SUBMERSIBLE ELECTRICAL PUMP AMMETER CHART INTERPRETATION

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INTRODUCTION

To protect the investment in a submersible pump all facilities available must be used to insure against premature unit failure. A combination of common oilfield test procedures, including the recording of fluid volumes, pressures, unit voltages, and amperages can provide the desired insurance.

A correctly designed submersible pump will provide a relatively maintenance-free, long duration operation. The usual cause of premature failure of a properly designed unit is an unattended correctable mechanical malfunction which results in downhole failure. It is, therefore, mandatory that each unit be properly and rigorously monitored in order that these malfunctions be corrected before premature failure occurs.

One of the most valuable and least understood tools available is the recording ammeter. The ammeter chart, much like a physician's electrocardiogram, is a recording of the "heart beat" of the submersible electrical motor. Proper, timely and rigorous analysis of amp charts can provide valuable information for the detection and correction of minor operational problems before they become costly major ones.

This paper deals with the proper interpretation of ammeter charts and their interrelationship with other guides in the trouble-shooting and preventive maintenance of electrical submersible pumps.

PUMPING SYSTEM

An electrical submersible pump package is typically comprised of six major components: (See Fig. 1)

1. One or more transformers providing the proper surface power, (transformer bank)
2. One motor control panel housing the necessary switchgear and surface controls necessary for operation, (switchboard)
3. A length of three-conductor, special power transmission cable to link power from the switchboard to the motor
4. One or more (in tandem) electrical submersible three-phase, two-pole, constant speed induction motors (motor)
5. One motor to bore fluid isolation section, (seal)
6. One or more (in tandem) submersible centrifugal pumps, (pump).

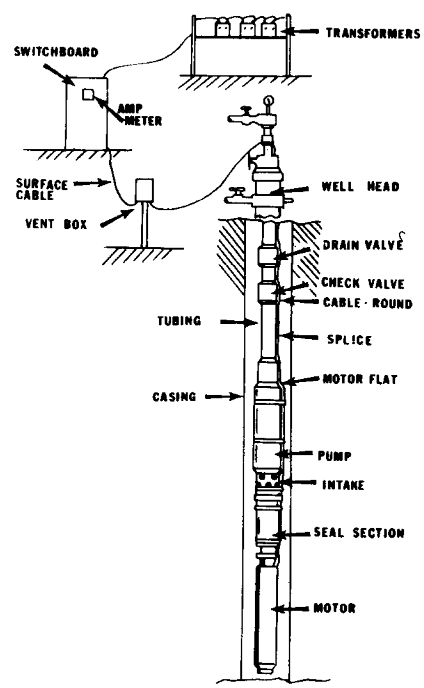

FIG. 1—PUMPING SYSTEM

SWITCHBOARD

The typical switchboard is constructed in two major sections; the high voltage compartment and the low voltage compartment.

The high voltage side is comprised of four basic elements; the surface power input cable, the contactor, a reducing current transformer, and the downhole power output cable. The input power circuit is opened or closed by the contactor, thereby supplying the power to the motor via the downhole cable. The current transformer supplies low voltage, usually 110V to the low voltage controls in the board.

The low voltage side provides the necessary controls to activate the contactor. These controls monitor one essential variable, the amperage. The controls consist of three manually reset current-sensitive circuit breakers, called overload relays (one on each leg) activated by current over a preset level, and one automatically resetting current-sensitive circuit breaker, called the under current relay (one on one leg) activated by current under a preset level.

Activation of any of the overloads causes briefly delayed deactivation of the contactor, resulting in complete unit shutdown. No automatic restart circuits are activated.

Activation of the undercurrent relay causes deactivation of the contactor and instant shutdown of the unit. An automatic restart sequence then begins through a timing relay, and restart occurs. During restart, the undercurrent relay is blocked from the circuit for a brief period by a second timing relay. The automatic restart sequence may be bypassed by use of the hand-off auto switch located on the switchboard.

The amperage is recorded from one power leg and displayed on the ammeter chart.

