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Standard

ESP Failure Nomenclature

Version 4.5

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NOTICE

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FOREWORD

The ESP-RIFTS Joint Industry Project (JIP) focuses on the development of an industry-wide Electric Submersible Pump (ESP) Reliability Information and Failure Tracking System (RIFTS), which shall facilitate sharing of ESP run life and failure information among a number of operators. The objective of this Standard on ESP Failure Nomenclature is to provide a common terminology for classifying, recording and storing ESP failure information, and therefore, consistency in failure analysis performed with data gathered by different operating and service companies.

An effort was made to conform, as much as possible, to: (1) the International Standard ISO 14224:2016 ("Petroleum and Natural Gas Industries – Collection and Exchange of Reliability and Maintenance Data for Equipment"); (2) the API RP 11S1:1997 ("Recommended Practice for Electrical Submersible Pump Teardown Report") and (3) the International Standard ISO 15551-1:2015[1] ("Petroleum And Natural Gas Industries - Drilling And Production Equipment - Part 1: Electric Submersible Pump Systems For Artificial Lift"). In general, broad definitions and failure attribute classifications were borrowed from the ISO 14224 standard, while nomenclature for components, parts and possible teardown observations were borrowed from the API RP 11S1:1997.

[1] This standard was under review during the generation of version 4.5 of the FNS. Version 4.5 of the FNS includes proposed changes to Annex I, "Analysis after ESP Use".

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1. SCOPE

Each ESP failure event can be identified by a number of attributes, with each attribute describing one piece of information. The various categories of attributes that together constitute a unique ESP failure record generally include:

- The well identifier.
- Installation, start, failure and pull dates.
- Well directional survey and completion information.
- Production and operational data in the period prior to failure (flow-rate, wellhead and bottomhole temperature and pressure, amps, Hz, etc.).
- Information on the ESP equipment (manufacturer, type, model, serial number, metallurgy, etc.).
- Information specific to the failure.

This ESP Failure Nomenclature Standard provides a terminology for classifying, recording and storing information specific to ESP failures (i.e. information related to the last category above), for use within the ESP-RIFTS JIP.

While not covered by this Standard, the importance of tracking all the information listed above cannot be overstressed. Note that the API RP 11S1 (1997), while covering only teardown observations, also recognizes the importance of collecting other data, thereafter referred as *Pertinent Data.*

An ESP failure tracking system should include records not only on failed systems, but also on systems currently operating. This is considered good practice, and allows for "censored" data analysis. A tracking system should also include records on ESP equipment stopped for reasons other than a system failure, such as well work over, tubing leak, change of Artificial Lift method, etc.

This Standard on ESP Failure Nomenclature covers only downhole ESP equipment, hereafter called the '*ESP System*'. Surface power supply equipment, are therefore, excluded. A boundary diagram of the equipment under consideration is shown in Figure 6.1 and the hierarchy of the equipment under consideration is shown in Figure 6.2. It is, however, recommended that information on relevant surface equipment type and model, as well as on the quality of the power supply be part of any ESP failure tracking system.

2. DEFINITIONS

For the purpose of this Standard, the following definitions of ISO 14224:2016, with slight modifications, will apply:

Failure: The termination of the ability of an item to perform a required function.

Reason for Pull: The motive for the ESP System pull.

Failed Item: Any part, component, device, subsystem, functional unit, equipment or system that can be individually considered and that has failed.

Failure Mechanism: The observed physical, chemical or other process that led directly to the *Failure*.

Failure Cause: The circumstances during design manufacture or use which have led to a *Failure*.

Operating State: The state when an item is performing a required function.

Required Function: A function or combination of functions of an item which is considered necessary to provide a given service.

Reliability: The probability of an item to perform a required function, under given conditions, for a given time interval.

The following definitions were added to this Standard specifically for tracking ESP reliability data:

ESP System: The assembly of downhole components that together comprises an ESP unit (i.e. those components that lie within the system boundary shown in Figure 6.1).

Primary Failed Item: The ESP System Failed Item responsible for initiating the failure of the *ESP System*[2].

More detailed comments on the above definitions are included in Sections 3 and 4 of this Standard.

[2] Primary Failed Item should only be set to non-ESP System Failure if a failure investigation determined that a non-ESP System Failure made the ESP System appear to have failed, when it was in fact performing its required functions (therefore had not actually failed).

3. FAILURE DATA STRUCTURE

In the ESP-RIFTS, information specific to ESP failures shall be classified according to the following attributes:

- *Reason for Pull;*
- *Failed Item(s);*
- *Primary Failed Item;*
- *Failure Mechanism(s); and*
- *Failure Cause.*

3.1 Reason for Pull

As per the definition in Section 2, the *Reason for Pull* is the motive for the ESP System pull. A *Reason for Pull* shall be defined once the operator has determined that the *ESP System* must be removed from the well because of a suspected *ESP System* failure or other circumstances.

In the case of a suspected *ESP System* failure, the *ESP System* is likely pulled from the well to be inspected and/or repaired. In this case, the *Reason for Pull* is the main evidence of the downhole equipment failure. It is usually a result of an abnormal operating condition as detected by the installation monitoring system, or a well test.

Table 3.1 contains possible *Reasons for Pull* of an *ESP System*.

Failure Data Structure

Reason for Pull: General	Reason for Pull: Specific	Description
Downhole Instrumentation Measured/Detected	High Motor Winding Temperature	Suspected failure indicated by abnormal downhole instrumentation measurements.
	High Vibration	
	Low Motor Oil Dielectric Capacitance	
	Abnormal Discharge Pressure	
	Unknown	
Electrical	High Current	Suspected failure indicated by abnormal electrical measurements or events (e.g. relay tripping, blown fuses, etc.).
	High Voltage	
	Low Current	
	Low Impedance/Resistance	
	Low Voltage	
	Phase Unbalance	
	Short Circuit	
	Current Leakage	
	Unknown	
Flow	Low Flow to Surface	Suspected failure indicated by abnormal flow rate measurements.
	No Flow to Surface	
	Unknown	
Maintenance / Repair	Casing Repair	System pulled to conduct maintenance or repair on the well or on other downhole equipment.
	Tubing Repair	
	Sand Control Repair	
	Other Downhole Equipment Repair	
	Proactive ESP Replacement	
	Clean-out	
Recompletion	Change Artificial Lift Method/Resize ESP System	System pulled to recomplete well.
	Converting Well	
	Change/Modify Producing Zone	
	Stimulation	
	Other	
Suspend	Permanent Abandonment	System pulled due to well being suspended.
	Temporary Abandonment	
	Shut In	
Other	Other	System pulled due to well being suspended.
	Economics	
	Logging Well	
Unknown	Unknown	Reason for pull is unknown.

Table 3.1 Possible Reasons for Pull

3.2 Failed Items

As per the definition in Section 2, a *Failed Item* is any part, component, device, subsystem, functional unit, equipment or system that can be individually considered and which has failed. Items specific to this Standard are the *ESP System*, components (e.g. motors, seal chamber sections, pumps, intakes, cables) and sub-components (e.g. impellers, shafts, o-rings).

As defined in Section 2, the *ESP System* is the assembly of ESP components that lie within the system boundary shown in Figures 1 and 2. Table 3.2 contains a list of the main ESP components, and associated sub-components, that may be subject to failure.

