ROOT CAUSE FAILURE ANALYSIS AND SOLUTIONS

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In the fall of2000 a team was formed to capitlize on the experience and knowledge of each and to continue work previously done by Bobby 'Turner (Pool Company). This paper is only an excerpt of the work completed by the team.

HOW WILL THIS ADD VALUE TO YOUR OPERATIONS?

The high cost of downhole equipment, combined with tlie additional requirement to pull the rods. pump and tubing place a high priority on reducing these failures. A thorough understanding of equipment failures. including both their root cause and potential solutions. will and should provide immediate financial benefits to your organization.

Downhole equipment that is properly designed - base upon experience. physically handled and made-up in accordance with the recorninendation of tlie manufacturer, and operated within acceptable design parameters with an effective downhole corrosion control program should give a long. satisfactory, and economical service life.

WHY DISCUSS ROOT CAUSE FAILURE ANALYSIS AND SOLUTIONS?

"Survey results by the attendees at the Permian Basin Artificial Lift Forum (2000) indicated the top interest and concern was for additional discussion on this topic (see Figure A)
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- **A.** Overview
- **B.** Root Cause Failure Analysis Flowchart
- **C.** Pump Failures
- **D.** Make Up Flowchart & Presentation
- **E.** Rod Failures
- **F.** Tubing Failures
- **G.** Corrosion Flowchart & Presentation

A. OVERVIEW

I. **Failure Analysis:** Would you consider that, Wear (Fatigue) arid Corrosion are not Causes of Failures". but rather mechanisms of the root cause'?

Mechanisin:
A process by which some result is produced

2. Would you consider that, Makeup is a "Process" and not an event'?

Makeup Process:
- Lubrication
- Handling
- Torque on equipment

3. **Root Cause** - what's the definition?
Root: The source. origin or cause of an action or condition
Cause:

- Anything producing an effect or result.
- The agent that brings about an effect or result.
- A reason, motive or ground for some action

FAILURE to an Oilfield mechanical system is like "Death and Taxes" to us humanoids!

It's going to happen …someday! Do you plan for death. taxes?

4. Major Failure Modes (see Table 1)

- Design
- Operation
- Handling
- Makeup
- Manufacturing Defect

B. RCFA IDENTIFICATION FLOWCHART (BEAMS)
(see Figures B-K)

The Root Cause Failure Analysis Flowchart is divided into 3 areas of process determination. The first area identifies the problem component. The second area engages in questions to examine the failing component. which concludes to an answer indicating the primary cause or group (failure mode) to which the problem can be applied.

C. PUMP FAILURES
(see Figures L, M)

D. ROD MAKEUP PROCESS
[SEE FIGURE N)
General Guidelines

1. Start - The rod makeup process begins w/ tubing landed. wellhead nippled up, all rods out of the well. and any additional equipment safely delivered to location.

2. Verify Size & Grade of Rod – Never assume that the equipment in the well matches the well data sheet and never assume equipment delivered to location matches rod design.

3. Picking Up Rods? – Typically "New" rods in bundles. Use prudent handling procedures

4. Unscrew Thread Protectors - Knocking off the thread protectors will leave plastic remnants on the rod threads that will damage the threads during makeup.

5. Tail Rods In To Floor – Prevent metal-metal contact dragging rods across the bundle and prevent rods from dragging in the dirt and contaminating the threads.

6. Clean & Inspect Pins & Boxes – "New" rod pins are coated w/ corrosion inhibitor from the manufacturer; not thread lubricant. The pins of the rods in the derrick often have been contaminated by wellbore fluid. unknown lubrication type. and even blowing sand.

7. Apply Lube Strip Across Threads – The threads require only moderate lubrication. The rod shoulder and box face contact requires friction to maintain proper makeup. Lubrication in the friction contact area will increase likelihood of pin failure.

8. Displacement Card Match – User must match all four (4) characteristics of the rod (sire, grade. condition, and manufacturer) to the appropriate displacement cards to ensure accurate displacement calibration.

9. Stabilize Hydraulic Oil Temperature – "Run In" the tongs until the oil temperature has reached operating temperature. Variations in oil temperature (effective pump pressure) will cause the tongs to drift out of calibration.

