Recommended Practice for the Operation, Maintenance and Troubleshooting of Electric Submersible Pump Installations

API RECOMMENDED PRACTICE 11 S
THIRD EDITION, NOVEMBER 1, 1994

American Petroleum Institute
1220 L Street., Northwest
Washington, D.C. 20005

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Exploration and Production Department

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FOREWORD

This recommended practice (RP) is under the jurisdiction of the American Petroleum Institute (API) Committee on Standardization of Production Equipment.

This document presents recommended practices for the operation, maintenance, and troubleshooting of electric submersible pumps and auxiliary equipment. This recommended practice is provided to meet the need for guidelines, procedures, and recommendations covering electric submersible pumping equipment. These recommended practices are those generally considered necessary for successful submersible pump operation.

This standard shall become effective on the date printed on the cover but may be used voluntarily from the date of distribution.

Recommended Practice for the Operation, Maintenance and Troubleshooting of Electric Submersible Pump Installations

1 Scope

This recommended practice covers all of the major components that comprise a standard electric submersible pumping system, their operation, maintenance, and troubleshooting.

It is specifically prepared for installations in oil and water producing wells where the equipment is installed on tubing.

It is not prepared for equipment selection or application.

2 Operation

2.1 CHECKS BEFORE START-UP

2.1.1 Make certain that the flowline hookup is completed, that all valves are of proper pressure ratings and are properly installed, including an adjustable tubing choke. All valves should be in their proper operating position (open or closed, as appropriate).

WARNING: A master or wing valve on the tubing could be exposed to the maximum discharge pressure of the pump when the fluid in the annulus is at the surface. Therefore, these valves must be able to withstand this pressure.

2.1.2 Check no-load voltage, potential, and current transformers for proper ratios, and adjust the underload and overload relays to proper setting for start-up according to the manufacturer's or user's specifications. Check to see that all the power fuses are sized properly for the downhole equipment.

2.1.3 Assure that other system relays and controls are in proper adjustment or position, and electrical connections are clean and tight. The system must be properly grounded and the junction box properly installed, including a cable vapor seal between the junction box and motor control panel.

2.1.4 Make certain that the proper scale ammeter chart paper is on the recorder, that the pen is operating properly and that the setting for the day and time are correct.

2.1.5 The control panel should contain a label or "Pull/Run Report" that gives "nameplate" information pertinent to the present equipment in the well. See Figure 1 for an example form that gives the data required.

2.1.6 Electrical checks, phase-to-ground, and phase-to-phase, should be made prior to start-up and readings recorded. Phase-to-phase readings must be balanced.

2.1.7 If scale or corrosion is a well problem, the preventative measures must be initiated before pump start-up. For further discussion of this matter, see 4.3.

2.2 SYSTEM START-UP

2.2.1 If the well has been killed with heavy mud it should be displaced with a light fluid before pump start-up.

2.2.2 For larger horsepower units (above 250 HP) regardless of setting depth and low capacity units (less than 600 barrels/day) set deep (with static fluid level below 7,000 feet), it is recommended that the tubing be filled before start-up. This means these installations must be equipped with tubing check valves and drain valves. The tubing should be filled with light, clean fluid.

2.2.3 With all checks completed, start the equipment. For control of the pump discharge rate, the pump can be started against a restricted choke setting, but, should not be started against a closed choke or valve. For immediate control of the pump discharge rate, a tubing check valve and drain valve could be installed and the tubing filled prior to start-up.

2.2.4 Immediately after start-up, check the line current with a "clamp-on" ammeter and record. Using this information, calibrate the recording ammeter.

2.2.5 Check the load voltage and record. Exercise extreme caution when doing this.

2.2.6 Rotation should be verified as soon after start-up as possible by using either "pump up" time, wellhead tubing discharge pressure and flow, production test, or other appropriate method as recommended by the pump company or operating company procedures. If sand or debris is present in the well, it is recommended that the pump not be shut down for rotational check until solids have been displaced from the tubing.

2.2.7 If actual "pump up" time is exceeding calculated "pump up" time, it should be assumed that the pump is in reverse rotation and appropriate action taken.

MOTOR DATA: INSTALLED: ________
____ H.P. ________ VOLTAGE ________ N.P. AMPS
PUMP DATA: INSTALLED: ________
-TYPE-STAGES ________ TYPE INTAKE
PUMP DESIGN CAPACITY ________________ B/D
CABLE DATA:
____________ TYPE ______ LENGTH ______ SIZE
TRANSFORMER DATA:
-TAP SETTINGS ________ SECONDARY VOLTAGE RANGE
VOLTAGE DATA :
________ VOLTAGE NO LOAD ________ LOAD VOLTAGE
COMMENTS: ______________________________
____

Figure I-Well Equipment

2.3 ADJUSTMENTS AFTER WELL STABILIZATION

2.3.1 After motor current stabilizes, the overload, underload and the restart timer should be reset for proper "normal running" condition as specified by manufacturer's or user's specifications.

2.3.2 Overload setting is normally set at 120 percent of motor nameplate amperage.

2.3.3 Underload setting is generally set at 80 percent of normal motor operating amperage. Gassy wells may require even a lower underload setting, but caution should be exercised to insure underload protection for pump off or gas lock conditions.

2.3.4 The restart timer is normally set at 10 minutes per 1000 feet of operating fluid level depth, however, not less than 30 minutes.

Note: Never restart pump by hand before recommended time lapse.

2.3.5 If an adjustable underload time delay control relay is provided in the motor control panel, it is normally set at 20 seconds. Local well operating conditions may require a different setting.

2.4 OPERATING DATA GATHERING

2.4.1 Accurate operating data:

a. Is required to monitor the system under normal operating conditions.
b. Will provide information that will be useful in troubleshooting the well under abnormal operating conditions.
c. Will be useful in accurate resizing of the equipment, if required.
d. Should be filed individually by well, and should always include:
1. Start-up ammeter chart
2. Well test data sheets with corresponding ammeter chart attached
3. Current regular ammeter chart
4. Any other pertinent system and well operating data.

2.4.2 Frequency of data gathering:

a. When well is initially put on production, data should be collected daily for first week, weekly for first month, and at least monthly thereafter.

