The Vision...
Total Workover Cost vs. ESP Run Life (Onshore)
Operators want to...

- Improve ESP Run-Life in existing applications
- Improve the chances of success in new applications
- Extend range and reliability of current ESP technology
- Get a better understanding of the factors affecting ESP Run-Life
The Vision …

Access a large set of hard ESP reliability data
  ➢ To avoid educated guesses
Ensure this reliability data is consistent
  ➢ To avoid misunderstanding
Incorporate reliability engineering analysis tools
  ➢ To analyze data appropriately
Benchmark results against other operators
  ➢ To determine attainable performance targets
Learn from others experience
  ➢ To find out what you can do to achieve better performance
ESP-RIFTS JIP was formed in 1999.

ESP Operators joined efforts to pursue...

“… development of an industry wide Electric Submersible Pump (ESP) - Reliability Information and Failure Tracking System (ESP-RIFTS), which will permit sharing of ESP run-life and failure information among a number of operators.”

“… ultimate goals ... [they] are two fold: (1) to accelerate the learning curve associated with new ESP applications; and (2) to increase average ESP run-life and operating range, by transferring knowledge and experience across the industry”
Implementation Strategy…
System Concept: Interface

End Users
Multiple users world-wide
Internet interface

World-Wide Network

C-FER Technologies
- System Maintenance
- Data Processing
- Benchmarking Analysis

End Users

ExxonMobil
Petrobras
Encana
Chevron
ConocoPhillips
Total
Petroleum Development Oman
Repsol YPF
Sinopec
StatoilHydro

ESP-RIFTS
http://www.esprifts.com

C-FER Technologies
1. Standard terminology (ESP Failure Nomenclature Standard)
   Consistency in classifying, recording and storing information
2. Common set of parameters (General Data Set)
   Tracked by all Participants in the project
3. Data Input Sheet (DIS)
   To assist in data collection, maintenance and upload
4. Procedure to ensure certain standards of data “quality”
5. Database structure to store the data collected
6. Internet based system
   Participants select records of interest
   Examine the contents of such records
   Conduct a variety of analyses with them
7. Set of reliability tools to support data analysis
   Various run-life measures, reliability functions and distributions
   Confidence level calculations
8. Model to predict run-life under new conditions (“What if”)
   Calibrated with database information
ESP-RIFTS
Failure Nomenclature Standard

Standard terminology for classifying, recording and storing ESP failure information,

Leading to consistency in failure analysis performed with data gathered by different operating and service companies

Conforms to (as much as possible):
1) International Standard ISO/DIS 14224
2) API RP 11S1

In general:

Broad definitions and failure attribute classifications were borrowed from the ISO/DIS 14224*;
Nomenclature for components, parts and teardown observations were borrowed from the API RP 11S1

*ISO 14224: Petroleum and Natural Gas Industries: Collection and Exchange of Reliability and Maintenance Data for Equipment
System Features ESP-RIFTS

1. Standard terminology (ESP Failure Nomenclature Standard)
   Consistency in classifying, recording and storing information

2. Common set of parameters (General and Minimum Data Sets)
   Tracked by all Participants in the project

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**Minimum Data Set**

List of ~ 37 key parameters
Subset of the General Data Set
Developed with the input of the ESP-RIFTS Steering Committee
Attempted to be consistent with other recommended parameter lists
➤ SPE ESP Workshop

The Minimum information that an ESP “Failure” record must have to be considered “Complete” (as per the ESP-RIFTS Qualification Standard)