10. 1" Rod Of String – Begin calibration

11. Approximate Oil Pressure -- Setting the hydraulic oil pressure is an iterative process that begins with an educated first guess. Most operators are familiar with the makeup process and their equipment and can closely approximate the correct setting.

12. Make Connection Hand Tight – Hand tight by hands: not. hand tight by hands using wrenches. If the rod will not screw on by hand there is already thread damage.

13. Place Mark Across Connection – The single line represents the first point of a distance of travel. This line represents zero displacement.

14. Unscrew Rod +/-Four Rounds – Backing off the rod allows the tongs time reach full speed and thus ensure the momentum force component of makeup is comparable to normal operating condition of the tongs.

15. Makeup Rod w/ Tongs – Use the esact same methodology as will be used on all other connections.

16. Maintain Constant Engine RPM – Reach and maintain a constant engine RPM within the system to eliminate variable from an already complex hydraulic/mechanical system and eliminate any mechanical hysterises effect.

17. Stall Tongs @ Engine RPM - The tongs must be fully engaged until the rod connection comes to a complete stop: meanwhile, the engine rpm must remain constant for the duration of the makeup. Always fully complete this step before moving to the next step.

18. Measure Mark Displacement -- Use the appropriate displacement card to compare the actual displacement versus the desired displacement of the card.

19. Displacement Correct? -- Displacement cards typically represent the minimum required displacement. Therefore, the actual measured value should meet/slightly exceed the desired displacement of the card. This is a "yes/no" question. The "Close Enough" response is not contained within this process.

20. Rod Wrench to Properly Displace – Using wrenches to complete the connection prevents the need to flip over the tong heads and is usually the fastest method to proceed. Removing the tong heads and flipping them (twice) may also introduce a variable into the system we a trying to calibrate.

21. Adjust Pressure Control -- A step in the iterative process. Match the step size to the error size

22. Move To Next Rod – Congratulations you have one (1) correctly displaced rod in the well

23. Tong MI Checked? – Mechanical integrity refers to performance repeatability of the rod tongs. Even a broken watch is correct twice a day. To validate the mechanical integrity of the tongs. repeat the calibration several times (usually 3-5) to ensure the makeup is consistent.

24. 1st Rod Of Row? – The makeup of the tongs should be checked at the beginning of every row to prevent the tongs from drifting out of calibration. Early detection of any problems mitigates the impact.

25. 1" Rod Of Taper? – Of coarse, each taper change requires a change of the required displacement and associated change in pressure setting. The entire calibration process (excluding the MI check) must be completed for the new system setting.

26. Start First Thread By Hand – Prevents damage to first thread that may be caused when the threads engage while under hydraulic power. Starting thread damage will propagate throughout the threads and may also lead to cross-threads.

27 Makeup Rod w/ Tongs --Apply the makeup methodology used during the calibration phase but without the displacement measurement to move throughout the remainder of the rod string.

28. Maintain Constant Engine RPM -- Exact methodology as in the calibration step

29. Stall Tongs @ Engine RPM - Exact methodology as in tlie calibration step.

30. Move To Next Rod -- Now progressing through the string.

31. Last Rod? -- Follow the process for tlie entire rod string.

32. End -- The rod string is installed up to the polish rod.

E. ROD FAILURES

All failures in tlie rod string are either a tensile failure or a fatigue failure. Tensile failures are characterized by a reduction in tlie cross-sectional area at tlie point ofrupture, or final shear tear.

Fatigue failures originate as small, progressive stress cracks that grow with the action of fluctuating. or cyclic. stresses to rupture. or tinal shear tear

The time to failure is influenced by many variables. of which the chemistry. maximum stress. operating conditions. stress range. type and orientation of discontinuity, and the type of heat treatment are tlie most important

Stress raisers are introduced into the rod string through:
- Design / Operating Conditions.
- Handling / Makeup Procedures.
- Manufacturing Defects.