RECORDING AMMETER

The recording ammeter is located visibly on the switchboard. (See Fig. 1). Its function is to record the input amperage of the motor. This is done by the use of a reducing current transformer coupled to one leg of the cable inside the switchboard. The linearly reduced amperage is then plotted on a circular chart whose grid carries the proper abscissa multiplier to indicate the actual cable amperage. A typical circular ammeter chart is shown in Fig. 2.

A properly designed combination of these components will provide the desired fluid production. When a change in equipment operation or well characteristics occurs, the interaction between these components will be upset. In these cases, the imbalance is reflected on the recording ammeter chart. The following text deals with the interpretation of ammeter charts, and from that, possible system corrections to avoid premature unit failure.

AMMETER CHART ANALYSIS

Assuming that the recording ammeter is functioning properly, a number of changes in operating conditions may be defined by proper interpretation of the amp chart. Some of these potentially damaging conditions are:

1. Primary power line voltage fluctuations
2. Low amperage operation
3. High amperage operation
4. Erratic amperage operation

NORMAL OPERATION—FIG. 2

A characteristic of three-phase two-pole constant speed induction motors under a nonvarying load is the constant amperage drawn. An ideal submersible installation is designed such that the actual horsepower to be used is within approximately 10% of the rated nameplate horsepower, and such that the total dynamic head and producing rate vary from actual to design by approximately 5%. Under these conditions the ammeter should draw a smooth symmetrical curve at an amperage near nameplate. Figure 2 illustrates ideal conditions. Standard operations may produce a curve above or below nameplate amperage but it should be a smooth symmetrical one to be considered ideal. The spike on start-up extends the full swing of the pen. This is a common occurrence.

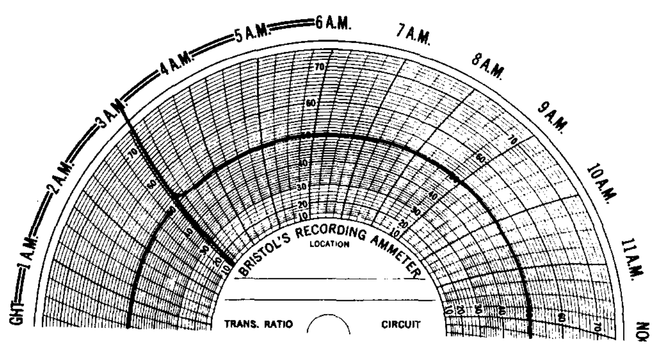

FIG. 2—TYPICAL AMMETER CHART, NORMAL OPERATION

POWER FLUCTUATIONS—FIG.3

Under continuous normal operation, the power output by the motor remains relatively constant. Under this circumstance, the amperage varies inversely with the voltage. Consequently, if the primary power supply voltage fluctuates, the amperage will fluctuate in an attempt to retain constant horsepower output. The fluctuations will be reflected on the ammeter chart as in Fig. 3. The most common cause of power fluctuation is periodic heavy drain loading of the primary power system. Such a drain, or sag, may be caused by the start-up of a high horsepower injection pump. Occasionally, it may be a combination of smaller simultaneous drains. If this is the case, some effort must be made to respace these drains such that their combined impact is small. By correlating the fluctuations, it may be possible to determine the exact cause.