2.4.3 Production well test data that should be taken and entered on a Production Test Data Sheet similar to Figure 2 includes:

a. Date, time and duration of test
b. Oil, water and gas (both tubing and casing gas)
c. Tubing pressure and choke size
d. Fluid level, flowline pressure, casing pressure, and choke size.
e. Operating bottomhole pressure (BHP)
f. Ammeter chart (24-hour) properly marked with date and time of test
g. Other data as shown on Production Test Data Sheet (Figure 2).

2.5 ANALYZING OPERATING DATA

2.5.1 Analysis of operating data must consider both permanent well installation data (i.e., tubing size and length, casing size, perforation depth, fluid characteristics, etc.) as well as production test data.

2.5.2 Once the pump is in the well and operating, it should be analyzed to determine if it is functioning properly. (The importance of collecting operating data was covered in Section 2.4.) This data should be analyzed as follows:

a. Date, Time and Duration of Test
1. Recording the date, time, and duration of the testing period, along with any other events occurring in the field, allows correlation of the events with the test ammeter chart. Examples of field events that may be important to data analysis are: nearby injection or producing wells down, large electrical equipment coming on-line, etc.

b. Oil, Water and Gas (both tubing and casing gas)
1. The fluid volumes being produced through the tubing should be used to determine if the pumping is properly sized and operating at maximum efficiency.
2. The water-oil ratio should also be analyzed to determine if any changes are occurring.

c. Tubing Pressure and Choke Size
1. This data is used to check pump sizing and efficiency.

d. Fluid Level, Casing Pressure and Choke Size
1. This data should be used to determine pump efficiency and well inflow performance (IPR or PI).

e. Operating Bottomhole Pressure
1. Used to verify PI of well and in conjunction with the fluid level it can be used to determine average annulus fluid density.

f. Ammeter Chart (24-hour, properly marked)
1. The ammeter chart is an extremely important data source for monitoring well operation and for troubleshooting. The ammeter chart should be observed daily to insure proper operation.
2. Use a 24-hour chart during production testing or during periods of troubleshooting and use 7-day charts during normal weekly operation.

g. Other Data as Shown on Production Test Data Sheet (Figure 2).

3 Troubleshooting

3.1 Historical Operating Information for the Producing Area

3.1.1 General operating parameters and limitations that have been found to be true historically in the operating area should be considered when troubleshooting.

3.1.2 The operating data that has been gathered during normal operation should be analyzed together with any data that is available during problem.

3.1.3 Analysis of data may not only aid in determining reason for shutdown or poor performance, but also may indicate that equipment should be resized.

3.1.4 Prior equipment inspection data can aid in determining possible well problems such as scale, temperature, corrosion, erosion, and solids problems.

3.2 AMMETER CHART ANALYSIS

3.2.1 A number of changes in operating conditions can be diagnosed by proper interpretation of the ammeter chart, and corrective action taken. Properly utilized and understood, the ammeter chart can be a very valuable tool.

3.2.2 The following are hand drawn examples of ammeter charts that are representative of actual ammeter charts that may be encountered. Actual charts may vary somewhat from these charts; but, with experience and the example charts as a guideline, actual ammeter charts can be analyzed with a high degree of accuracy.

Initial or Monthly
Test Data
Electric Submersible Pump

Well Name & No. ____________
Date of Test ____________
Time of Test ____________ AM PM

Field ____________ Reservoir ____________ County ____________

1. Is Well Being Tested Under Stabilized Flow Rate Conditions? ____ YES ____ NO

2. Does Pump Operate Continuously? ____ YES ____ NO

Note: If Pump is Cycling, Test Should Be for 24 Hours

3. Length of This Test Hours

4. Duration of Downtime During Test ____________ Hours

5. Production During Test:

	Measured	24-Hour Calculated
A. Oil	____ BBLS	- B / D
B. Water	____ BBLS	- B / D
C. Gas-Produced through Tubing		____ MCF
D. Gas-Produced through Casing		____ MCF

6. Pressures During Test:

A. Tubing	Choke Size ____	____ PSIG
B. Casing	Choke Size ____	____ PSIG
C. BHP Device		____ PSIG
D. Fluid Submergence (Sonic)		____ FT
E. Separator Pressure		____ PSIG
F. Flowline Pressure		____ PSIG

7. Remarks ____________

8. Data Taken By: ____________ Date ____________
Signature

Note: (1) Items not actually measured indicate by an "E" following number

Figure 2-Production Test Data Sheet

a. Normal Operation-Figure 3.

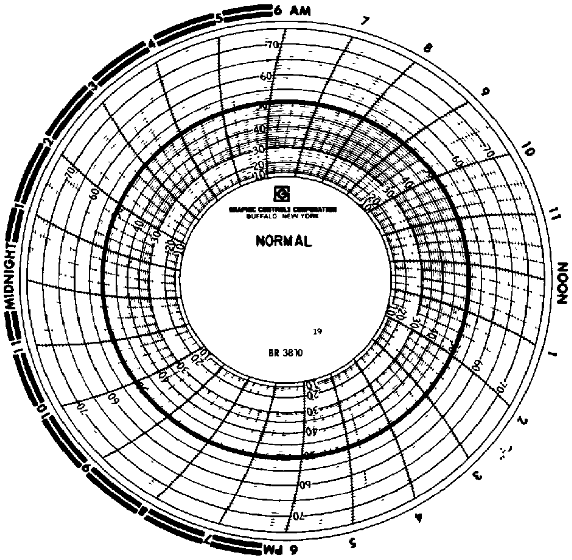

Figure 3

1. Under normal operating conditions, the ammeter recorder should draw a smooth symmetrical curve with an amperage value at or near motor nameplate amperage. This figure illustrates this “ideal” condition.

2. Actual normal pump operations may produce a similar curve slightly above or below motor nameplate amperage; but, as long as the curve is symmetrical and consistent from day to day, the system is operating properly.

3. Any deviation from this “normal chart” is a clue to possible system problems or changing well conditions.

b. Primary Power Fluctuations-Figure 4.