F METHODOLOGY OF EVALUATING TUBING FAILURES

Recommended Plan Of Action

- Identify **A** Tubing Failure Has Occurred
- Identify The Location And 'Type Of Failure
- Perform Visual Examination Of Failure
- Consult With Company Representatives and Mgmt
- Consult With Industry Technical "Experts"
    - Vendor / Supply Company
    - Provide General And/Or 'l'eclinical Expertise
    - Chemical Company
    - Provide Corrosion And Treating Expertise
    - Tubular Inspection Company
    - Perform Examination Of The Entire Tubing String
    - Metallurgical Laboratory
    - Perform Examination Of Failure

Most Common Mistakes In Use Of Tubing
- Use of Non-Standard Equipment (Non-API)
- Modification Of Equipment Beyond Its Design Parameters
- Turned Down Couplings
- Using Tubing With An API Connection Where Premium Connection Strength Is Required
- Use of High Hardness Tubing In A Sour Environment
- Potential Sultide Stress Cracking From Hydrogen Embrittlement
- Using Internally Coated Tubing As A Workstring

G. CORROSION FAILURE

(see Figures O-Q)

Direct Causes of Corrosion

Specific Corrodants

- CO_2 (Carbon Dioxide)
- H_2S (Hydrogen Sulfide)
- O_2 (Oxygen)

Oilfield Corrosion Conditions

- sweet ——any amount of CO_2, 5 ppm or less H_2S in fresh sample of water
- sour ——any amount of CO_2; 10 ppm or more H_2S in fresh sample of water
- oxygen influenced ——any amount of CO_2/H_2S, 50 ppb or more oxygen in water

Corrosivity of oil/gas field water is related to how much $H_2S + CO_2 + O_2$ is present
The more of any one or the combination, the more the corrosivity

Table 1

Failure Modes				
Design	**Operating Conditions/Practices**	**Handling**	**Makeup**	**Manufacturing**
Coating Disbonded	Abrasion/Fluid Cut	Bent	Contamination	Coating Disbonded
Corrosion	Bridge in Casing	Improper handling	Hammer Mark	Defective
Electrical	Corrosion	Nicks/Dents	Improper Tools	Metallurgy
End of Life	Crooked Hole	Threads Stripped	Loose Collars	Material
Fatigue	Erosion		Lubrication	
Gas Interference	Gyp Scale		Overtorque	
Improper Application	Material in Pump		Slip Marks	
Lightning	Mud		Thread Sealant	
Material in Pump	Paraffin		Undertorque	
Metallurgy	Pounding		Unscrewed	
Overload	Pump Discharge		Wrench Mark	
Pump Discharge	Sand			
Wear	Tagging			
	Trash			
	Wear			

Topics Most Want to Hear Case Studies

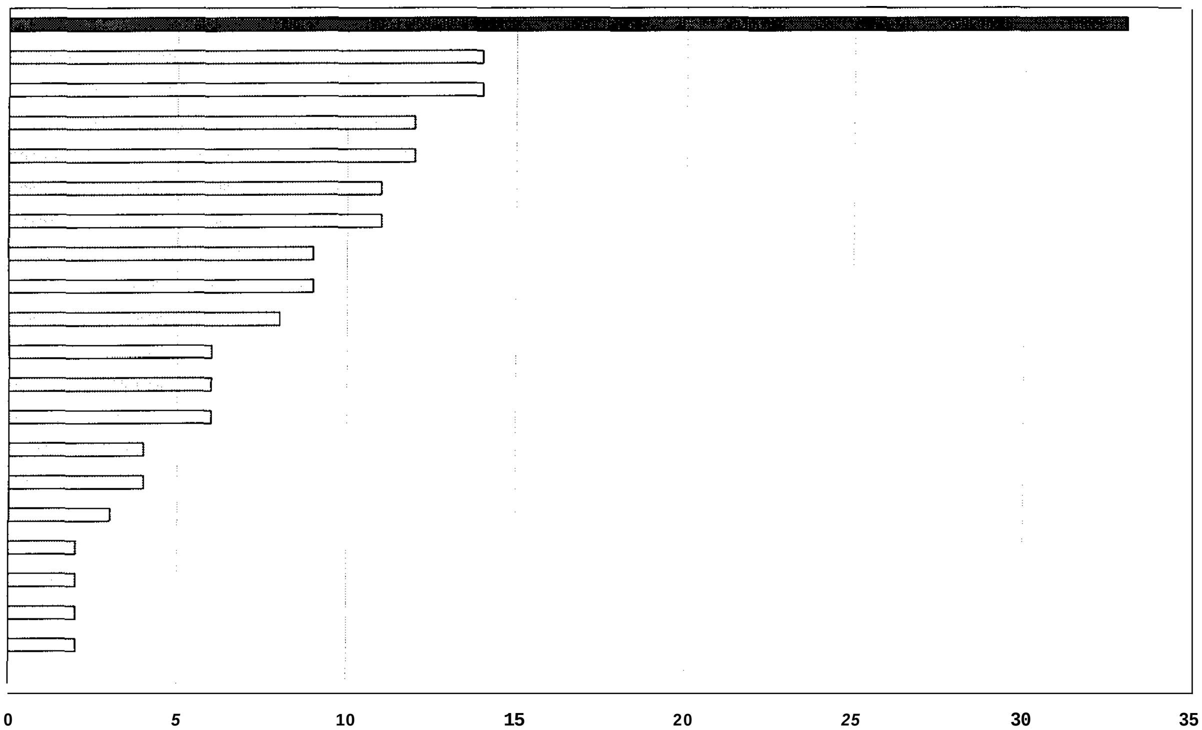
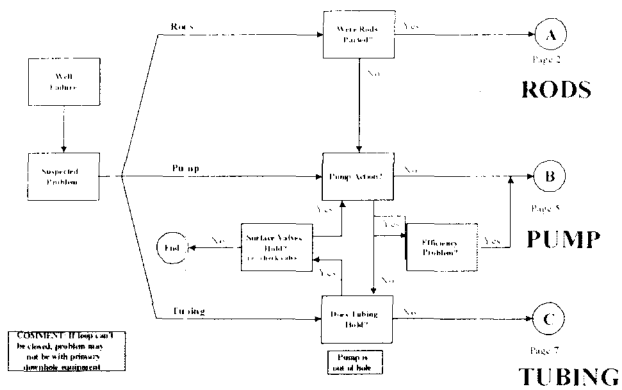