---

**ESP-RIFTS: Minimum Data Set**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Field Information</th>
<th>Fluid Information</th>
<th>Well Information</th>
<th>Runtime Data (dates)</th>
<th>Failure Information</th>
<th>Surface Equipment Data</th>
<th>Downhole Equipment Data</th>
<th>Operating and Production Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Field Name</td>
<td>Oil Density</td>
<td>Well Name</td>
<td>Production Period No.</td>
<td>ESP System Failed?</td>
<td>Control Panel Type</td>
<td>Pump Vendor</td>
<td>Total Flow Rate</td>
</tr>
<tr>
<td></td>
<td>Field Type</td>
<td>Bottomhole Temperature (BHT)</td>
<td>Reservoir(s) Type</td>
<td>Date Started</td>
<td>Primary Failed Item</td>
<td></td>
<td>Pump Type/Model</td>
<td>Water Cut (or oil and water rates)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Casing Size</td>
<td>Date Failed / Shutdown</td>
<td>Primary Failure Descriptor</td>
<td></td>
<td>Number of Pump Stages</td>
<td>Pump Intake Pressure (PIP)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Motor Type/Model</td>
<td>Gas-Oil Ratio (GOR) or gas rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Motor Horsepower</td>
<td>Sand Production (Concentration)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pump Intake /Gas Separator Vendor</td>
<td>Scale (None/Light/Moderate/Severe)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pump Intake /Gas Separator Type</td>
<td>Asphaltene (None/ Light/Moderate/Severe)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cable Vendor</td>
<td>CO₂ (Concentration)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Cable Model/Size</td>
<td>H₂S (Concentration)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Pump Seating Depth (PSD)</td>
<td>Emulsion (None/Light/Moderate/Severe)</td>
</tr>
</tbody>
</table>

| Number Minimum Data Set Parameters | 37 |

---

Average data for period or more frequent e.g., monthly or number of intervals (must provide start and end dates of these intervals) during which operating conditions were reasonably constant.
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Data Processing and Qualification Overview

Participants
- Participants send new data & data updates to C-FER
- Feedback from C-FER to the Participants:
  - Apparent problems with the data
  - Processed data sent back to Participants in ESP-RIFTS or PCP-RIFTS Data Input Sheet

Data Processing
- C-FER processes and enters data into the Development Server
- Processed data and New Web pages are uploaded to the Production Server

Data Qualification
- Participants conduct analyses via the web

Web
- Participants send new data & data updates to C-FER
- FTP
- C-FER processes and enters data into the Development Server
- Processed data and New Web pages are uploaded to the Production Server
- Data Qualification
- Participants conduct analyses via the web
Our confidence in any analysis will always be strongly dependant on our perception of the quality of the data collected.

Goal of data qualification process is to yield “quality data”; as per the ISO Standard:

- **Complete** – in relation to a specification
- **Compatible and Consistent** – with a standard set of definitions and formats, with other information pertaining to the record, with the principles of PCP technology and with basic laws of engineering/science
- **Accurate** – truly representative of the PCP installation that it describes
Data Input Sheet (DIS)

Microsoft® Access based database file with structure similar to ESP-RIFTS master database
Developed to assist in data collection and qualification
Field level data capture and tracking
DIS

Benefits to the Participants

Ability to check and improve their own records before sending the data to C-FER

DIS can generate automated reports on level of completeness and inconsistencies

Ability to analyze the data shortly after providing data to C-FER

DIS allows for quicker data processing, qualification and uploading by C-FER

Ability to work in different unit systems

SI, British and North Sea units

Ability to work in different languages

Currently English, Spanish, Portuguese, Russian and French

Ability to perform basic Analysis on your own data

Run-Life Calculations (e.g. MTTF, Average Runtime), Reliability Functions (e.g. Survival Probability), Failure Rates by ESP Component) and Reporting of Results
Select either chart or table output format

Results can be saved and printed
Reliability Functions

Grouping Variables:
- Company, Division, Field, Well
- MORE options have been added as well (e.g. Cable AWG Size, Motor Series, Solids?, etc.)

Survival Probability and Hazard Function shown
DIS

Failure Rates by ESP Component

Output Options Include:
1. Service-Life of Failed
2. Number of Failed ESPs
3. Average Runtime of Failed
4. Failure Rate

Outputs Segregated by:
1. Failed Item – Main Component
2. Failed Item – Subcomponent
3. Failure Cause: General

Grouping Variables:
- Company, Division, Field, Well
- MORE options will be added soon (e.g. Vendor, Model #), as in the Website

Note: Field names have been “masked” for confidentiality
Percentage breakdown of all the specific vendors for the ESP motors and pumps in the specific DIS file.
Data Processing
Locations of Fields in ESP-RIFTS

Note: Company IDs have been “masked” for confidentiality
Grow of Database as of March 2009

79,754 ESP Installs as of March 2009
- 17 companies
- 88 divisions
- 494 fields
- 25454 wells

March 2009 ESP-RIFTS Overview March 2009
System Features for ESP-RIFTS

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Database Structure

Five main groups of data

Field, Well, Fluid, and Reservoir data
- Field, Reservoir, Drilling/Completion, Fluid, Workovers, Operator info.