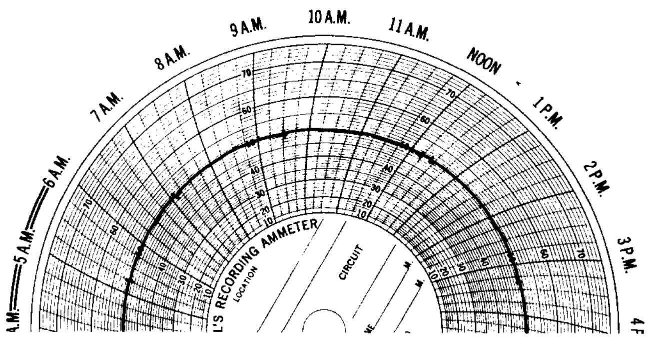

FIG. 3—AMMETER CHART, ILLUSTRATING POWER FLUCTUATIONS

GAS LOCKING—FIG.4

Figure 4 shows the chart of a pump which gas-locked and consequently shut down. Section A shows start-up. At this time the annular fluid level is high; thus, the production rate and amperage are accelerated slightly due to the reduced total dynamic fluid head. Section B shows a normal operating curve as the fluid level nears the design value. Section C shows a decrease in amperage as the fluid level falls below design and fluctuation as gas begins to break out near the pump. Finally, Section D shows erratic low amperage as the fluid level nears the pump's intake. Cyclic loadings of free gas and slug fluid eventually cause undercurrent shutdown of the unit.

It is possible to remedy this situation by lowering the pump to a point where gas breakout is low enough to permit continuous operation. 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. If neither of these avenues are possible, 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.

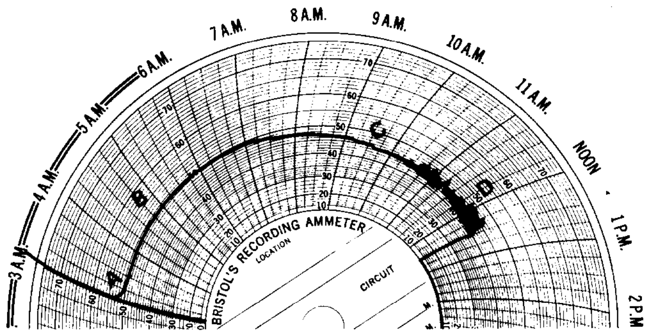

FIG. 4—AMMETER CHART SHOWING SHUTDOWN DUE TO GAS LOCKING

FLUID PUMP-OFF CONDITIONS—FIG. 5

Figure 5 shows the chart of a unit which has pumped off and shut down on undercurrent, restarted automatically and shut down for the same reason.

Analyses of Sections, A, B, and C are identical to that for gas-locking except no free gas breakout fluctuations are evident due to the assumption of no gas present. In Section D the fluid level approaches the pump intakes, and the rate and amperage decline. Finally, the preset undercurrent level is reached and the unit drops off line. As was outlined, when a unit drops off line due to undercurrent, an automatic restart sequence is triggered. As is shown, 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 somewhere in Section C.

The problem revolves around the fact that the unit is too large for the application. Remedial action is the same as that for gas-locking, plus one more. A stimulation treatment may enhance the productivity of the well to suit the unit.

If the unit is to be lowered, 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.

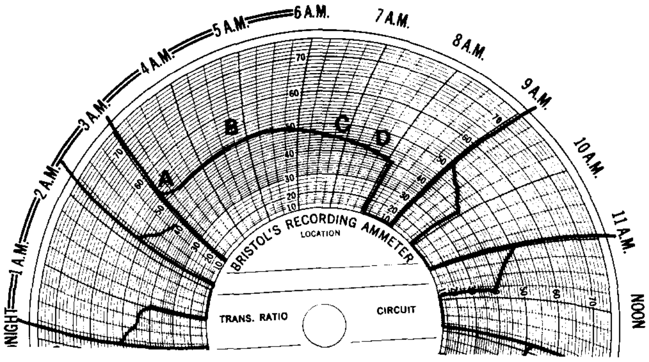

FIG. 5—AMMETER CHART SHOWING FLUID PUMP-OFF CONDITIONS

FLUID PUMP-OFF CONDITIONS—RESTART FAILURE—FIG. 6

Figure 6 shows a 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.

Analysis of this plot is similar to that for pump-off of fluid conditions except that the auto-restart delay is not of sufficient length to allow adequate annular fluid buildup for loading the pump on alternate restart attempts. Remedies are also similar.