Figure A



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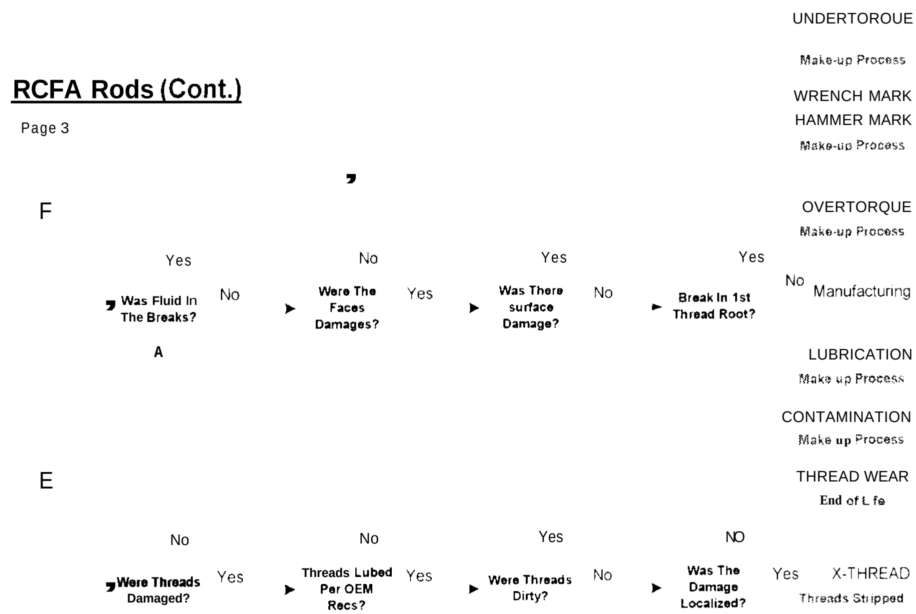