System	Component	Subcomponent		
ESP Assembly	ESP Cable	• Clamps/Straps • Main Power Cable • Motor Lead Extension	• Packer Penetrator • Pigtail • Pothead Connector	• Splices • Wellhead Penetrator • Unknown Subcomponent
	ESP Motor	• Base • Coupling • Drain Port/Fill Valve • Fastener • Filter • Head	• Housing • Motor End Connectors (Y-point/Leads) • Oil (Motor Fluid) • O-rings and Other Seals • Radial Bearing • Retaining Rings	• Rotors • Shaft • Stator • Thrust Bearing • Unknown Subcomponent • Varnish
	ESP Pump*	• Base/Intake • Coupling • Diffusers • Fastener • Head/Discharge	• Housing • Impellers • O-rings and Other Seals • Radial Bearings • Retaining rings	• Screen • Shaft • Thrust Washers • Unknown Subcomponent
	ESP Pump Intake**	• Base • Coupling • Diffusers • Discharge Ports/Screen • Fastener • Head	• Housing • Impellers • Inducer Section • Intake Ports/Screen • O-rings and Other Seals • Radial Bearings	• Retaining rings • Separation Section/Rotor • Shaft • Thrust Washers • Unknown Subcomponent
	ESP Seal Chamber Section	• Bag/Bladder/Bellows Chamber Assembly • Base • Coupling • Drain Port/Fill Valve • Fastener • Head	• Housing • Labyrinth Chamber • Mechanical Seals • Oil (Motor Fluid) • O-rings • Radial Bearings	• Relief Valves • Sand Separator • Shaft • Thrust Bearing • Unknown Subcomponent
	Other ESP System Component	• Downhole Sensors • Shroud		
	Unknown	• Unknown		

* Includes Gas Handler

** Includes Gas Separator

Table 3.2 Possible Failed Items

Note that there is a lot of consistency between the parts included in Table 3.2, the ones listed in API RP 11S1 (1997), and the ones mentioned by Lea and Powers (1994).

Observations regarding the conditions of all downhole ESP components and their associated parts (e.g. from pull and teardown reports) shall be maintained in the tracking system (see Section 3.3).

3.2.1 Primary Failed Item

As per the definition in Section 2, the *Primary Failed Item* is the ESP System Failed Item responsible for initiating the failure of the *ESP System*. Thus it is the root failed-item in the sequence of interrelated events that lead to an *ESP System Failure.* Tracing back this sequence of events from the *ESP System Failure* and identifying the *Primary Failed Item* normally requires some in-depth investigation.

The *Primary Failed Item* is not necessarily the item considered most severely damaged, nor the item whose *Failure* generated the evidence of the downhole equipment failure (Reason for Pull).

3.3 Failure Mechanisms

As per the definition in Section 2, a *Failure Mechanism* is the observed physical, chemical or other process that led directly to the *Failure*. These observations are probably made during the ESP downhole equipment pull, or teardown inspection. They are the main symptoms, or perceptible signs of damage to the ESP components or their parts, that may have resulted in the system failure. The "observation codes" described in API RP 11S1 (1997), Figure A.2, are essentially *Failure Mechanisms* for the various parts of the ESP components.

Table 3.3 lists possible *Failure Mechanism*s for the main ESP components and associated parts. Note that some *Failure Mechanisms* may not be applicable to some parts.

Failure Data Structure

Category	Failure Mechanisms		Comments
Electrical	• High Impedance/Resistance • Low Impedance/Resistance • Open Circuit	• Short Circuit • Phase Unbalance	Failures related to the supply and transmission of electrical power.
External	• Coated • Contaminated	• Plugged	Failures caused by external events or substances, e.g. paraffin, asphaltene, scale, sand, iron sulphide.
Material	• Burn • Corroded • Eroded/Pressure Washed	• Overheated • Worn	Usually related to the physical characteristics of the material, i.e. colour, hardness, finish, etc.
Mechanical	• Bent/Buckled • Broken/Fractured/Torn • Burst/Ruptured • Collapsed • Dented/Squashed • Disconnected • Faulty Clearance/Alignment	• Leaking • Loose/Spinning • Low Efficiency • Punctured • Stuck • Twisted • Vibration/Unbalanced	Usually the result of force, pressure or torque.
Other	• Missing	• Other/Damaged	
Unknown	• Unknown		

Table 3.3 Possible Failure Mechanisms

3.4 Failure Causes

As per the definition in Section 2, the *Failure Cause* is associated with the circumstances during design, manufacture or use, which have led to a failure. As noted in ISO 14224:2016, identification of the *Failure Cause* normally requires some in-depth investigation to uncover the underlying human or organizational factors as well as the technical cause.

Note that the approach recommended by the API RP 11S1 (1997)[3] will not be adopted in the ESP-RIFTS project, because it contradicts the definitions adopted (from ISO 14224:2016) (see Section 2).

[3] The API RP 11S1 (1997) suggests assigning some of the teardown observation codes (or failure mechanisms for the component parts) to a Primary Cause of Failure, Secondary Cause of Failure, and to Contributing Factors.

Failure Data Structure

Failure Cause: General	Failure Cause: Specific		Comments
• System Design/Selection	• Equipment Selection • Equipment Selection – Materials • Improper Data Used in Design/Selection	• Equipment Selection – Pressure Capacity • Equipment Selection – Volumetric Capacity • System Configuration	• Improper system design/selection, including use of improper data or errors in calculations • Inadequate pump flow or head capacity, motor power capacity, etc. • Improper equipment selection • Improper material selection
• Manufacturing	• Equipment Testing • Fabrication Problem	• Materials Selection • Quality Control • Mechanical Design	• Improper mechanical design of parts or components • Improper fabrication or assembly of parts or components • Improper equipment testing or quality control
• Storage and Transportation	• Packaging or Restraints • Storage	• Transportation	• Improper or inadequate equipment handling during storage or transportation
• Installation	• System Assembly • Well Cleanout • Installation – ESP Field Service	• Installation – Service Rig • Reran Damaged Equipment	• Improper procedures during installation or well preparation • Improper system assembly, including cable splices and flange connections
• Operation	• Enhanced Recovery Method or Production Strategy • Inadequate Monitoring	• Operating Procedure • Operation of Other Wells in Field • Well Treatment	• Improper operating procedures or inadequate monitoring • Field management practices
• Reservoir or Fluids	• Asphaltene • Bottomhole Temperature • Free gas • Sand • Reservoir Failure • Low or No Inflow	• Scale • Paraffin • Corrosive Fluids • Water Cut • High Inflow	• Unexpected reservoir conditions, leading to (1) plugging by scale, paraffin asphaltene, sand, etc. or (2) lower/higher productivity, higher GOR or water cut • Reservoir fracturing, subsidence, etc
• Completion	• Failure of Perforations/Liner/Openhole • Failure or Improper Sand Control System	• Wellbore Completion Failure • Non-ESP Downhole Failure	• Failure of the wellbore completion (e.g. casing, tubing, packer, safety valve, liner)
• Normal or Expected Wear and Tear	• Normal or Expected Wear and Tear		• Equipment run-life met or exceeded expectations
• Technology Limitation	• Technology Limitation		• Current ESP technology unable to operate reliably in a given operation
• Well Construction	• No Tangent Section		• The well was not designed/drilled for ESP application
• Facilities	• Poor Power Quality	• Surface Equipment Failure	• Failure of Surface Instrumentation or Control
• Other	• Natural Disaster • Power Disruption/Lightning	• Sabotage/Vandalism • Weather/Oceanographic	• Weather, war, terrorist attack, etc. • Failure of instrumentation or control
• Unknown	• Unknown		• Failure cause unknown

Table 3.4 Possible Failure Causes

4. DETERMINING WHEN A FAILURE OCCURS

As defined in Section 2, a *Failure* occurs when an item has lost its ability to perform a *Required Function*. Implicit in this definition is the recognition that the *Required Functions* have been clearly established, which involves identifying both the functions necessary for providing a given service and the desired level of performance for each function. The desired level of performance defines the boundary between satisfactory and unsatisfactory operating conditions and will generally be different between operations, applications and even within the same application as conditions change with time.