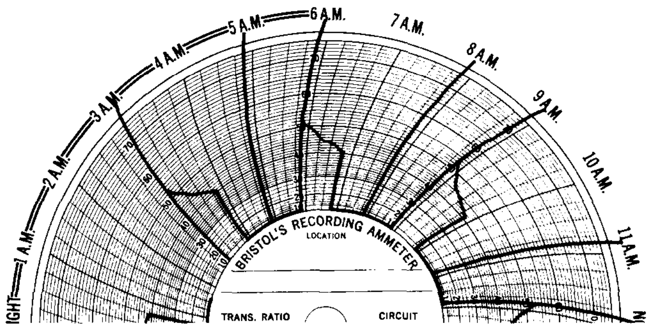

FIG. 6—AMMETER CHART SHOWING FLUID PUMP-OFF CONDITIONS WITH RESTART FAILURE

FREQUENT, SHORT DURATION CYCLING—FIG. 7

Figure 7 shows a chart similar to that of fluid pump-off conditions except that the running times are more brief and the cycles more frequent. This configuration chart usually applies to a unit which is too large for the application. However, if the productivity of the well appears to be compatible with the unit, other problems may cause a similar plot.

Corrective action would consist of fluid level determination immediately after unit shutdown. If the sounding shows fluid over the pump, a check for unusually high tubing pressure should be made. If the discharge line is plugged or a valve is closed against the flow, a reduction in fluid production should occur, accompanied by a drop in amperage. If the discharge pressure is reasonable or low, check for low fluid production rate immediately after pump-up. An abnormally low rate may be caused by a tubing leak. Generally, a tubing leak near the surface will result in reduced fluid to surface and accompanying reduced amperage.

This type of operation is extremely detrimental to submersible motors and should be corrected immediately.

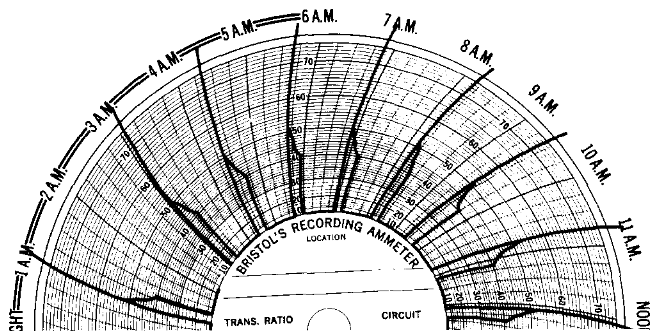

FIG. 7—AMMETER CHART ILLUSTRATING FREQUENT, SHORT DURATION CYCLING

GASSY CONDITIONS—FIG.8

Figure 8 shows the chart of a unit which is operating near designed levels, but which is handling some gas.

The fluctuation is caused by entrained and free gas punctuating heavier fluid production. This condition is usually accompanied by a reduction in total fluid production (actual stock tank barrels).

A submersible pump will attempt to pump whatever is present at the pump intake. It will attempt to pump the predesigned number of barrels of whatever fluid is available, including gas. With this in mind, one barrel of gas represents a very small stock tank contribution, but represents a substantial volume through the pump.

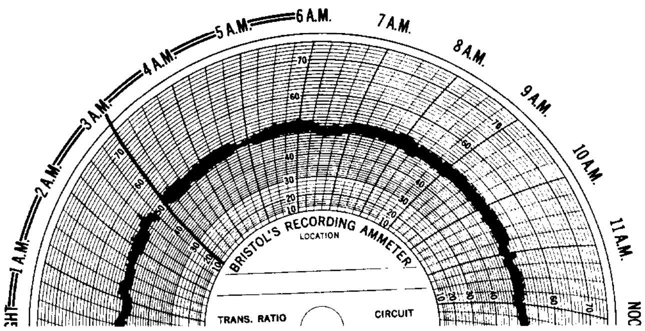

FIG. 8—AMMETER CHART SHOWING GASSY CONDITIONS IN THE SUBMERSIBLE PUMP

IMMEDIATE UNDERCURRENT SHUTDOWN—FIG. 9

Figure 9 shows a chart of a unit which is starting, running a very short time, and shutting down due to undercurrent. This cycle is repeated by the automatic restart sequence. Generally, this type curve is caused by fluid lacking sufficient density or volume to load the motor to an amperage above the undercurrent setting. If productivity tests show fluid available at the pump intake, it is possible to rectify this problem by lowering the undercurrent shutdown amperage. This job is best left to the pump company representative. It is not recommended that the undercurrent relay be adjusted by field personnel. Another cause of this type curve is failure of the timing relay used to block the undercurrent relay from the control curcuit during the automatic restart sequence. This problem is best rectified by the pump company representative.