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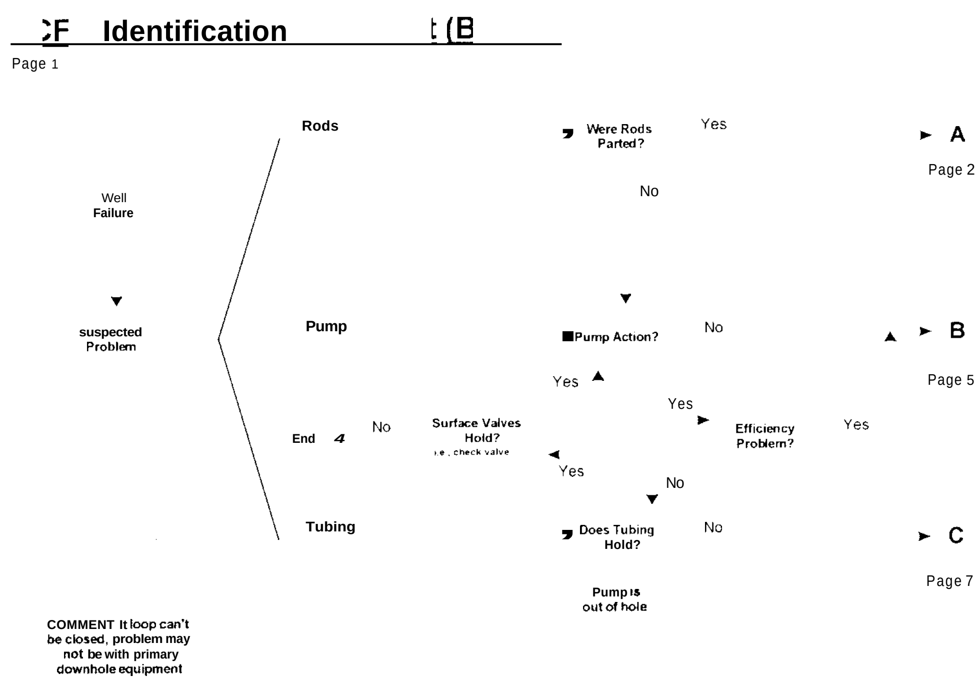

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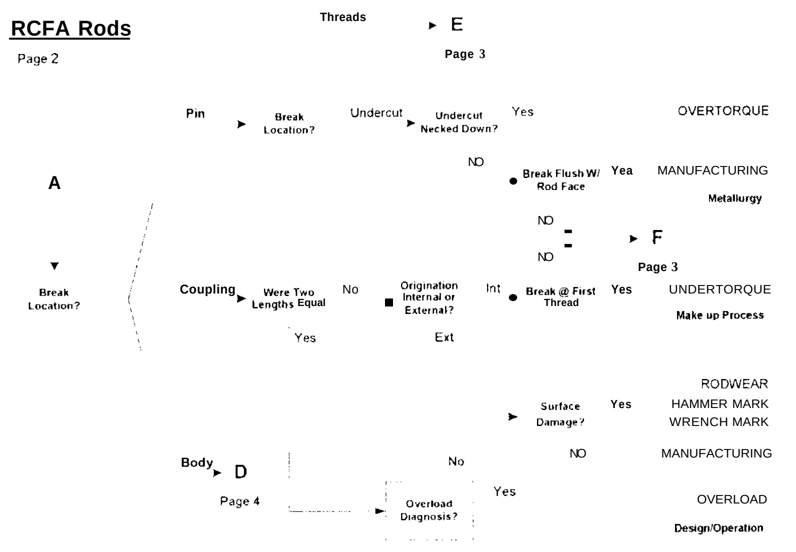

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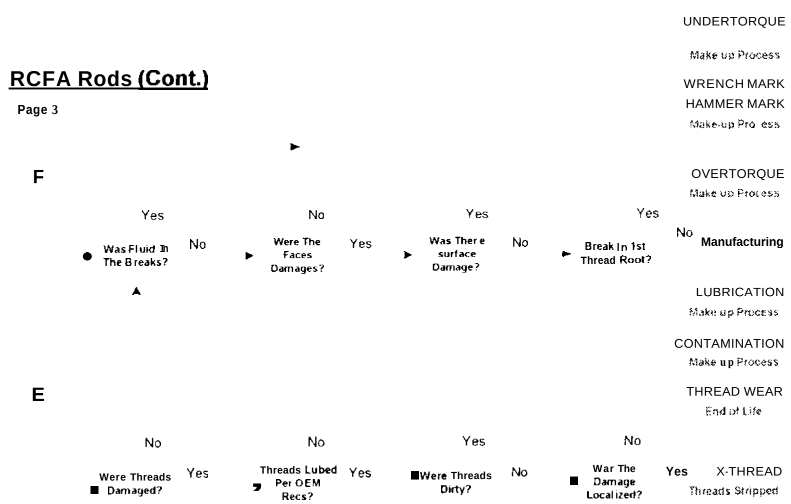

