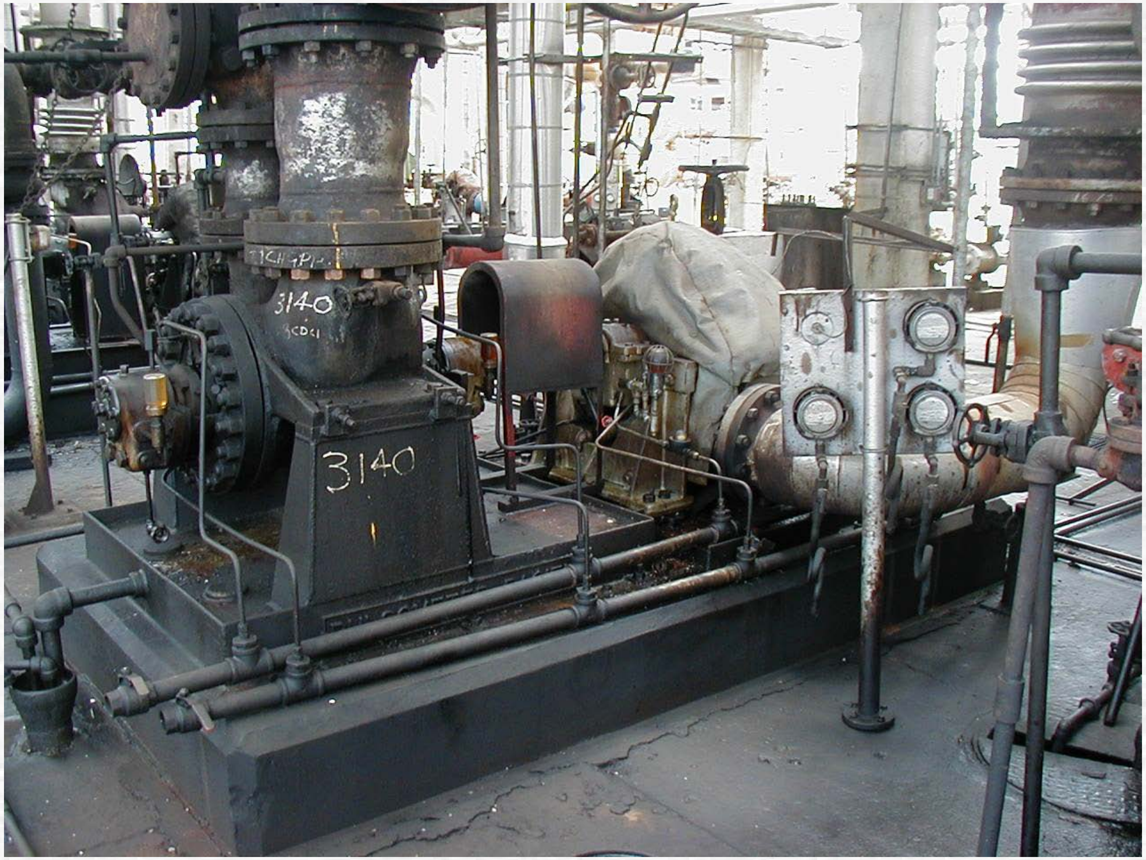


Results - Reduced Maintenance Costs For No. 8 CDU.
Average Cost Per Pump
Maintenance Costs in US$,000
12
10
8
6
4
2
0
1999
2000
2001
2002
Year
bad actors -Qty 12
all pumps - Qty 49

Obsolete Turbine

Barrier Tank on LPG Pump

Charge Pump TT-3140



Section of No. 8 CDU