Run time information
- Install, Start, Stop, Pull dates, etc.

Production and Operating Information
- Producing rates, GOR, BSW, Fluid Level, Wellhead and Bottom Hole Pressure and Temperature

Failure data
- Item(s), Descriptor, Mode, Cause
- Teardown/Inspection reports, bench test reports, photographs, scanned documents
- Comments

Equipment data
- Motor model, Motor HP, Intake Model, Cable Size, Manufacturer “Catalogue” information
Database Structure (cont’d)

The link between these groups of data is a **Production Period**, which includes:

- One specific ESP or PCP assembly
- Installed, Started, Stopped and Pulled
- Serial numbers, completion assembly/sequence in the well and associated surface/downhole equipment
- Well Service and Production/Operating histories
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Measures of Run-Life
Some Key Concepts
Censoring

For some systems, the RL is not known:
- Systems still running
- Systems pulled for reasons other than a system failure
- The data is said to be “censored”

However, **proper analysis must consider all data**
- Considering only the failed items will tend to underestimate the reliability of the system

Therefore, **all systems must be tracked:**
- Pulled systems
  - Failed
  - Not Failed
- Running systems
Run-Life Flow Chart

- **Running**
  - **Period Status**: all periods
    - #still running
  - #completed
  - Valid Last Date

- **Completed**
  - ESP System Failed ?
    - Yes: # failed
    - No: # not failed
Reliability Functions
Survival and Hazard Curves

[Graphs showing survival and hazard curves with axes labeled 'month' and 'S(t)' (survival percentage) against months ranging from 0 to 150.]
Component Failure Rates
### Failure Rates of Cables for a Field

<table>
<thead>
<tr>
<th>Primary Failed Item</th>
<th>ESP Cable</th>
<th>ESP Gas Handler</th>
<th>ESP Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cable</td>
<td>Service Life (day-periods)</td>
<td>No. of Failure Data Periods (periods)</td>
<td>Number Failed (periods)</td>
</tr>
<tr>
<td>New</td>
<td>67107</td>
<td>113</td>
<td>7</td>
</tr>
<tr>
<td>Repaired</td>
<td>5763</td>
<td>27</td>
<td>0</td>
</tr>
<tr>
<td>Used</td>
<td>127323</td>
<td>287</td>
<td>55</td>
</tr>
<tr>
<td>(Blank)</td>
<td>103298</td>
<td>258</td>
<td>66</td>
</tr>
<tr>
<td>Total</td>
<td>303491</td>
<td>685</td>
<td>128</td>
</tr>
</tbody>
</table>

90% confidence level on equality of sample means:

- FR of New Cable is 4 times smaller than that of Used Cable.
System Features for ESP-RIFTS

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   - Calibrated with database information
   - Developed for ESP-RIFTS
What-If Model

A “Proportional-Hazard-Model” based on data in the System
Some details presented by C-FER in the 2003 ESP-Workshop
Has evolved with time
Allows for benchmarking taking into account differences in operating conditions
One way to identify key influential factors affecting Run-Life
What-If Model (contd.)

Field A  Field B  Field C

Low R-L but above expectations
High R-L but below expectations

Note: Field names have been “masked” for confidentiality
Some Analysis Examples
Using Website Data and Tools
How is My Field doing?  
- MTTF and Average Run-Life -

Based on Date Installed, MTTF shows continuous improvement. Uncertainty bars on MTTF depend on number of failed systems. Average Run-Life decrease in 2003-2005 is does not necessarily indicate worse performance. Only indicates that more recently installed systems are “younger”
How is My Field doing?
- Cumulative and Moving Window metrics -

Based on more recent data (i.e. Moving Window of last 1200 days at each point in time), MTTF and Average Run-Life shows larger improvement than based on all (cumulative) data.