A Functional Block Diagram of the *ESP System* with its main components and corresponding *Required Functions* is shown in Figure 6.3. One of the primary *Required Functions* of an *ESP System* is to produce pressure and flow. Functions other than the ones shown in Figure 6.3 (e.g. gas compression) may also be considered "required" depending on the ESP configuration and application.

It is important that all of the *Required Functions* (and desired levels of performance) be clearly defined and understood in advance to allow operational personnel to identify *Failures.*

4.1 ESP System Failure

As defined in Section 2, an *ESP System* fails when it has lost its ability to perform a *Required Function*. In this case, a *Reason for Pull* is identified as the main evidence of the downhole equipment failure (see Section 3.1).

4.2 Condition of ESP Components and Parts

For the purpose of the ESP-RIFTS project, a "service life perspective" is used to describe the condition of ESP components and parts. Thus, ESP components and parts are considered "not reusable" when either the item fails while operating *or if the condition of the item is considered inadequate for reuse in the intended application in its current state.*

Therefore, items to be considered "not reusable" include:

- Items that have failed while in operation (i.e. have lost their ability to perform a required function).
- Items that have been subject to shop tests or teardown inspections and have failed to meet the required specifications.
- Items that require repair or are discarded and thus deemed unsuitable for reuse in their current state.

Determining When a Failure Occurs

- Items that have not failed while in operation, are not subjected to shop tests or teardown inspections, but are deemed not reusable. Such items may be simply discarded because they are considered as having achieved a "reasonable" run life or believed to have reduced *Reliability*.

Components or parts that have not failed while in operation and that are submitted to shop tests, pass the required specifications, and are deemed to be in appropriate condition for reuse are to be considered *Reusable*. This includes components and parts that only require minor regular servicing prior to reuse. Examples of "minor servicing" may include (but are not limited to):

- ESP Motor or ESP Seal Chamber Section oil changes;
- ESP Motor or ESP Seal Chamber Section flushing or drying; and
- ESP component cleaning or painting.

5. REFERENCES

API RP 11S1. 1997. Recommended Practice for Electrical Submersible Pump Teardown Report, Third Edition, American Petroleum Institute.

International Standards Organization (ISO) 14224. 2016. Petroleum and Natural Gas Industries – Collection and Exchange of Reliability and Maintenance Data for Equipment.

International Standards Organization (ISO) 15551-1. 2015. Petroleum and Natural Gas Industries - Drilling And Production Equipment - Part 1: Electric Submersible Pump Systems For Artificial Lift

Lea, J.F. and Powers, B. 1994. Electrical Submersible Pump Teardown Inspection, Parts 1-6, Petroleum Engineering International, April-September.