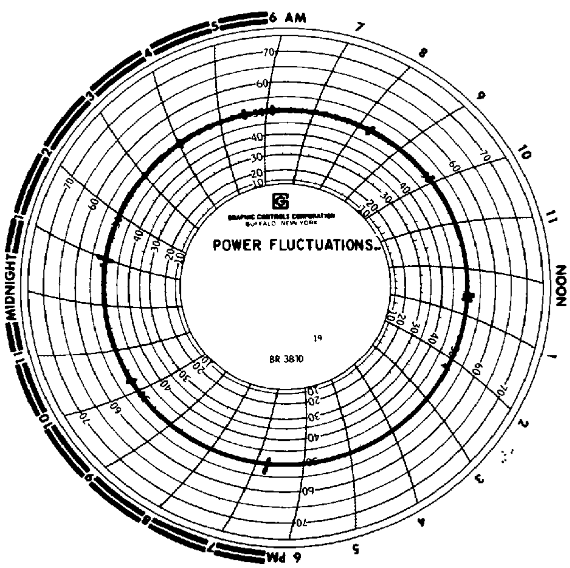

Figure 4

1. In the electric submersible pump operation, the system amperage varies inversely with the system voltage. Therefore, if the primary power supply voltage fluctuates, the system amperage will also fluctuate in an attempt to maintain constant load. These amperage fluctuations will appear as shown in Figure 4.

2. The most common cause of primary fluctuations is periodic heavy loading of the primary power system. For example, it could be caused by the start-up of a high horsepower water injection pump or the simultaneous start-up of other electrical loads. Such primary power drains should be timed so that they are not simultaneous, and their effect is minimized.

3. Ammeter “spikes” are often observed during an electrical disturbance, such as a lightning storm.

c. Pump Gas Locking-Figure 5.

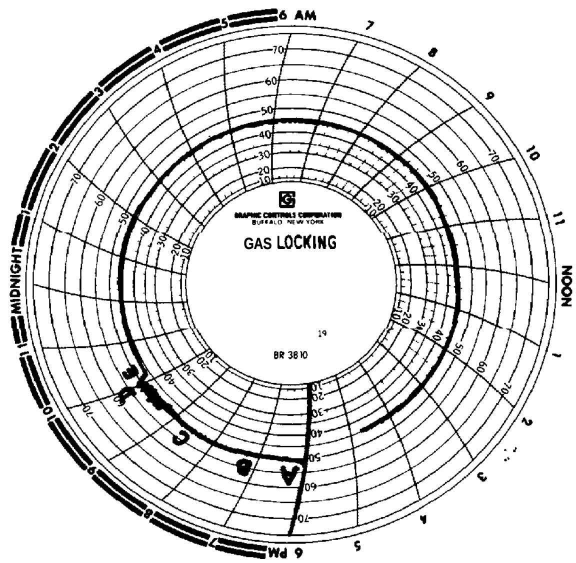

Figure 5

1. Figure 5 shows the ammeter chart of a pump which has gas locked and continues to operate at a slightly lower amperage. If amperage drop is greater than shown in Figure 5, it is possible for the pump to shut down on underload.

a. Section A shows pump start-up. At this time, the well annular fluid level is high; thus, the production rate and amperage are increased slightly due to the reduced head requirement.

b. Section B shows a normal operating curve as the fluid level nears the design value.

c. Section C shows a decrease in amperage as the fluid level falls below design and an amperage fluctuation as gas begins to break out near the pump intake.

d. Section D shows an erratic amperage due to gas interference as the fluid level nears the pump’s intake.

The pump "gas locks" at this time resulting in a slight decrease in amperage as shown in Section E. The pump is now not producing any fluid.

2. It is possible to remedy this situation by:

a. Shutting down the unit long enough to allow the "gas lock" to be "broken."

b. If the gas lock condition continues, it is possible to correct it by lowering the pump to the point where gas breakout at the pump intake is reduced enough to permit continuous operation, but must have a motor shroud if the pump is set below the point of fluid entry into the well bore. Care should be taken to insure that the unit will not be underpowered due to the depressed fluid level and resultant increased total dynamic head.

c. If lowering the pump is not feasible, it may be possible (depending on the unit configuration) to choke production back until a suitable fluid level is established. Care should be taken that production rates are not reduced to a point that will result in damage to the pump or motor.

d. If the pump continues to shut down, it should be pulled and resized. If the decision is made to continue cyclic operation, a system of programmed downtime cycling should be designed for the maximum fluid withdrawal, using the fewest number of cycles. The pump should be resized on the next pump changeout.

d. "Pump Off' Condition with Gas Interference-Figure 6.

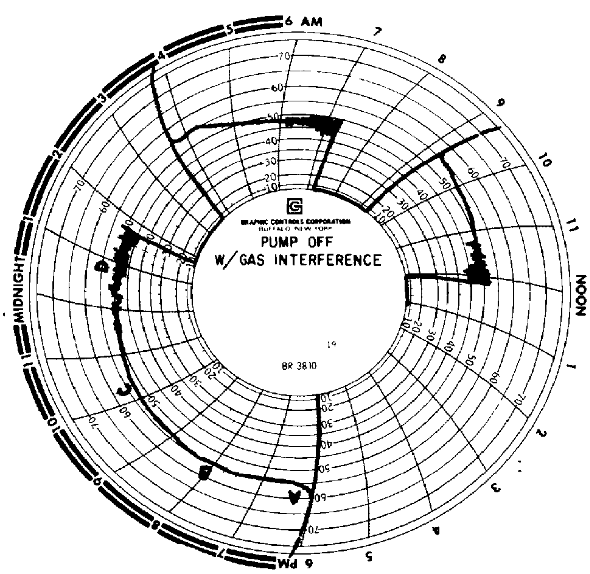

Figure 6

1. Figure 6 shows the ammeter chart of a pump which has lowered the fluid level to a point which leads to gas interference.

a. Section A shows pump start-up. At this time, the well annular fluid level is high; thus, the production rate and amperage are increased slightly due to the reduced head requirement.

b. Section B shows a normal operating curve as the fluid level nears the design value.

c. Section C shows a decrease in amperage as the fluid level falls below design point.

d. Section D shows an erratic amperage due to gas interference as the fluid level nears the pump's intake. The pump "gas locks" at this time resulting in an undercurrent shutdown as shown in Section E. The pump is not now producing.

e. "Pump Off' Condition Without Gas Interference-Figure 7.