Not shown (but available): Other R-L metrics used by Operators
  All have advantages and disadvantages
  Some are indicators of “age of population” and not necessarily equipment reliability
### How is My Field doing? - Primary Failed Items and Failure Mechanisms -

<table>
<thead>
<tr>
<th>Periods with Failures at $t \leq 90$ days</th>
<th>All Failed Periods</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary Failed Items:</strong></td>
<td><strong>Primary Failed Items:</strong></td>
</tr>
<tr>
<td>Motors  36.8%</td>
<td>Pumps  33.8%</td>
</tr>
<tr>
<td>Cables  21.1%</td>
<td>Motors  22.4%</td>
</tr>
<tr>
<td>Pumps  21.1%</td>
<td>Intakes  18.8%</td>
</tr>
<tr>
<td>Intakes  9.2%</td>
<td>Cables  16.5%</td>
</tr>
<tr>
<td>Seals  9.2%</td>
<td>Seals  6.5%</td>
</tr>
<tr>
<td><strong>Most Severe Mechanisms:</strong></td>
<td><strong>Most Severe Mechanisms:</strong></td>
</tr>
<tr>
<td>Short Circuited Motors  14.5%</td>
<td>Broken Pumps  14.1%</td>
</tr>
<tr>
<td>Short Circuited Cables  14.5%</td>
<td>Short Circuited Cable  11.5%</td>
</tr>
<tr>
<td>Phase Unbal. Motors  9.2%</td>
<td>Short Circuited Motor  10.6%</td>
</tr>
<tr>
<td>Plugged Pumps  7.9%</td>
<td>Stuck Pumps  6.5%</td>
</tr>
<tr>
<td>Broken/Fract. Intakes  7.9%</td>
<td>Fractured Pumps  6.2%</td>
</tr>
<tr>
<td>Overheated Motors  4.0%</td>
<td>Phase Unbal. Motors  4.4%</td>
</tr>
<tr>
<td>Low Impedance Motors  4.0%</td>
<td>Plugged Pumps  2.9%</td>
</tr>
</tbody>
</table>

Failure Mechanisms are **different for early and all failures**
How is My Field doing?

- Failure Rates (FRs) by ESP system component: evolution with time -

FR’s of Pump Intakes, Seals and Cables show deceasing trend (improving)
FR of Motors shows increasing trend
FR of Pumps varies with no clear trend
Pump and Motors are components currently with higher FRs
How is **My Field** doing?

- **Failure Rates (FRs): effect of scale** -

<table>
<thead>
<tr>
<th>Primary Failed Item</th>
<th>ESP Assembly</th>
<th>ESP Cable</th>
<th>ESP Motor</th>
<th>ESP Pump</th>
<th>ESP Pump Intake</th>
<th>ESP Seal</th>
<th>ESP Shroud</th>
<th>Non-ESP System Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scale?</td>
<td>Failure Rate</td>
<td>Failure Rate</td>
<td>Failure Rate</td>
<td>Failure Rate</td>
<td>Failure Rate</td>
<td>Failure Rate</td>
<td>Failure Rate</td>
<td>Failure Rate</td>
</tr>
<tr>
<td>Moderate</td>
<td>(×10^{-6}/day)</td>
<td>(×10^{-6}/day)</td>
<td>(×10^{-6}/day)</td>
<td>(×10^{-6}/day)</td>
<td>(×10^{-6}/day)</td>
<td>(×10^{-6}/day)</td>
<td>(×10^{-6}/day)</td>
<td>(×10^{-6}/day)</td>
</tr>
<tr>
<td>Moderate</td>
<td>12.47</td>
<td>130.97</td>
<td>180.86</td>
<td>224.51</td>
<td>155.91</td>
<td>81.07</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Severe</td>
<td>8.2</td>
<td>143.57</td>
<td>192.79</td>
<td>324.05</td>
<td>159.97</td>
<td>36.92</td>
<td>4.1</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>9.9</td>
<td>138.57</td>
<td>188.05</td>
<td>284.56</td>
<td>158.36</td>
<td>54.44</td>
<td>2.47</td>
<td>0</td>
</tr>
</tbody>
</table>

ESP Pumps are affected by **severe** scaling conditions: +44% higher FR’s than for **moderate** scaling conditions.
How does My Field compare with “similar” fields?
- Search data in the system -

Field B has a large # of “similar” records
Other fields have just a few records

Note: Company Names have been “masked” for confidentiality
Comparison of Cumulative MTTF and Average Run-Life

MTTF Estimate

MTTF (days) Avg. Run-Life (days)

B Field

My Field

MTTF is approximately 4 months lower in My Field

Note: Field names have been “masked” for confidentiality
Closure
Current Project Participants

Project Phases

  ➢ Project Web Site: online since July 2000
III: May 2001 – Apr. 2002
IV: May 2002 – Apr. 2003
V: May 2003 – Apr. 2004
VI: May 2004 – Apr. 2005
VII: May 2005 – Apr. 2006
VIII: May 2006 – Apr. 2007