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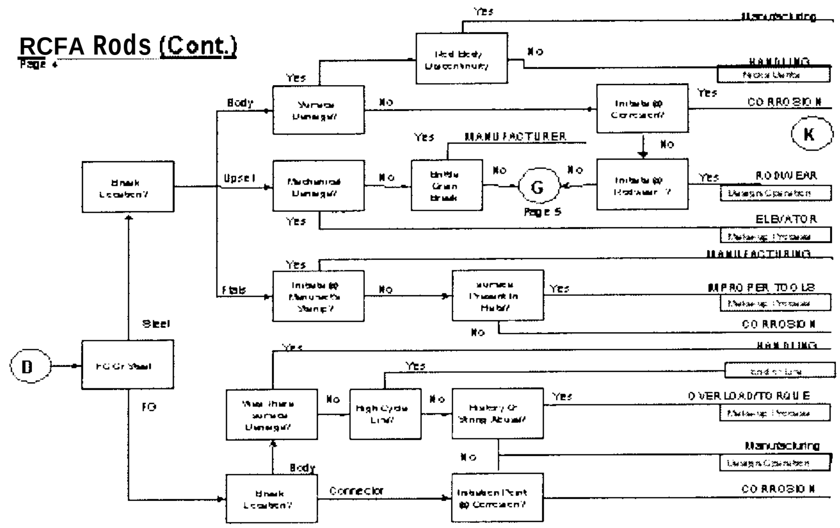
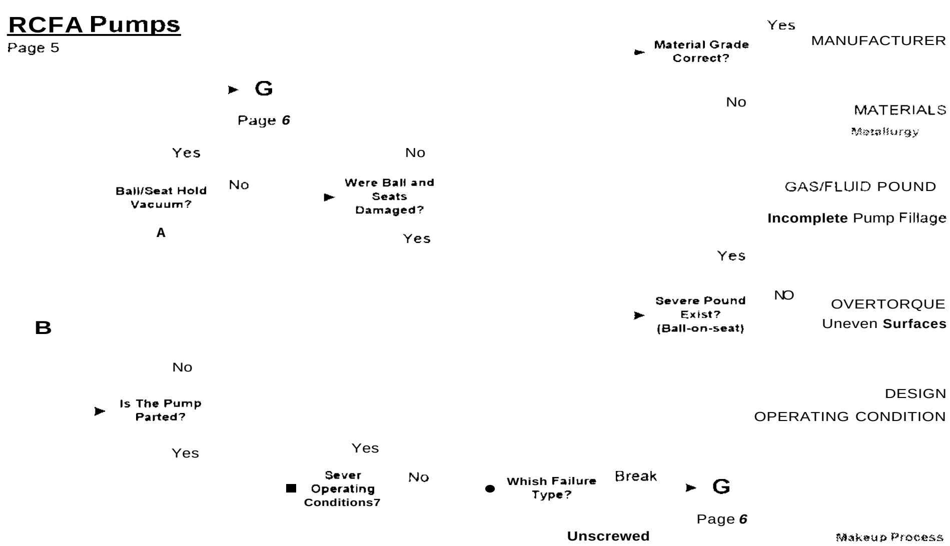


Figure G



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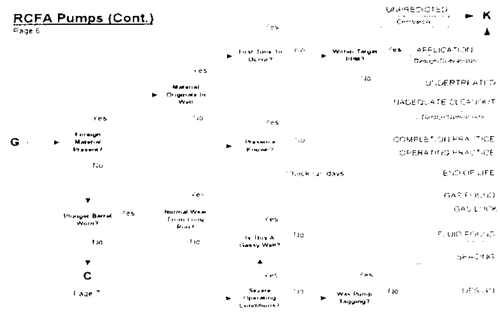
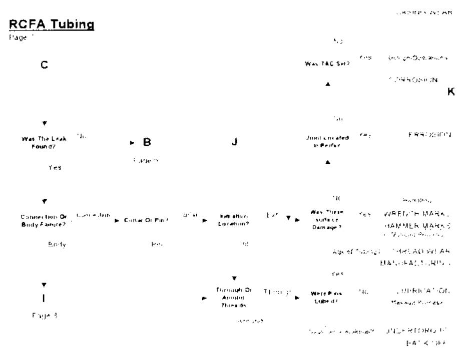