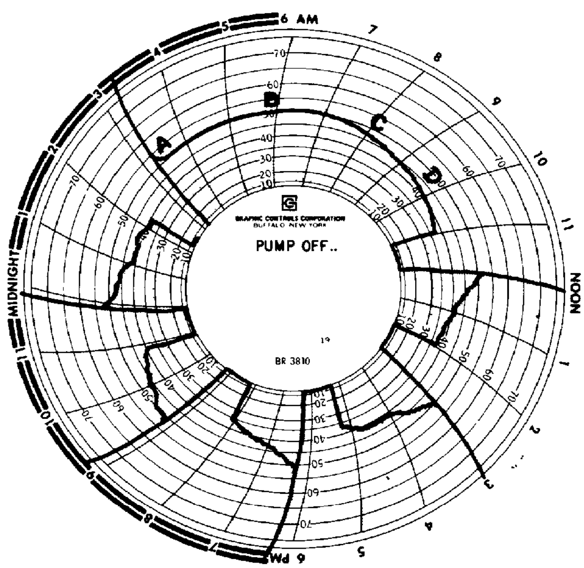

Figure 7

1. Figure 7 shows the ammeter chart of a unit which has pumped off the well and shut down on undercurrent, then restarted automatically and shut down again for the same reason.

2. Analysis of Section A, B, and C are identical to that for gas locking (Figure 6), except no free gas breakout fluctuations are evident due to the assumption of no gas present.

3. In Section D, the fluid level approaches the pump intake, and the rate and amperage decline. Finally, the preset undercurrent level is reached, and the unit drops off-line.

4. When a unit drops off-line due to undercurrent, the automatic restart sequence is triggered. As shown on the ammeter chart, the 'unit restarted automatically after the preset time delay. During shutdown, the fluid rose slightly. When the unit restarted, the fluid level had not reached static. Thus, the pump off cycle began some-

where in Section C.

5. This condition exists because the unit is improperly sized for the application and the remedial action is the same as for gas locking. A well stimulation treatment may increase productivity of the well to better suit the unit.

f. "Pump Off' Condition with Restart Failure-Figure 8.

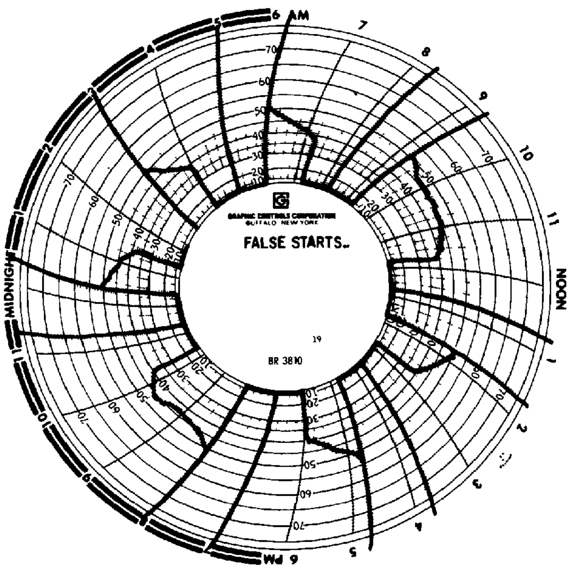

Figure 8

1. Figure 8 shows an ammeter chart from a unit which has shut down on underload, failed in an attempt to restart automatically, timed out and restarted beginning the cycle again.

2. Analysis of this chart is similar to that for pump off of fluid conditions (d) except that the auto-restart delay is not of sufficient length to allow adequate well fluid build-up for loading the pump.

3. This unit is improperly sized. Pump should be resized on next changeout or the well should be worked over to provide additional fluid to be pumped.

g. Short Duration Cycling-Figure 9.

1. Figure 9 shows an ammeter chart similar to that for fluid pump off conditions except that the running times are of shorter duration and the cycles more frequent. This type of operation is extremely detrimental to submersible motors and should be corrected immediately.

2. This chart could apply to a unit which is too large for the application, or has insufficient head capacity. Close the wellhead discharge valve and observe "shut in" pressure. This will confirm which condition exists.

CAUTION: For momentary testing only. Check the pressure rating of every component in system.

3. Additional corrective action would consist of checking for a plugged discharge line or a closed valve in the system. If none is found, a fluid level determination should be done immediately after the unit shuts down.

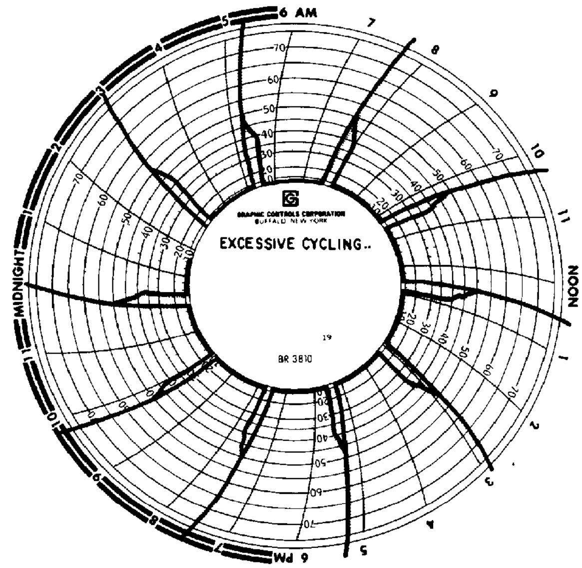

Figure 9

h. "Gassy" Well Condition-Figure 10.

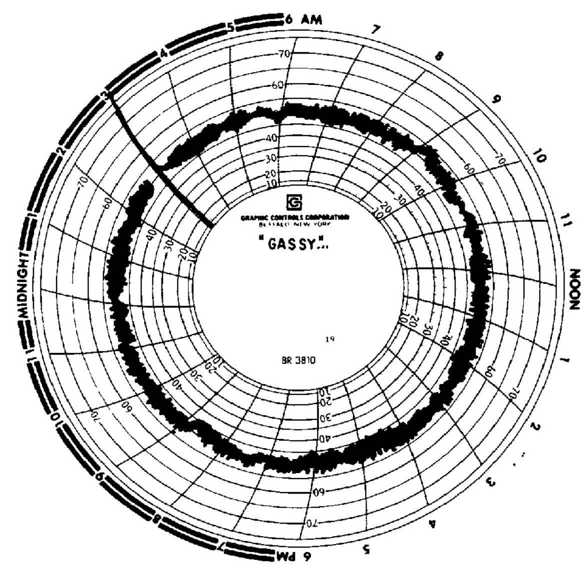

Figure 10

1. Figure No. 10 shows the chart of a unit which is operating near designed levels, but which is handling light gassy fluid.