Current Participants

BP
ChevronTexaco
ConocoPhillips
EnCana
ExxonMobil
Nexen
Petrobras
Repsol-YPF
Shell Intl.
StatoilHydro
TNK-BP
TOTAL
Benefits to New Participants
Upon joining ESP-RIFTS

1. Immediate access to the system - user accounts will be assigned to a number of New Participant personnel
2. Ability to query the data and conduct analyses - display the results in a number of numerical and graphical formats
3. Improved ability to make good decisions on issues affecting ESP run life
4. Access to about US$ 3,500,000 worth of work conducted in the previous phases of the JIP (phases I - IX)
5. Two-Three day workshop (at a location of choice) to quickly bring the New Participant personnel up to speed
6. Improved understanding of run-life and failure tracking issues and analysis techniques
7. Opportunity to upgrade current ESP failure tracking systems to the ESP-RIFTS standard:
   Achieving consistency within own Company
   Achieving consistency within the group of industry Participants
Benefits to New Participants

Long-Term Benefits

1. **Business results**, which can span over a variety of aspects, including:
   - Improved chances of overall economic success in new projects
     - Because there will be less uncertainty in the expected run-life
   - Reduced production losses in the upcoming years
     - Because improved rig scheduling will be possible
   - Improved overall run-life and reduced operational costs
     - Because best practices can be implemented

2. **Business results can start to be obtained as soon as possible**
   - In terms of run-life, the effects of good decisions made at one point in time are only felt in the long term

3. **Ability to make direct benchmark comparisons**
   - Within own Company’s operations
   - Within the Participants' operations

4. **Guidelines for negotiations between the Participant and ESP vendors (e.g., as in alliance situations)**
   - Using benchmarks established with the system
Fee Structure
Year 2009/2010 (Phase XI)

New Participant Fee
US$ 48,000 (one-time)
- Covers
  - Initial Development Cost Sharing
  - New Participant Orientations (in-house training)
  - Mapping and Input of Historical Data

JIP Participation Fee
US$48,000
- Covers Core Tasks
  - Data Processing and Qualification
  - Data Analysis (within the limits of the System)
  - Web Site Maintenance
  - Project Steering Committee Meetings (Nov/Dec 2009 and Apr/May 2010)
  - Project Management and Reporting
Further Documentation Available

Project web site:  [http://www.esprifts.com](http://www.esprifts.com)
General Information on the ESP-RIFTS JIP

Detailed work scope, deliverables, and milestone schedule for Phase X:

2001 SPE - ESP Workshop Paper
“ESP Failures: Can We Talk the Same Language?”

2003 SPE - ESP Workshop Paper
“Benchmarking ESP Run Life Accounting for Application Differences”

For addition information, please contact:
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e-mail:  f.alhanati@cfertech.com
Support Slides
Predicting ESP Run Life for New Applications

Questions in field development feasibility studies

What is the expected ESP run life for the field?

What are the future service rig requirements for the field?

What type of equipment is best suited for a given application?
  - E.g., Is the run life for wells equipped with VSDs the same as wells equipped with switch boxes?
  - E.g., Are coiled tubing deployed systems less reliable than systems deployed on jointed tubing? If so, how much?

What is the effect of well completion type on ESP run life?
  - E.g., Should sand control (gravel pack) be used to prevent sand inflow (but perhaps at the cost of lower well productivity)? Would the ESP run-life be acceptable if the sand is produced?

What operating practices/conditions are best?
  - E.g., Should the wells be produced at a flowing bottomhole pressure that is above the bubble point pressure to avoid failures associated with free gas?
Early Stages of a Feasibility Study

How ESP run-life affects the project economics?

Offshore Platform Example

- 20 Wells
- Average oil production per well: 1200 bopd
- Average intervention cost: 150 k (10 days @15k/day)
- Average equipment cost: 100 k
- Average workover & waiting time: 60 days

Onshore Example

- 100 wells
- Average oil production per well: 200 bopd
- Average intervention cost: 20 k
- Average equipment cost: 50 k
- Average workover & waiting time: 7 days
Total Workover Cost vs. ESP Run Life (Offshore)
Total Workover Cost vs. ESP Run Life (Onshore)