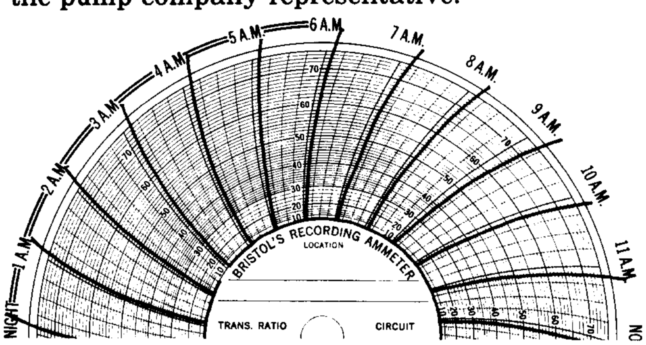

FIG. 9—AMMETER CHART INDICATING IMMEDIATE UNDER CURRENT SHUTDOWN

UNDERLOAD SHUTDOWN FAILURE—FIG.10

Figure 10 shows a normal start-up followed by a decline in amperage to the no-load idle amperage of the motor. Finally, after a period of loadless operation, the unit faults on overload.

This curve is typical of a unit oversized for the application. The unit eventually pumps the well down to a point where the undercurrent relay should drop the unit off line. In this case, however, the undercurrent relay failed or was preset below idle amperage of the motor. With the fluid production retarded, the motor ran at idle until heat buildup caused a motor or cable burn. It is to be noted that fluid passage by the motor provides cooling mandatory for submersible operation.

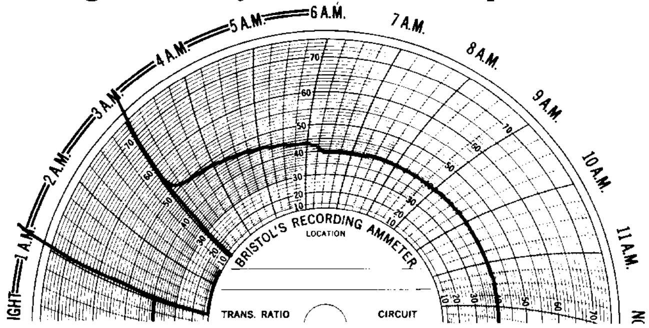

FIG. 10—AMMETER CHART INDICATING UNDERLOAD SHUTDOWN FAILURE

TANK LEVEL CONTROLS—FIG. 11

Figure 11 shows a plot of a unit which is being controlled by a tank switch. The switch drops the unit off line and starts the auto-restart sequence. This type of operation is normal, but the focus should be made on the restart delay. In this case, the delay is far too short. 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. A minimum of 30 minutes is required to insure against backspin by allowing all fluid levels to stabilize. A convenient way to insure against this is to set the auto-restart delay timer above 30 minutes and use the H-O-A switch on the switchboard for an automatically delayed start.

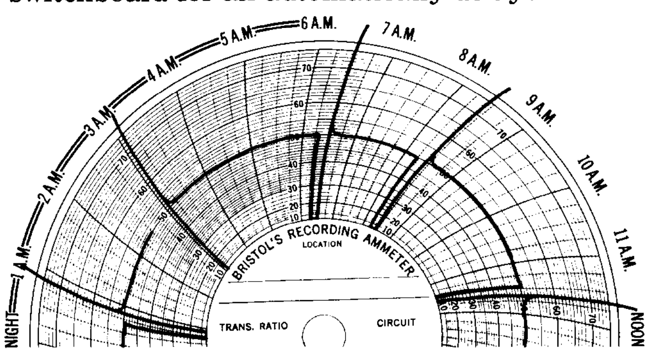

FIG. 11—AMMETER PLOT FOR PUMP CONTROLLED BY TANK SWITCH

NORMAL OVERLOAD CONDITIONS—FIG. 12

Figure 12 shows a chart of a unit which has shut down due to overload (high current) conditions.