2. The ammeter fluctuation is caused by the pump intermittently handling entrained and free gas along with heavier fluid production. This condition is usually accom-

panied by a reduction in total fluid production (actual stock tank barrels). It is possible that this problem can be reduced or eliminated by proper adjustment of casing and/or tubing pressure.

3. This type chart can also be the result of pumping an emulsified fluid where the intake is being plugged momentarily by the emulsion. On the emulsion block, the spikes will usually drop below the normal amperage line. It may be possible to correct this problem with emulsion breakers.

i. Immediate Undercurrent Shutdown-Figure 11.

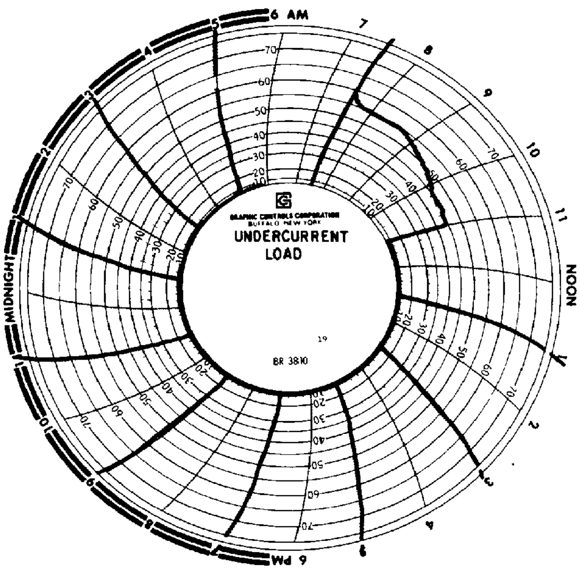

Figure 11

1. Figure 11 shows the ammeter chart of a unit which is starting, running a very short time, and then shutting down due to undercurrent. This cycle is repeated by the automatic restart sequence.

2. Generally, this type curve is caused by the pump handling fluid which lacks sufficient density or volume to load the motor to an amperage above the undercurrent setting.

3. If productivity tests show fluid available at the pump intake, it is possible to rectify this problem by lowering the undercurrent shutdown amperage. This should be done by qualified personnel only.

4. Another cause of this type curve is failure of the timing relay used to block the undercurrent relay from the control circuit during the automatic restart sequence. This problem is best rectified by qualified personnel, as several areas in the motor control panel should be checked to pinpoint the problem.

5. A broken unit shaft could also cause this same ammeter chart.

j. Underload Shutdown Failure-Figure 12.

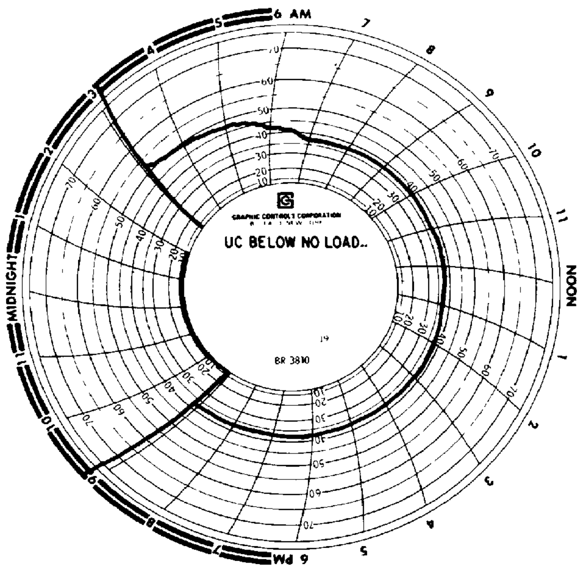

Figure 12

1. Figure 12 shows a normal pump start-up followed by a slow decline in amperage down to the no-load idle amperage of the motor. Finally, after a period of loadless operation, the unit faults and shuts down on overload,

2. This curve is typical of a unit which is improperly sized for the application and which also has had the underload protection relay set improperly.

3. With the fluid production retarded, the motor ran at idle load until heat build-up resulted in a system failure causing the unit to overload and shutdown. IT IS TO BE NOTED THAT FLUID PASSAGE BY THE MOTOR PROVIDES COOLING MANDATORY FOR PROPER SUBMERSIBLE PUMP OPERATION.

k. Pump Control by Tank Level-Figure 13.

1. Figure 13 shows an ammeter chart for a unit which is being controlled by a tank switch. The switch drops the unit off-line and starts the auto-restart sequence.

2. This type of operation is often necessary, but the focus should be made on the restart delay and the minimum amount of cycling. In this case, the delay is far too short.

3. In almost all cases, when a unit is shut down, fluid will tend to fall back through the pump, spinning the unit backwards (backspin). Attempting to restart any submersible pump in a backspin mode may result in damaged equipment such as twisted or broken shafts.

4. A tubing check valve should not be depended on to prevent this backspin problem, due to possible leakage of the check valve.

5. A minimum of 30 minutes is the normal setting to insure against backspin by allowing all fluid levels to stabilize.

6. Actual minimum downtime required should be determined by checking the voltage generated by the backspin and thereby determine how long it actually takes the well to stabilize.

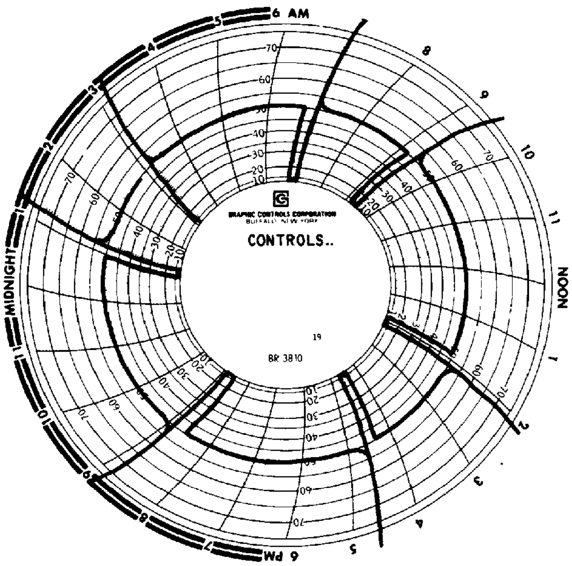

Figure 13

7. A convenient way to insure against starting a pump against backspin is to set the auto-restart delay timer above 30 minutes with the H-O-A switch set on automatic.