6. FIGURES

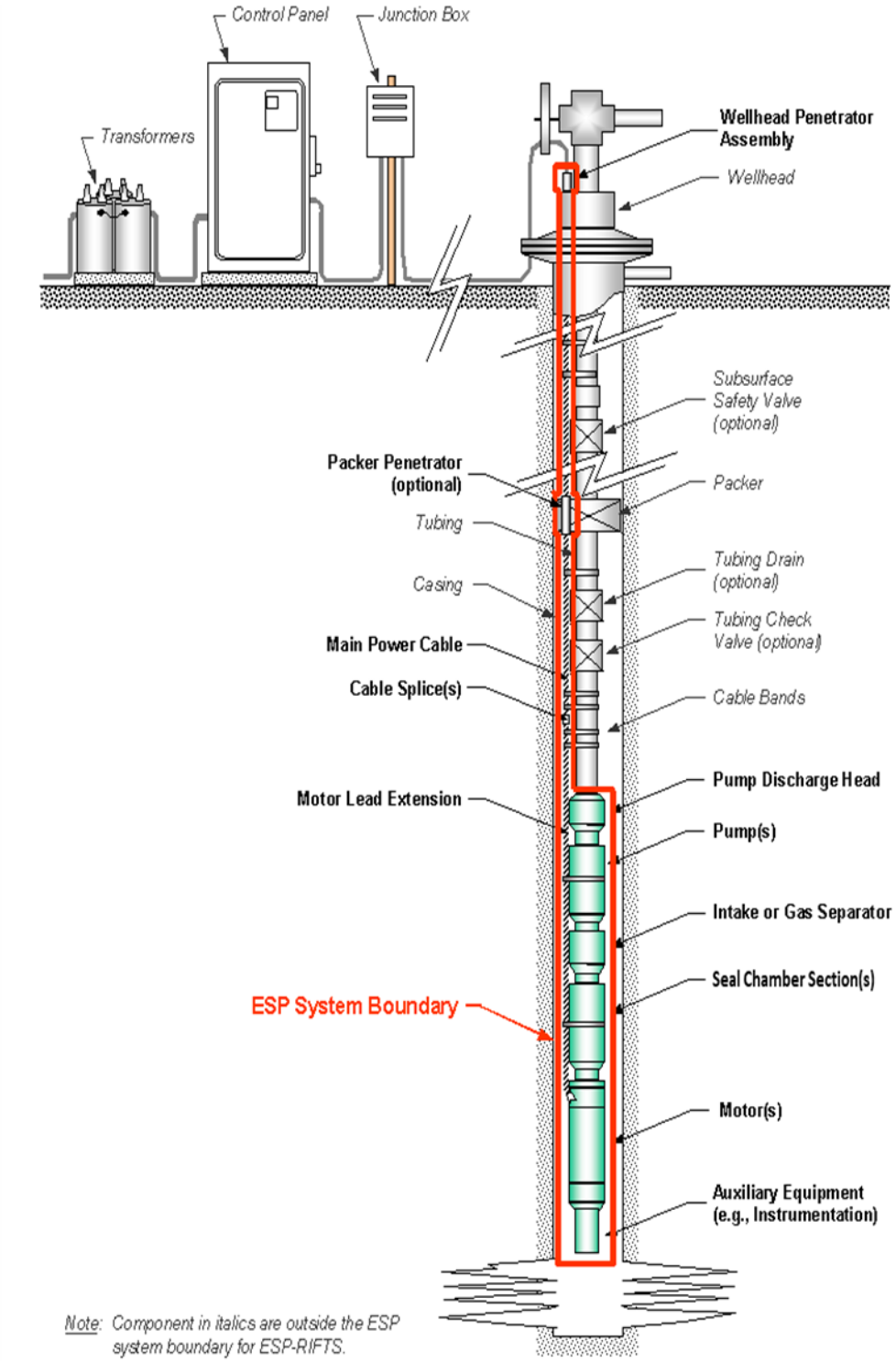


Figure 6.1 System Boundary for ESP-RIFTS

Figures

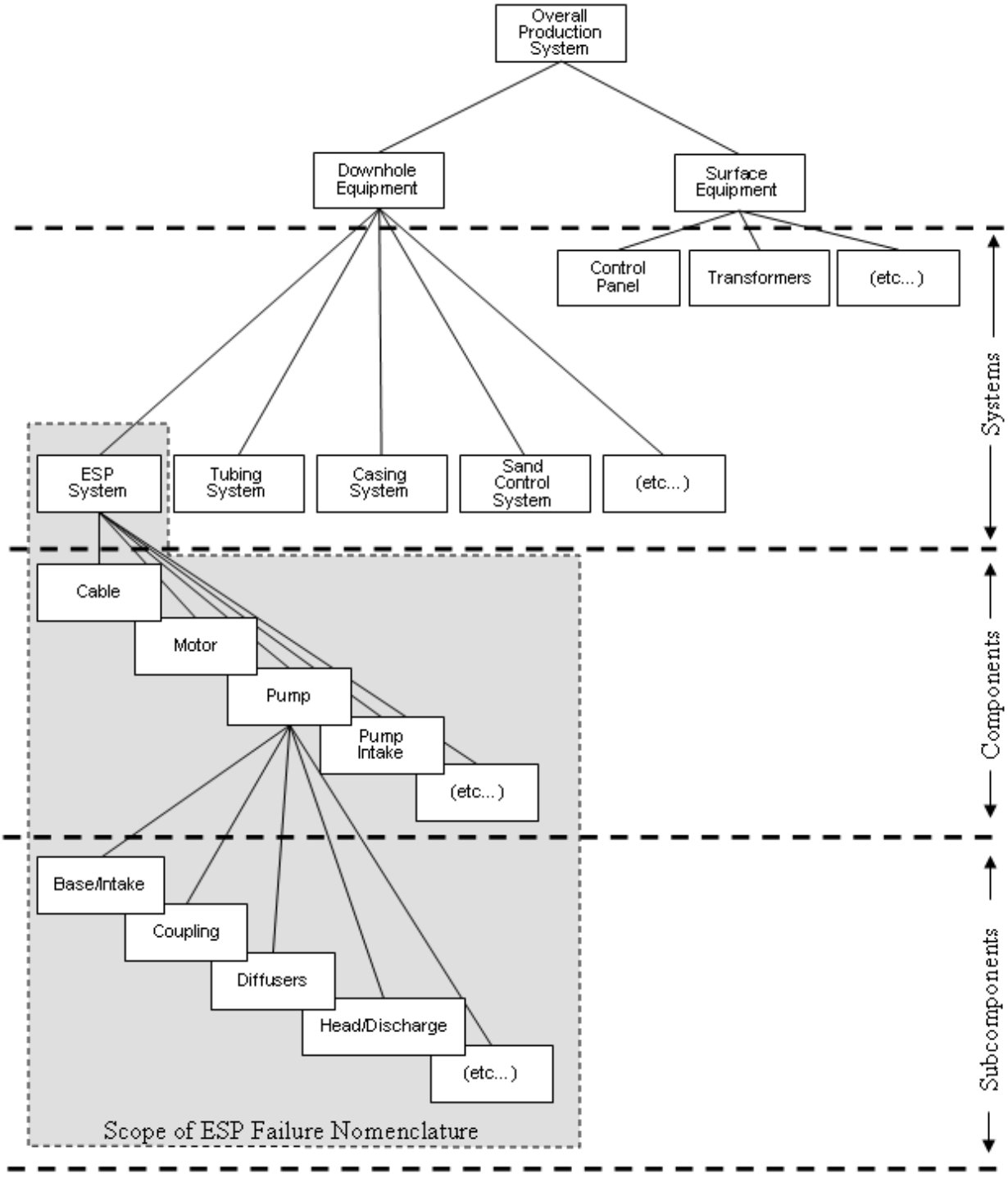


Figure 6.2 Equipment Hierarchy

Figures

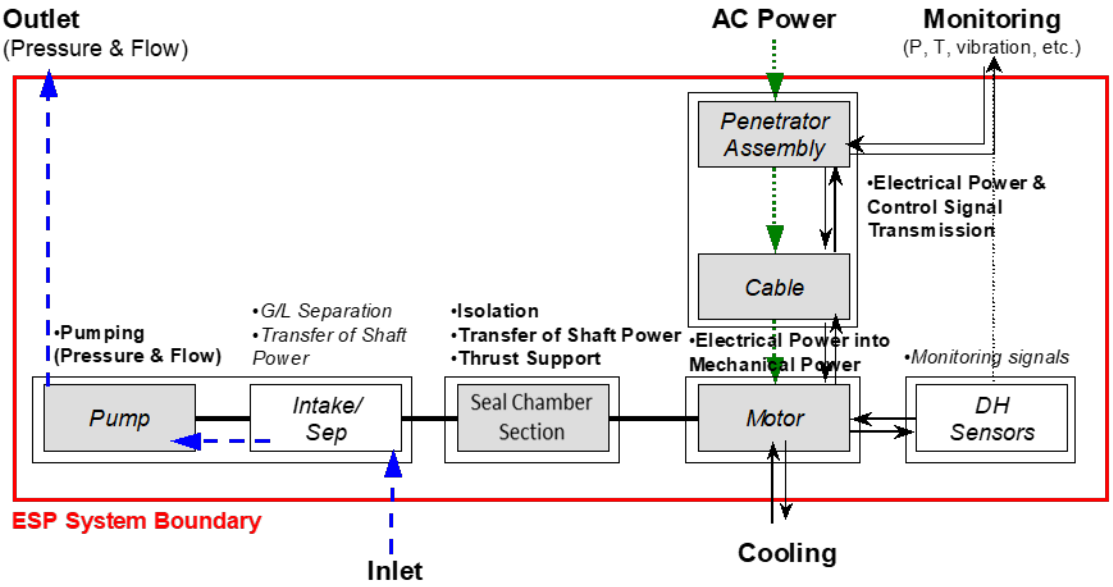


Figure 6.3 Functional Block Diagram

APPENDIX A - TYPICAL STEPS INVOLVED IN APPLYING THE STANDARD

This Appendix describes how to apply the ESP Failure Nomenclature Standard in determining the failure attributes used to store *ESP System Failure* information.

As noted in Section 1 of the Failure Nomenclature Standard, a failure tracking system should track *ESP Systems* that have failed, *ESP Systems* that are currently operating and *ESP Systems* that were stopped for reasons other than an *ESP System* failure. The flowcharts presented in Figures A.1 and A.2 illustrate how to record failure attributes for all of these conditions. The steps shown in the flowcharts are described in the following section.

Step 1: Setting the Initial Values of the Failure Attributes

A Production Period is initiated when an *ESP System* is installed. Before the system is started, there will be no information regarding failure attributes as the ESP will generally be in a functional state. Therefore, the failure attribute *ESP System Failed?* should be set to "No", while all other failure attributes should be blank.