Figure I



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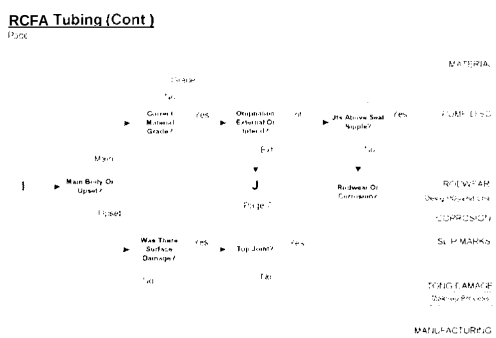


Figure K

Some Causes & Solutions to Pump Failures
Problem:
Excessive Pump Friction
Solution:Increase Pump Clearance

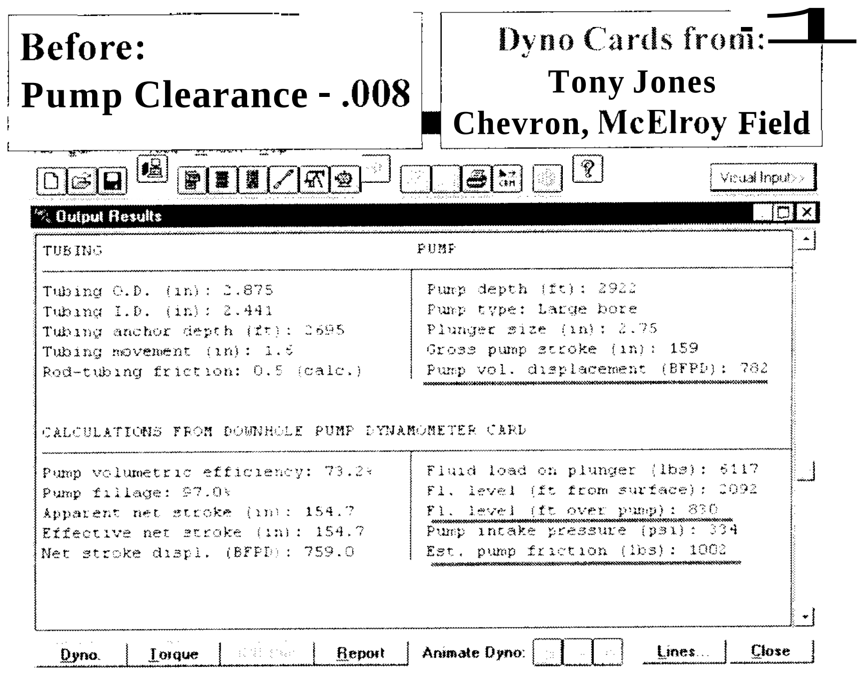


Figure L

After: Pump Clearance - .011