1. Normal Overload Condition-Figure 14.

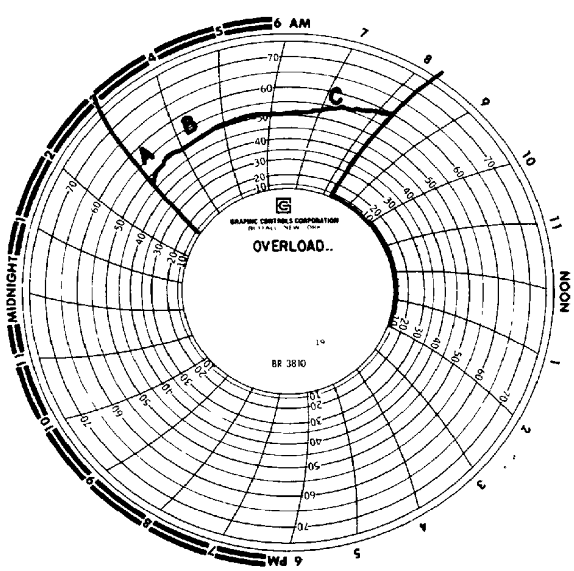

Figure 14

1. Figure 14 shows the chart for a unit which has shut down due to overload (high current) conditions.

2. Section A of the curve shows pump start-up at an amperage below nameplate amperage (normal for some unit configurations). The amperage then gradually rises to normal.

3. Section B shows the unit running normally.

4. Section C shows a gradual rise in amperage until the unit finally drops off-line due to overload.

CAUTION: Until the cause of this overload has been corrected, restart should not be attempted.

5. Automatic restart sequences are not instigated due to the manual reset required by the overload relays.

6. The complete installation should be checked out before a restart of the unit is attempted.

7. Common causes of this type shutdown are:

a. Increases in fluid specific gravity (such as heavy brines or muds)

b. Sand production

c. Emulsions or viscosity increases

d. Mechanical or electrical problems such as motor overheat or wearing equipment

e. Electrical power problems

m. Pump Handling Solids-Figure 15.

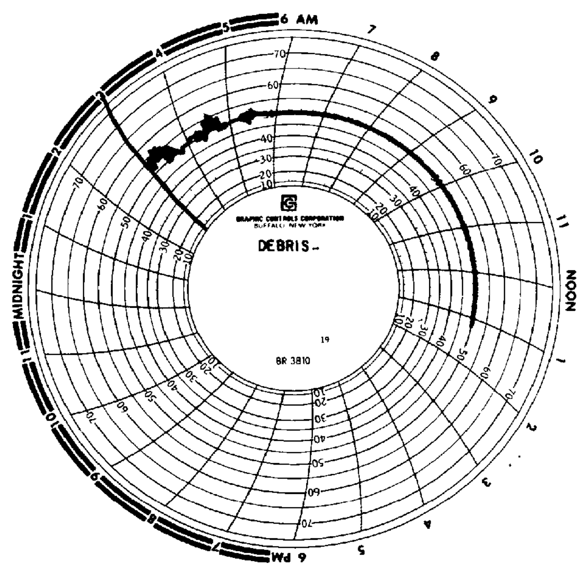

Figure 15

1. Figure 15 shows a unit which started, pumped erratically for a short period, and then proceeded under normal conditions.

2. This type operation can be expected when a well contains debris such as scale, loose sand and weighted muds or brines.

3. This type operation is not unusual, but is not recommended where avoidable.

4. The **actual** pump horsepower required is a multiple function of the specific gravity of the fluid. If it becomes necessary to kill a well, use the lightest and cleanest possible kill fluid that will control the well.

5. Consult the pump manufacturer on the start-up horsepower that will be required to handle the kill fluid. The manufacturer can determine if the present motor is of sufficient size to pump the kill fluid.

6. Under certain circumstances, it may be necessary to hold back pressure on the well to prevent excess amperage.

7. If a well produces sand initially, it should be produced at a reduced rate to provide a slower drawdown on the formation. (See 2.2.3.) The reduced rate should be determined by the operator by whatever means available.

n. Excessive Manual Restart Attempts-Figure 16.

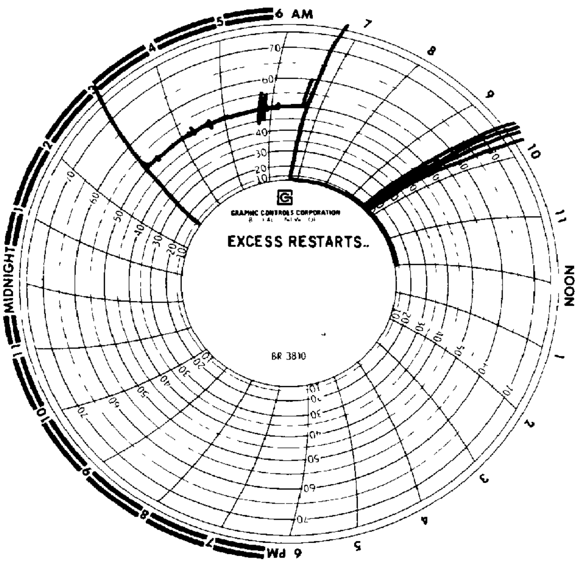

Figure 16

1. Figure 16 shows a relatively normal chart until power fluctuation kicks are noticed. Finally, the unit dropped off-line due to overload. It is also evident that several manual restarts were attempted.

CAUTION: This type of restart attempt will destroy the equipment.

2. No manual restarts should be attempted until the system is checked by qualified personnel.

o. Erratic Loading Conditions-Figure 17.