Step 2: Determining Reason for Pull

Failure attributes should be determined whenever the *ESP System* appears to have failed or the *ESP System* is stopped for any other reasons. At this point, a decision may have been made to pull the ESP System from the well, and a *Reason for Pull* is generally available. The failure attributes, *Reason for Pull: General* and *Reason for Pull: Specific* should be assigned appropriate values from Table 3.1[4]

Step 3: Determining if the *ESP System* has Failed

3.1 ESP System appears to have failed

If the *ESP System* appears to have failed, the failure attribute *ESP System Failed?* should be tentatively set to "Yes". This failure attribute may be changed based on the results of a failure investigation (see Step 5).

[4] A failure does not necessarily result in pulling the ESP from the well or even stopping production; thus an *ESP System* can fail and still be operating. Nevertheless, if an *ESP System* failure is suspected, the suspected failure date must be recorded.

Until the ESP is pulled from the well and a failure investigation is conducted, the Primary Failed Item and Failure Cause will generally be unknown. The failure attributes Primary Failed Item, Failure Cause: General and Failure Cause: Specific should all be set to the value "Unknown". Continue onto Step 4 followed by path 5.1 of Step 5.

3.2 ESP System stopped for some other reason

If an ESP System is stopped for reasons other than a suspected *ESP System* failure, the failure attribute *ESP System Failed?* should be left as "No". Similarly, the failure attributes *Primary Failed Item, Failure Cause: General* and *Failure Cause: Specific* should all be <blank>. Continue onto Step 4 followed by path 5.2 of Step 5.

Step 4 Determining Component Conditions, *Failed Items* and *Failure Mechanisms*

In general, the *Failed Item(s)* and associated *Failure Mechanism(s)* will not be apparent until after the system has been pulled from the well. In many cases, the *Failed Items* and associated *Failure Mechanisms* may only be evident following further inspection and/or testing. Therefore, after the ESP System is stopped and until the ESP System is pulled from the well, these failure attributes (e.g. *Motor Pull Condition* and *Motor: Primary Failure Mechanism*) should be set to the value "Unknown".

Based on the observations from the pull and teardown inspections, the component conditions (e.g. *Motor Pull Condition*) should be set to "Reusable" or "Not Reusable" using the "service life perspective" described in Section 4 of the Failure Nomenclature Standard.

Also based on the observations from the pull and teardown inspections, the *Primary Failure Mechanism* and *Secondary Failure Mechanisms* of each *ESP System* component may be assigned values from the list of mechanisms shown in Table 3.3. The most severe or predominant mechanism should be assigned as the *Primary Failure Mechanism*. Note that a mechanism may be assigned even for a component that has been considered reusable (e.g. Pump worn but still with acceptable performance).

Step 5 Determining Primary Failure Item and Failure Cause

5.1 ESP System appears to have failed

Some level of investigation will generally be required to determine the *Primary Failed Item* and the *Failure Cause* (as well as the remedial action necessary to prevent failures of that type from occurring in the future). Until a failure investigation has been conducted, the failure attributes *Primary Failed Item, Failure Cause: General* and *Failure Cause: Specific* should all be left as "Unknown".

If the *ESP System* was stopped because of a suspected *ESP System* failure, the failure attribute *ESP System Failed?* was tentatively set to "Yes" in Step 4. However, if the investigation finds the *ESP System* was in fact performing its *Required Functions*[5], then *ESP System Failed?* must be reset to "No". Furthermore, the failure attributes *Primary Failed Item* and *Failure Cause* will have to be reset. The *Primary Failed Item* may be reset to either "Non ESP System Failure" or <blank> and the *Failure Cause* may be reset to <blank>. If the *Primary Failed Item* was reset to "Non ESP System Failure", the *Primary Failure Mechanism* and *Secondary Failure Mechanism* may be assigned values that describe the condition of the Non-ESP System component which failed. For example, the *ESP System* may appear failed and be pulled because there is low production to surface. However, if a hole in the production tubing is found to be the reason for the low production and if the *ESP System* is found in good operating condition, then the *ESP System* did not fail.

Nevertheless, if a non-ESP item failure (e.g. sand control failure) results in an *ESP System* failure, then the field "ESP System Failed?" should be left as "Yes". Furthermore, in this case, the *Primary Failed Item* must be an *ESP System* component.

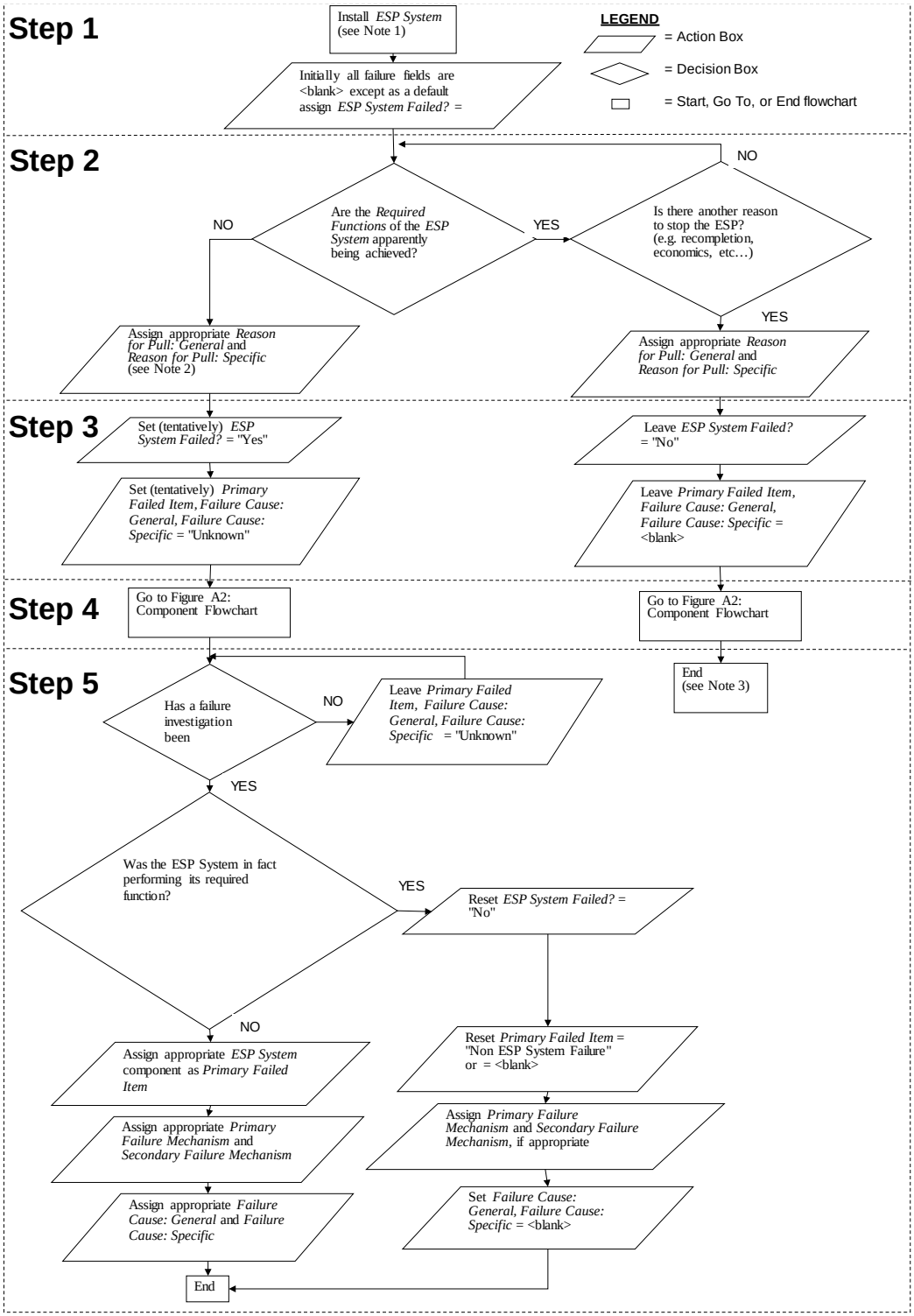
Generally, once a failure investigation is conducted, the *Primary Failed Item* can be determined based on Section 3.2.1 of the Failure Nomenclature Standard, with its associated *Primary Failure Mechanism* and *Secondary Failure Mechanism*. The failure attributes *Failure Cause: General* and *Failure Cause: Specific* should be assigned appropriate values from Table 3.4.

