Dismantle Inspection and Failure Analysis (DIFA) has driven a number of key ESP improvements for Apache by properly establishing failure mode and providing good, workable recommendations. Establishing the correct root cause is ultimately where the value lies in this process.

This presentation will look at the following:

- How has failure analysis benefited Apache’s Forties Field over the past 10 years?
- How can improved identification of true root cause of failure help to improve ESP runlife?
AGENDA

- Forties Field
- DIFA driven improvements
- ESP failure by categories
- DIFA standard API 11S1
- DIFA developments
- Trends and challenges
- Additional analysis
- Improvement opportunities
FORTIES FIELD

- 5 platforms, one satellite platform, one subsea tieback: Forties (A, B, C, D, E, FASP and Bacchus)
- 190+ ESP installations in Apache era
- ~60 ESP wells, 35 gas lifted wells and three subsea gas lifted wells.
- Production potential of 51Mbd
- ~43% of field production through ESPs.
- ESP runlife on upward trend thanks to high efficiencies, good operational procedures, incentivised contract with service provider, more focus on ESP reliability and DIFA.
DIFA DRIVEN IMPROVEMENTS

Combined Chart (Mar 14)

- Run Life (Running ESP's)
- Run life (All ESP's)
- Run Life (Failed ESP's)

- ESP failure due to sand fall back / pump bearings failing
- MLE damage during installation/operation
- Sand related well failures
- Implementation of fit for purpose sand control
- Sinewave filtering, power quality metering, more viscous motor oil and 'mine duty' motors.
- Full bearing housing pumps, adv. Protector head and shedder in top of pump
- Keyless pump bearings, minimum sand lift speeds
ESP FAILURES BY CATEGORY

FAILURE CATEGORIES (APACHE ERA) End 2013:

- Manufacturing and Electrical (design) cover motor/general electrical failures
- Green underline considers problem to be eradicated with implemented measures under present conditions
- Reservoir covers ESPs that did not fail; watered out etc.
- Awaiting 13 DIFA reports and root causes – Reason for pull mainly electrical with 1 elective pull.
Most ESP vendors use recommended practice API 11S1 as a guide which provides a good framework to ESP dismantle. Some of the key points to consider are as follows:

**Pros**
- Comprehensive enough to cover ESP dismantle in detail
- Ensures comments are recorded at each step in a structured and methodical manner
- Provides details of additional information required prior to starting any dismantle/failure analysis

**Cons**
- Does not give guidelines for lab analysis upon finding any unknown substances in pump
- Does not offer guidelines on root cause analysis which is left to the failure analyst
- Can direct the analysis towards the cause of the system failure rather than that of the component initiating the path to failure
Better understanding of failure modes – Schlumberger feeding back to engineering

Schlumberger/Apache have been routinely carrying out lab analysis on foreign items found in pulled ESP systems

Usable and focused recommendations in reports

Excellent detail in explanation of root cause

Penetrator system suppliers providing comprehensive tear down reports upon discovery of system failures

Attention to the ESP lifecycle in every report

Preliminary dismantle findings available upon viewing equipment
Electrical failures have been the most common failure mode, particularly motor failures, since the widespread implementation of sand control.

- Initial DIFA findings from motor failures recommended using higher viscosity oil and add one snap ring per rotor.
- Further succession of motor failures and general electrical failures prompted an investigation into electrical power quality.
- Common themes in failed motors prompted further analysis to be carried out on bearings:
  - Lab analysis of oil
  - Specialist analysis of bearing assemblies
**ADDITIONAL ANALYSIS - ELECTRICAL**

Electrical power study and lab testing carried out by specialist consultants Magney-Grande and David Shipp of Eaton.

Test set up to mimic offshore installation using typical medium voltage VSD, tuneable sinewave filter (SWF) and power quality meter.

- Findings concluded addition of SWF eliminated high frequency voltage and current
- SWF helped balance motor current
- Power quality meter will also allow for monitoring therefore better operation of ESPs
- Power quality meter will prove helpful for determining if power quality played a role in system failure – identification of root cause

![Without SWF](image1)

![With SWF](image2)
ADDITIONAL ANALYSIS - BEARINGS

Expert bearing investigation carried out by Andrew Marshall of Scots Bearings.

- Findings indicated mechanical wear rather than previously suspected electrical
- Sample oil analysis from test bearings showed kinematic viscosity to be lower than the data sheets stated
- Root cause of damage was determined to be poor lubrication between surfaces
- Reduction in hydrodynamic film could be caused by:
  - Increase surface roughness of bearing mating surfaces
  - Mixing of oil during filling process
- Recommendation: #6 oil deemed to be adequate as long as it is not diluted i.e. no less than 220cSt @40degC (agrees with SLB earlier recommendations)
IMPROVEMENT OPPORTUNITIES

- More detailed analysis of failure trends (like bearing trend)
- Avoid just accepting a higher spec without attempting to find root cause
- Understanding of the cause of electrical failures still remains one of the weakest parts of the DIFA process
- DIFA reviews between SLB and Apache to tackle divided opinion
- Inclusion in the DIFA report of the Apache cause analysis map drafted by the offshore team as part of plant upset report (PUR)
IMPROVEMENT OPPORTUNITIES

Apache PUR Cause Map

Why

- Effect
- Cause

NOTE: Read the Cause Map from left to right with the phrase "Was Caused By" in

Actions items shown in green

Interventions / observations shown in red

Safety Goal Impacted

Production Goal Impacted

Environmental Goal Impacted

Mat’s/Labor Goal Impacted

Customer Goal Impacted

Action: Investigate why Motor T alarm is unavailable - Downhole gauge is not, therefore no alarm triggers available. Expected weekly work.

Action: Checklist to be drafted on correct method of reducing HZ on ESPs - This action has been cancelled, we will stop ESPs rather than allowing them.

Action: Checklist to be drafted on correct method of reducing HZ on ESPs -

HZ on ESP reduced to aid FCV100 ECS

HZ were reduced below minimum operating speed causing ESP to dead head.

Data V trend indicates dead head scenario

Reducing total fluids has previously been proven to aid ECS.

On previous occasions reducing the throughput has quickly improved ECS results.

Operator unaware of minimum HZ.

MOL driver increased HZ further after advice from Red room. General opinion was that flow had been achieved.

No downhole data or motor temp data on Data V

Action: Ops techs to use available trends to monitor variables eg WHFT trend would indicate loss of flow.

Action: Communicate the procedure of stoppage ESPs, instead of allowing them down.

FC6-3 tripped on IOC

Lack of flow on ESP - causing ESP to overheat.

E. Alexander with concern over lack of flow. E. Alexander contacted platform as MOL driver had no motor temp or downhole data due to comm issue. Also did not monitor WHFT. Additionally Red room comm were down due to office relocation.

Delta V trend indicates dead head scenario
ACKNOWLEDGEMENTS