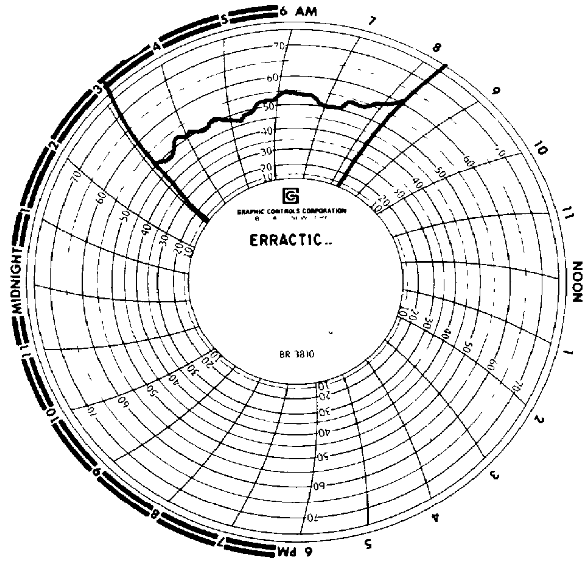

Figure 17

1. Figure 17 exhibits an unpredictably varying chart. This type chart is usually produced by fluctuations in fluid specific gravity, or large changes in surface pressure. The unit finally dropped off-line due to overload and will not automatically restart.

2. Manual restart should not be attempted until the unit is thoroughly checked by qualified personnel, and the cause of the problem solved.

3. Some typical results or simultaneous causes for overload failure of this nature are a frozen pump, burned motor, burned cable, blown fuses (primary and/or secondary).

3.3 BASIC PROBLEM TROUBLESHOOTING

The following troubleshooting charts can be used to diagnose and correct many of the problems that may be encountered.

System Condition	Apparent Problem	Possible Causes	Action Required and/or Corrective Measures
3.3.1 Pump Running	a. Production greater than pump design capacity or range.	1. Well productivity greater than pump design capacity or range.	(a) Obtain fluid level and operating BHP to determine pump submergence. (b) If fluid level is in acceptable operating range, increase tubing well head pressure to bring pump production rate within design range. (c) Evaluate resizing equipment.
		2. Change in fluid characteristics.	(a) Increase tubing well head pressure to bring pump production rate within design range. (b) Resize pump considering the changes in fluid characteristics.
	b. No production or production below pump design capacity or range.	1. Total pump discharge head not sufficient for application.	(a) Check pump design head in connection with the operating fluid level.
		2. Reverse Rotation.	(a) Reverse any two of the three conductors at well cable connections and operate in opposite direction. ***CAUTION:*** Verify no backspin before turning pump back on.
		3. Tubing leak.	(a) Pressure test at tubing well head to determine if leak exists. If so, tubing must be pulled and faulty joint or joints replaced. (b) A high or low current may be noted depending on location of leak, working fluid level, and size of unit; but this does not always indicate a tubing leak. (c) If "Y Tool" is used, the blanking plug may be possible cause of leak.
		4. Obstruction in flow line.	(a) Check pressure in flow line at well head. If abnormally high, take appropriate measures to correct.

System Condition	Apparent Problem	Possible Causes	Action Required and/or Corrective Measures
3.3.1 (Continued:		5. Restricted pump.	(a) If well has a scale, paraffin or salt problem, pump may be restricted. Take appropriate corrective action. (b) Trash may be restricting pump intake. This may be cleaned by reversing flow through the pump if no tubing check valve in system. (c) If pump is restricted by highly viscous oil, a solvent or higher gravity fluid should be dumped down the well annulus to dilute.
		6. Broken pump shaft.	(a) Unit will need to be pulled and failed piece of equipment replaced. (b) Where undercurrent relay is employed, this condition will usually stop pump on undercurrent.
		7. Worn pump.	(a) Obtain fluid level and BHP to determine pump submergence. (b)Check pump discharge pressure by closing well head tubing valve. Compare this data to previous data in well file. ***CAUTION:*** For momentary testing only. Check the pressure rating of every component in system. (c) If (a) and (b) confirm a worn pump, unit should be pulled and replaced.
		8. Leaking casing check valve.	(a) Check casing check valve and replace if leaking.
		9. Flow line leak.	(a) Check flow line and repair leak.
		10. Change in fluid characteristics.	(a) Check pump design head in connection with the operating fluid level.
		11. Well productivity less than pump design capacity or range.	(a) Determine working fluid level and refer to "Well Pumped Off' *(3.3.2,* a., 2).
3.3.2 Pump Not Operating	a. Down on undercurrent.	1. Pump gas locked.	(a) Excessive casing pressure. Open casing valve to relieve.

System Condition	Apparent Problem	Possible Causes	Action Required and/or Corrective Measures
3.3.2 (Continued			(b) In some cases of low casing pressure, more pressure is required to keep gas in solution at pump intake. Temporarily increase casing pressure to keep the gas in solution. Reduce the casing pressure after gas lock is broken. (c) If tubing check valve is installed, it should be located 6 to 8 joints above pump to allow gas to be purged from pump on start-up. (d) If possible, the pump should be lowered to lower setting depth provided sufficient discharge head is available from the pump. (e) If pump is pulled, a gas separator should be included on re-installation.
		2. Well pumped off.	(a) Obtain fluid level to confirm pumped off condition. If well is pumped off, possible corrective actions are: (1) Lower pump in well. (2) If pump capacity is greater than well production, it may be possible to choke back on production to obtain continuous operation. (3) Stimulate or clean out well to increase well's production. (4) Pump additional fluid down the annulus to prevent pump from pumping off. This is only a contingency action if unit cannot be pulled. Care must be taken to insure that flow by motor is sufficient for cooling.
		3. Total head of pump not sufficient for aoolication.	(a) Check pump design head in connection with operating fluid level.
		4. Primary power system surge or outage.	(a) If repeated problem, use of power system monitoring equipment recommended to determine cause of problem. Correct as appropriate.