5.2 ESP System stopped for some other reason

If the ESP was stopped for a reason other than a suspected *ESP System Failure,* there will generally be no failure investigation and no *Primary Failed Item* or *Failure Cause.* Thus, the failure attributes *Primary Failed Item*, *Failure Cause: General* and *Failure Cause: Specific* should all be left as <blank>.

[5] The abnormal operating condition was in fact a result of a non-ESP System failure (e.g. tubing leak)

Appendix A - Typical Steps Involved in Applying the Standard

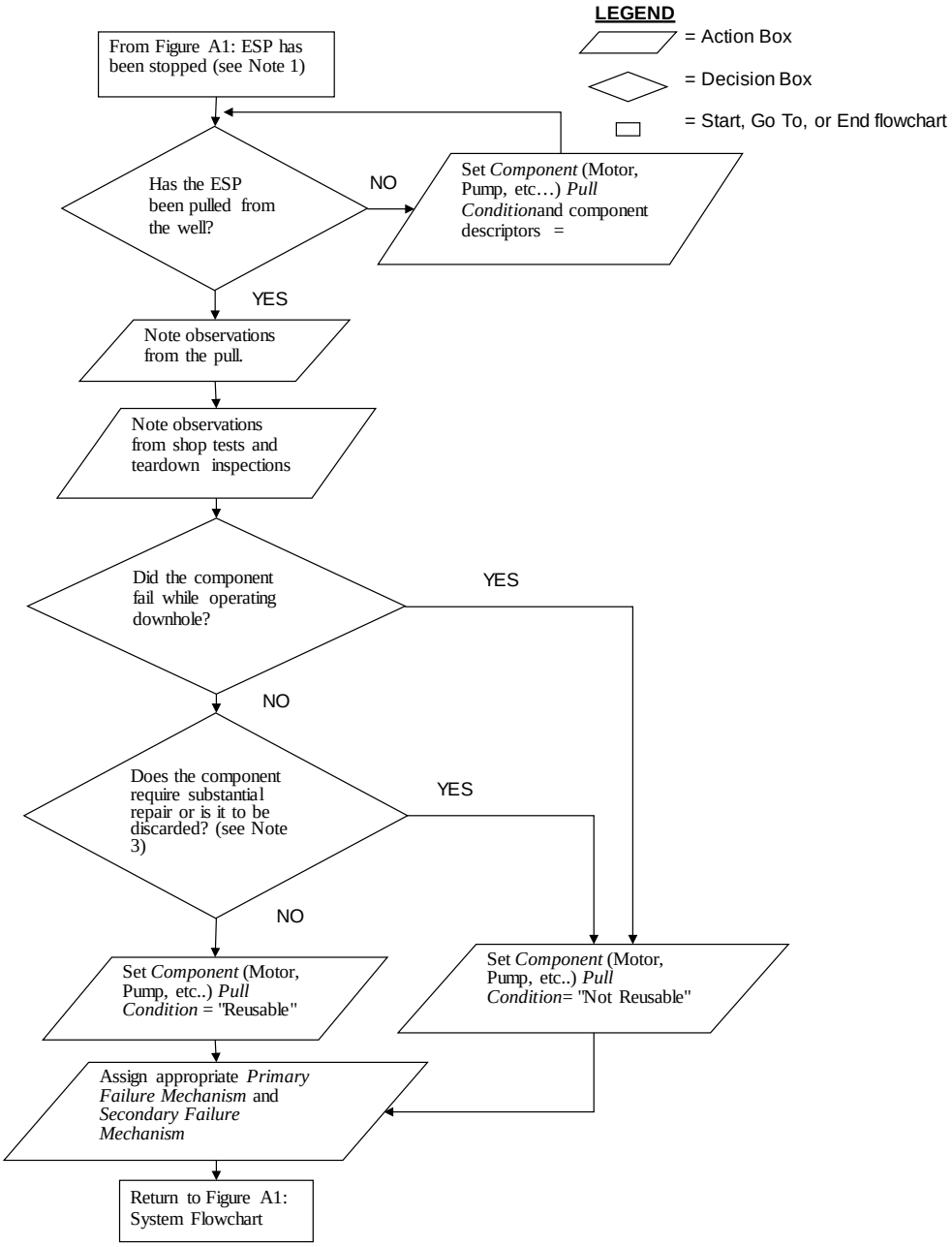


Notes: 1. Assign *Period Status* = "Still on Production" when the *ESP System* is started
2. *Reason for Pull* is usually the main evidence of downhole failure, as detected by monitoring systems or well tests
3. If the ESP was pulled for reasons other than an *ESP System Failure* then a failure investigation will probably not be conducted

Figure A.1 Steps in Applying Failure Nomenclature: System Flowchart

Appendix A - Typical Steps Involved in Applying the Standard

Step 4



Notes: 1. If the ESP has been stopped, assign *Period Status* = "Period Completed"
2. Generally, *Failed Items* and *Failure Mechanisms* will not be determined until the *ESP System* has been pulled from the well.
3. Minor service (e.g. cleaning, flushing) may still be requried before a component can be actually reused

Figure A.2 Steps in Applying Failure Nomenclature: Component Flowchart

APPENDIX B - EXAMPLES OF APPLYING THE STANDARD

This Appendix contains examples of how the ESP Failure Nomenclature should be applied.[6]

- Example 1: Failure of a non-ESP component (surface valve)
- Example 2: Human Error
- Example 3: Failure of a non-ESP downhole component (slotted liner)
- Example 4: ESP components are discarded without test or inspection
- Example 5: Improper ESP design
- Example 6: Unscheduled preventative maintenance: downhole monitoring shows onset of failure (potential failure)
- Example 7: Difficult application: Numerous application related problems
- Example 8: A non-ESP item failure resulted in the ESP System appearing to have failed

[6] Only "difficult" situations were included, in most cases, application of the Standard should be relatively straightforward.

Appendix B - Examples of Applying the Standard

Example 1

Type of Failure:	Failure of a non-ESP component (surface valve)

Production Report:	Well down on short to ground. Wellhead flowline valve plugged with paraffin. ESP must be pulled.
Pull Report:	Motor burnt. Some paraffin in production tubing near surface. Other components appear to be OK but will be sent to pump shop for inspection. Cable low resistance phase to ground and armour damaged at collar.
Teardown / Inspection Report:	Motor stator housing burnt. Motor stator shorted to ground. Pump stages showing downthrust wear.
Failure Investigation:	The plugged flowline valve caused the motor to short circuit. Improper paraffin monitoring and control. Recommend better monitoring for paraffin accumulation and evaluation of chemical treatment program.