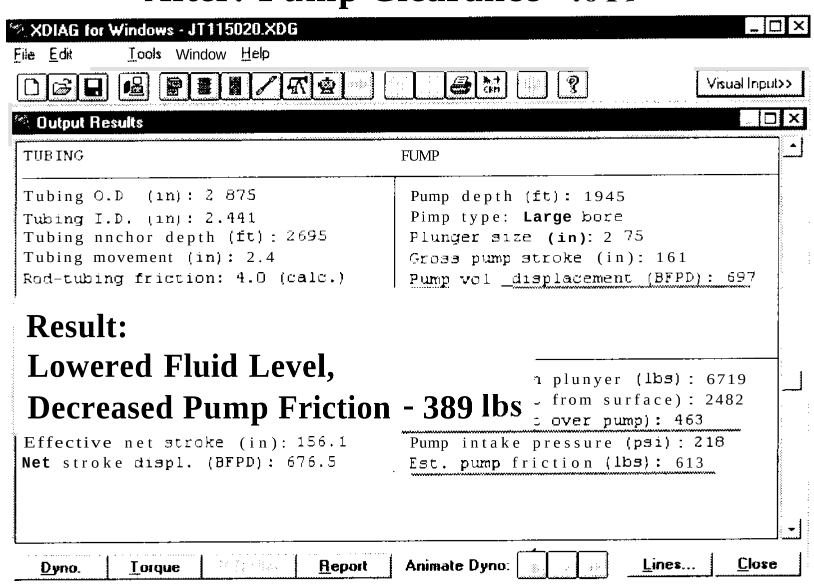


Figure M

Rod Makeup Process Flowchart

Figure N

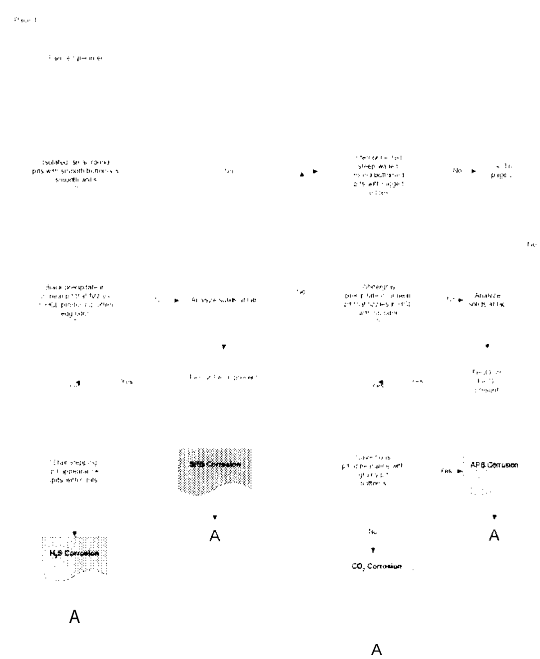
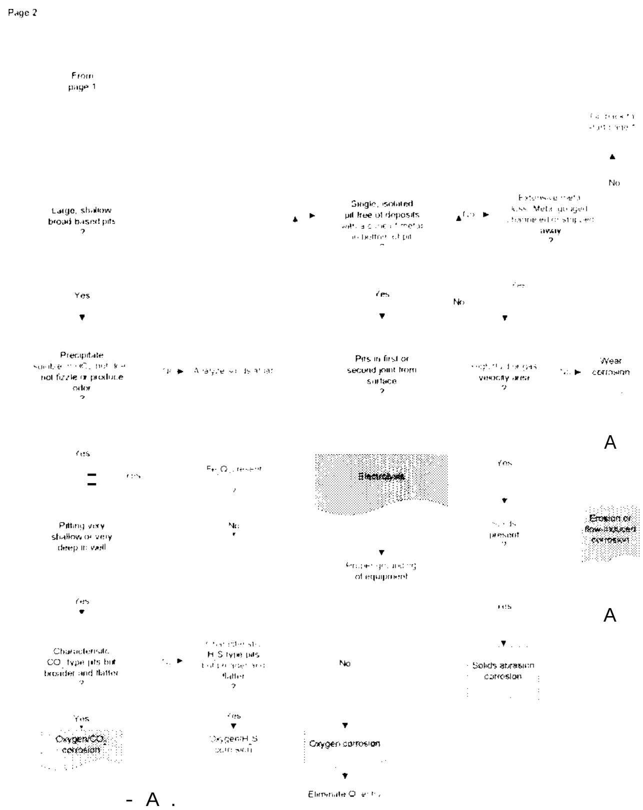


Figure O



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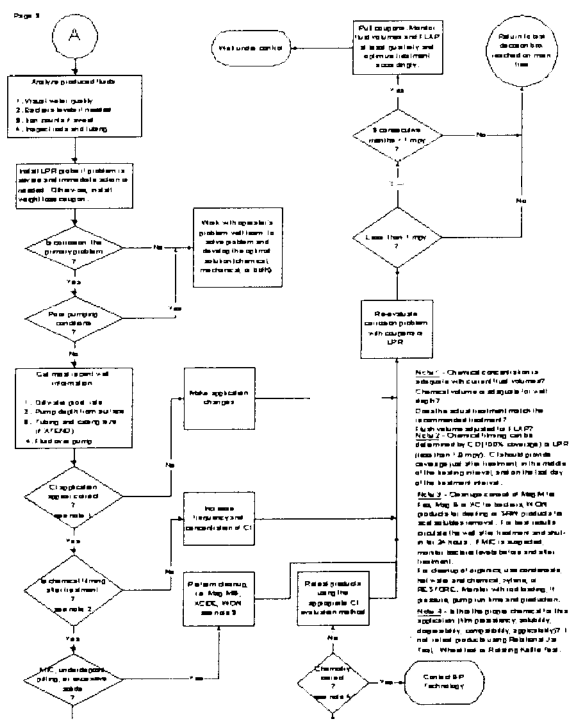

Figure Q