System Condition	Apparent Problem	Possible Causes	Action Required and/or Corrective Measures
3.3.2 (Continued:		5. Generator used as power source—generator speed decreases.	(a) When generator slows down, the frequency (hertz), voltage, current, and power all decrease. Speed generator up to normal speed.
		6. Broken pump shaft.	See under 3.3.1, b.
		7. Tubing leak.	See under 3.3.1, b.
		8. Plugged pump.	See under 3.3.1, b.
		9. Worn pump.	See under 3.3.1, b.
		10. Reverse rotation.	See under 3.3.1, b.
		1. Power system sag	(a) If repeated problem, use power system monitoring equipment. Investigate any unusually heavy electrical loads that may have been added to power system. (b) Improved power distribution system may be required.
		2. Debris, solids, sand, etc., in system.	(a) Check flow line or gathering system for evidence of sand, mud or debris. Well clean out mav be reauired.
		3. Change in fluid characteristics.	(a) Check pump discharge head in connection with operating fluid level. Unit may have insufficient horsepower.
		4. Worn pump.	(a) Consider past running time of pump and well history, sand, mud, etc. Possibly thrust washers and bearings are worn causing undue friction. Unit should be pulled and replaced.
		5. Locked pump.	(a) Sometimes locked pumps can be "freed" by reversing rotation. (b) If there is no check valve, clean fluid can be pumped down tubing and through pump to remove debris. (c) Acid can be pumped through pump if scale is the problem.
		6. Unit in bind due to crooked place in well bore.	(a) Raise or lower unit to straight portion of well bore.
		7. Pump start-up attempted while pump back-spinning.	(a) Can occur trying to start pump too soon after shutdown without check valve or if check valve is leaking. (b) Always make certain pump is not back-spinning before trying to restart.

System Condition	Apparent Problem	Possible Causes	Action Required and/or Corrective Measures
3.3.2 (Continued		8. Blown fuses.	(a) Check incoming voltage-all 3 phases. (b) Check line fuses and motor control panel fuses. Repair or replace as required.
		9. Improperly set or faulty overload relays.	(a) Check and reset, repair or replace as required.
		10. Electrical fault in system.	(a) Disconnect power cable at junction box and check down hole cable for shorts. (b) If short found, equipment must be pulled. (c) If no short is found, check surface power system for shorts.
	c. Motor control panel will not operate. *CAUTION:* Test To Be Performed by Qualified Personnel	1. No power to motor control panel.	(a) Check fuses on primary system transformer and main switch. (b) Check voltage at potential transformer. (c) Check control circuit fuses.
		2. Loose, dirty or open electrical contacts and/or terminals.	(a) See that overload relay contacts are clean and closed. May be checked with ohmmeter to determine if contacts are solidly closed. (b) Check all other relay contacts and door interlock switches for correct operation. (c) Check all terminal screws at relays, door switches, and terminal strips.
		3. Open circuit on remote control, float switches or pressure switches.	(a) Check continuity on all such circuits. (b) If remote control has been used and later removed, make certain that the proper jumper is in place in the motor control panel.
		4. Defective solid state unit.	(a) Test unit per manufacturer's instructions.
		5. Improperly installed auxiliary equipment.	(a) Check for auxiliary equipment improperly connected to the electrical system.

4 Maintenance

4.1 PREVENTATIVE MAINTENANCE WITH WELL DOWN AND WITH PRIMARY POWER DISCONNECTED

4.1.1 The following preventative maintenance should be done periodically on a scheduled basis, the frequency dependent on the severity of the environmental and operating conditions. This may be scheduled to be done while the well is down for other reasons.

4.1.2 Perform test of cable and motor to determine resistance to ground and phase-to-phase. Phase-to-phase readings must be balanced.

4.1.3 Motor Control Panel Check and Maintenance

a. The motor control panel should be cleaned periodically to remove moisture and dirt.
b. The door seal should be checked and replaced, if necessary, to insure a seal against dirt and moisture.
b. Electrical contacts, lights, and connections should be checked and cleaned.

4.1.4 Transformer Checks and Maintenance

a. Check transformer for oil leaks, corrosion, broken insulators, loose connections, and overall condition of transformer case.
b. The transformer oils should be checked by an industry accepted standard. Frequency of testing depends upon local conditions.
c. If the oil is below minimum industry standards, it should be filtered or replaced.

4.1.5 Electrical Connections and Ground Wires

a. Regular routine checks should be made of all electrical connections to insure they are clean and secure. This should include connections at the junction box, motor control panel and wellhead.
b. The ground wires between all components and enclosures should be carefully checked for continuity and secure connections.

4.1.6 Power Factor Corrections

a. An analysis of the power factor for the system should be made periodically (see 4.2.2).
b. Corrective action should be taken, as necessary.

4.2 PREVENTATIVE MAINTENANCE CHECKS WITH SYSTEM OPERATING

4.2.1 Wellhead Cable Packoff

a. The wellhead cable packoff gland should be carefully inspected periodically to determine if the seal is leaking.
b. If leakage is detected. corrective action should be taken.

4.2.2 Power Factor Analysis

a. Power factor determination is important because a poor power factor results in damage to the motor due to excessive voltage drop.
b. Low voltage at the cable and motor increases the current in both and, therefore, reduces the life of each component.
c. A poor power factor also results in increased electrical power costs.

4.2.3 Ammeter Maintenance

a. Ammeter should be checked for proper calibration.
b. Check the ammeter pen for cleanliness and proper operation.

4.3 EQUIPMENT AND SYSTEM MAINTENANCE

4.3.1 Corrosion and Scale

a. Acid soluble scales in the production equipment can be removed by pumping acid down the tubing and through the pump, providing a check valve is not installed in the tubing.
b. Corrosion inhibitors, protective coatings or special metallurgy should be considered if corrosion is a problem. If protective coatings are used, they should be carefully checked for integrity if equipment is pulled.

4.3.2 Sand

a. If sand production is evident, proper action should be taken to minimize its effect upon equipment.
b. When equipment is pulled, the well should be checked for fill and be cleaned out, if required.

4.3.3 Cable Maintenance

a. Replace defective sections of cable as needed.
b. Where possible, a standby cable should be kept for immediate cable replacement. Standby cable should be stored in accordance with 2.4 of API Recommended Practice 11R.

4.3.4 Tubing Maintenance

a. Replace any deteriorated or damaged tubing.

4.3.5 Production and Testing Facilities

a. Periodically check test vessels and related equipment to insure proper operation.
b. Periodically check test manifolds, solenoid valves and piping to insure integrity and proper operation.

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