System	**Period Status:**	Period completed
	Reason for Pull General:	Electrical
	Reason for Pull Specific:	Short Circuit
	ESP System Failed?:	Yes
	Primary Failed Item:	ESP Motor - Stator
	Primary Failure Mechanism:	Short circuit
	Secondary Failure Mechanism:	Burn
	Primary Contaiminant	
	Failure Cause General:	Operation
	Failure Cause Specific:	Inadequate Monitoring
Components	**Motor Pull Condition**	Not Reusable
	Motor: Primary Failure Mechanism:	Short circuit
	Seal Chamber Section Pull Condition	Reusable
	Seal Chamber Section: Primary Failure Mechanism:	
	Intake Pull Conditoin	Reusable
	Intake: Primary Failure Mechanism:	
	Pump Pull Condition	Not Reusable
	Pump: Primary Failure Mechanism:	Worn
	Cable Pull Condition	Not Reusable
	Cable: Primary Failure Mechanism:	Low Impedence / Resistance

Notes:

1. The wellhead flowline valve should not be identified as the "Primary Failed Item". As defined in the Failure Nomenclature Standard, when the *ESP System* has failed, the "Primary Failed Item" should be an ESP component.

2. The reservoir (and paraffin) should not be identified as the "Failure Cause General" (and "Failure Cause Specific") because the failure investigation concluded inadequate monitoring caused the failure. Furthermore, the *Failure Cause* should preferably be identified as something that can be corrected; the existence of paraffin in the reservoir can not be changed only managed.

Appendix B - Examples of Applying the Standard

Example 2

Type of Failure:	Human error

Production Report:	New operator in field closed flowline valve during first production test on well after workover. Well went down. Short phase-to-ground. High current levels not reset for well when new ESP installed.
Pull Report:	Motor burnt and shorted phase-to-ground. Other components appear to be OK but will be sent to pump shop for inspection.
Teardown / Inspection Report:	Motor stator housing burnt. Motor stator shorted to one phase-to-ground. Pump stages showing downthrust wear.
Failure Investigation:	Improper training and mentoring of junior operators. Revise training program for new operators to include closer supervision and training. Revise operating/installation procedures to verify current limits before start new ESP.

System	**Period Status:**	Period completed
	Reason for Pull General:	Electrical
	Reason for Pull Specific:	Short Circuit
	ESP System Failed?:	Yes
	Primary Failed Item:	ESP Motor - Stator
	Primary Failure Mechanism:	Short circuit
	Secondary Failure Mechanism:	Burn
	Primary Contaiminant	
	Failure Cause General:	Operation
	Failure Cause Specific:	Operating Procedure
Components	**Motor Pull Condition**	Not Reusable
	Motor: Primary Failure Mechanism:	Short circuit
	Seal Chamber Section Pull Condition	Reusable
	Seal Chamber Section: Primary Failure Mechanism:	
	Intake Pull Conditoin	Reusable
	Intake: Primary Failure Mechanism:	
	Pump Pull Condition	Not Reusable
	Pump: Primary Failure Mechanism:	Worn
	Cable Pull Condition	Reusable
	Cable: Primary Failure Mechanism:	

Appendix B - Examples of Applying the Standard

Example 3

Type of Failure:	Failure of a non-ESP downhole component (slotted liner)

Production Report:	Rapid drop in production rates and sudden increase in sand production in well with slotted liner. Before can schedule pull, well goes down on overload. Restarts fail - pump appears to be stuck. Try "rocking" ESP with increasing kicks to try to free pump but results in downhole short after several attempts.
Pull Report:	Motor burnt. Top seal chamber section contaminated but bottom seal chamber section OK. Pump and tubing above pump plugged with sand.
Teardown / Inspection Report:	Motor stator housing burnt. Pump plugged with sand. Upper stages showing severe wear.
Failure Investigation:	Large volumes of sand found in wellbore. Discovered slotted liner failed. Recommend evaluate liner design and completion practices.

System	**Period Status:**	Period completed
	Reason for Pull General:	Electrical
	Reason for Pull Specific:	Short Circuit
	ESP System Failed?:	Yes
	Primary Failed Item:	ESP Pump - Unknown Subcomponent
	Primary Failure Mechanism:	Plugged
	Secondary Failure Mechanism:	Worn
	Primary Contaiminant	Sand
	Failure Cause General:	Completion
	Failure Cause Specific:	Failure or improper sand control system
Components	**Motor Pull Condition**	Not Reusable
	Motor: Primary Failure Mechanism:	Short circuit
Top Seal Chamber Section	**Seal Chamber Section Pull Condition**	Not Reusable
	Seal Chamber Section: Primary Failure Mechanism:	Contaminated
Bottom Seal Chamber Section	**Seal Chamber Section Pull Condition**	Reusable
	Seal Chamber Section: Primary Failure Mechanism:	
	Intake Pull Condition	Reusable
	Intake: Primary Failure Mechanism:	
	Pump Pull Condition	Not Reusable
	Pump: Primary Failure Mechanism:	Plugged
	Cable Pull Condition	Reusable
	Cable: Primary Failure Mechanism:	

Appendix B - Examples of Applying the Standard

Example 4

Type of Failure:	ESP components are discarded without test or inspection

Production Report:	Well productivity (fluid level) declining below lower limit of pump range. ESP ran for over two years. Pull ESP to resize system. New ESP ready to be installed.
Pull Report:	All components appear to be OK. Sent to shop.
Teardown / Inspection Report:	Pump, motor and intake OK and will be flushed and stocked. Seal chamber sections and cable to be discarded at customer's request.
Failure Investigation:	Inadequate water injection program or pressure support from nearby injectors.

System	**Period Status:**	Period completed
	Reason for Pull General:	Recompletion
	Reason for Pull Specific:	Change Artificial Lift Method / Resize ESP System
	ESP System Failed?:	No
	Primary Failed Item:	
	Primary Failure Mechanism:	
	Secondary Failure Mechanism:	
	Primary Contaiminant	
	Failure Cause General:	
	Failure Cause Specific:	
Components	**Motor Pull Condition**	Reusable
	Motor: Primary Failure Mechanism:	
	Seal Chamber Section Pull Condition	Not Reusable
	Seal Chamber Seciton: Primary Failure Mechanism:	
	Intake Pull Conditoin	Reusable
	Intake: Primary Failure Mechanism:	
	Pump Pull Condition	Reusable
	Pump: Primary Failure Mechanism:	
	Cable Pull Condition	Not Reusable
	Cable: Primary Failure Mechanism:	

Notes: **1.** A change in reservoir productivity is the main reason the pump is operating out of range; however, because the *ESP System* did not fail there should be no Primary Failed Item or *Failure Cause.*

Example 5

Type of Failure:	Improper ESP design

Production Report:	New ESP installation not achieving desired fluid rates. Design did not properly take into account all flow losses in selection of required pump head. Must pull ESP and install pump with more lift and motor with additional horsepower capacity.
Pull Report:	All components appear to be OK. Sent to shop for inspection.
Teardown / Inspection Report:	Tested all components. All OK. Will be put into customer stock for reuse in another application.
Failure Investigation:	Recommend ESP design team to cross-check design parameters and review vendor design.

System	**Period Status:**	Period completed
	Reason for Pull General:	Flow
	Reason for Pull Specific:	Low Flow to Surface
	ESP System Failed?:	Yes
	Primary Failed Item:	ESP Pump - Unknown Subcomponent
	Primary Failure Mechanism:	Other
	Secondary Failure Mechanism:	
	Primary Contaiminant	
	Failure Cause General:	System Design / Selection
	Failure Cause Specific:	Equipment selection - pressure capacity
Components	**Motor Pull Condition**	Reusable
	Motor: Primary Failure Mechanism:	
	Seal Chamber Section Pull Condition	Reusable
	Seal Chamber Section: Primary Failure Mechanism:	
	Intake Pull Conditoin	Reusable
	Intake: Primary Failure Mechanism:	
	Pump Pull Condition	Reusable
	Pump: Primary Failure Mechanism:	
	Cable Pull Condition	Reusable
	Cable: Primary Failure Mechanism:	

Notes: **1.** According to the operator, the ESP had to be pulled because it was not performing a required function (i.e. not producing the desired or designed head); thus the *ESP System* failed.

Example 6

Type of Failure:	Unscheduled preventative maintenance: Downhole monitoring shows onset of failure (potential failure)

Production Report:	Downhole monitoring system shows high vibration (over upper limit specified by engineering). Schedule rig to avoid catastrophic failure and avoid production loses.
Pull Report:	Pulled ESP. All components appear to be OK. Some vibration marks on motor housing.
Teardown / Inspection Report:	Motor housing bent. Wear in bearings. Fails imbalance and vibration criteria.
Failure Investigation:	Ran ESP through high dogleg. Redesign ESP to prevent damage as run through dogleg or land higher in well.

System	**Period Status:**	Period completed
	Reason for Pull General:	Downhole Instrumentation Measured/Detected
	Reason for Pull Specific:	High Vibration
	ESP System Failed?:	Yes
	Primary Failed Item:	ESP Motor - Housing
	Primary Failure Mechanism:	Bent/Buckled
	Secondary Failure Mechanism:	Vibration/Unbalanced
	Primary Contaiminant	
	Failure Cause General:	System Design / Selection
	Failure Cause Specific:	System configuration
Components	**Motor Pull Condition**	Not Reusable
	Motor: Primary Failure Mechanism:	Bent/Buckled
	Seal Chamber Section Pull Condition	Reusable
	Seal Chamber Section: Primary Failure Mechanism:	
	Intake Pull Conditoin	Reusable
	Intake: Primary Failure Mechanism:	
	Pump Pull Condition	Reusable
	Pump: Primary Failure Mechanism:	
	Cable Pull Condition	Reusable
	Cable: Primary Failure Mechanism:	

Notes:

1. Unscheduled maintenance of an *ESP System* should be considered a failure
2. Operating with vibration within specified limits was considered a *Required Function* in this example. If operating with vibration within a specified limit was not considered a *Required Function* then ESP System may not be considered failed.

Example 7

Type of Failure:	Difficult application: Numerous application related problems

Production Report:	ESP down on short circuit. Motor and cable were used when installed. CO2 WAG EOR field. Amp chart showed some surging prior to system going down. High GOR. Asphaltene treatment program in field.
Pull Report:	Seal chamber section and motor oil wet and contaminated with wellbore fluid. Rotary gas separator and pump appear to be OK. Cable shorted at pothead. Some asphaltenes in tubing, pump and intake and some external corrosion (pitting) throughout.
Teardown / Inspection Report:	Evidence of some gas impregnation and decompression blistering in cable. Seal chamber section and motor wet - flushed and tested OK. External CO2 corrosion throughout. Pump and intake to reuse.
Failure Investigation:	CO2 slugs causing significant fluid level and current surging, cycling seal and stressing cable. Recommend closer assessment of EOR program and monitoring/control of susceptible wells.

System	**Period Status:**	Period completed
	Reason for Pull General:	Electrical
	Reason for Pull Specific:	Short Circuit
	ESP System Failed?:	Yes
	Primary Failed Item:	ESP Cable - Pothead Connector
	Primary Failure Mechanism:	Short circuit
	Secondary Failure Mechanism:	Contaminated
	Primary Contaiminant	
	Failure Cause General:	Operation
	Failure Cause Specific:	Inadequate Monitoring
Components	**Motor Pull Condition**	Reusable
	Motor: Primary Failure Mechanism:	Contaminated
	Seal Chamber Section Pull Condition	Reusable
	Seal Chamber Section: Primary Failure Mechanism:	Contaminated
	Intake Pull Conditoin	Reusable
	Intake: Primary Failure Mechanism:	Corroded
	Pump Pull Condition	Reusable
	Pump: Primary Failure Mechanism:	Corroded
	Cable Pull Condition	Not Reusable
	Cable: Primary Failure Mechanism:	Short circuit

Notes:

1. Difficult application (System Design/Selection) was not identified as the *Failure Cause* because the failure investigation identified that monitoring of the EOR program was at fault and that it could be improved. *Failure Cause* should preferably be identified as something that can be corrected.
2. Difficult application is intended for systems operating close to the limits of technology (taking into account economics)
3. Because the motor tested OK, the contamination of the seal chamber section and motor may have occurred after the system was stopped. The motor and Seal Chamber Section are considered reusable because they likely did not fail while operating and they are "reusable-as-is" (after flushing).

Example 8

Type of Failure:	A non-ESP item failure resulted in the ESP System appearing to have failed

Production Report:	No flow to surface - can't pressure up tubing.
Pull Report:	Unit pulled. Two holes in production tubing found; one above packer and one below packer; evidence of pressure wash. ESP sent to shop for teardown inspection.
Teardown / Inspection Report:	Couplings were seized on pump intake and shaft pulled out during dismantle. Entire unit turns free. Some lateral play in head end of pump. No excess bushing wear noticed on any other piece of equipment. Top protector appeared contaminated, lower protector top section gasified. Clean oil in bottom chamber. Motors checked O.K. electrically. Clean oil throughout with some bronze filings noticeable.
Failure Investigation:	Erosion/pressure wash caused hole in tubing. High rate unconsolidated sandstone reservoir. No sand control.

System	**Period Status:**	Period completed
	Reason for Pull General:	Flow
	Reason for Pull Specific:	No Flow to Surface
	ESP System Failed?:	No
	Primary Failed Item:	
	Primary Failure Mechanism:	
	Secondary Failure Mechanism:	
	Primary Contaiminant	
	Failure Cause General:	
	Failure Cause Specific:	

Components	**Motor Pull Condition**	Reusable
	Motor: Primary Failure Mechanism:	Contaminated
Top Seal Chamber Section	**Seal Chamber Section Pull Condition**	Not Reusable
	Seal Chamber Section: Primary Failure Mechanism:	Contaminated
Bottom Seal Chamber Section	**Seal Chamber Section Pull Condition**	Reusable
	Seal Chamber Section: Primary Failure Mechanism:	
	Intake Pull Condition	Reusable
	Intake: Primary Failure Mechanism:	
	Pump Pull Condition	Reusable
	Pump: Primary Failure Mechanism:	
	Cable Failed?	Reusable
	Cable: Primary Failure Mechanism:	

Notes: **1.** Primary Failed Item, Failure Mechanisms and Failure Cause should only be filled-in for ESP System failures only.