Section A of the curve shows start-up at some amperage below nameplate (normal for some unit configuration) and gradually rising to normal. Section B shows the unit running normally. Section C shows a gradual rise in amperage until the unit finally drops off line due to overload. Until the cause of this overload has been corrected, restart should not be attempted. Automatic restart sequences are not instigated due to the manual reset required by the overload relays. Before restart of the unit, it should be thoroughly checked by the pump company representative.

Common causes of this type shutdown are increases in fluid specific gravity or viscosity (such as heavy brines or muds), sand production, emulsions, or mechanical problems such as lightning, motor overheat or wearing equipment.

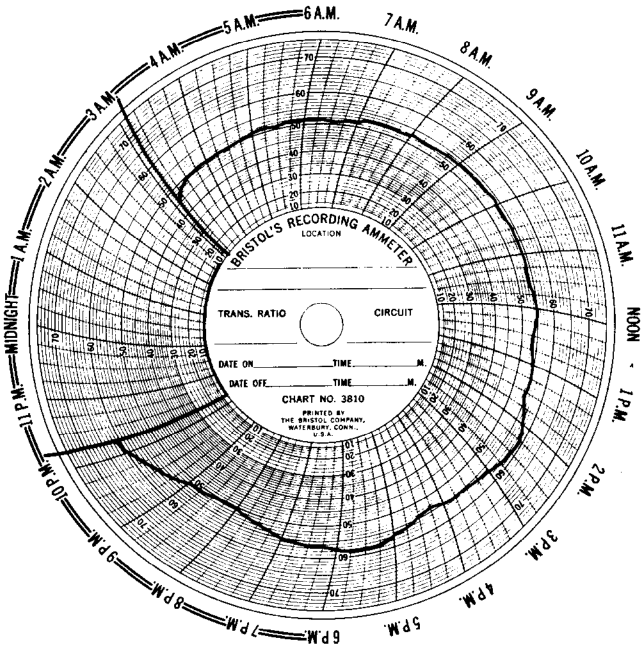

FIG. 12—AMMETER RECORDING SHOWING NORMAL OVERLOAD CONDITIONS

DEBRIS PUMPING CONDITIONS—FIG. 13

Figure 13 shows a unit which started, pumped erratically for a short period, and then proceeded under normal conditions.

This type operation is expected when cleaning a well of such debris as scale, loose sand and weight muds or brines. This type operation is not unusual, but is not recommended where avoidable.

Keeping in mind that the actual horsepower required is a multiple function of the specific gravity of the fluid, if it becomes necessary to kill a well use the lightest possible brines and consult the vendor on start-up horsepower. The vendor can determine if the motor is of sufficient size to "clean up" the kill fluid.

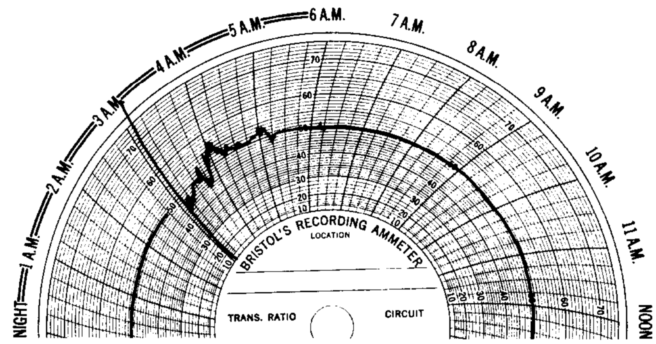

FIG. 13—AMMETER CHART INDICATING PUMP IS HANDLING WELL DEBRIS

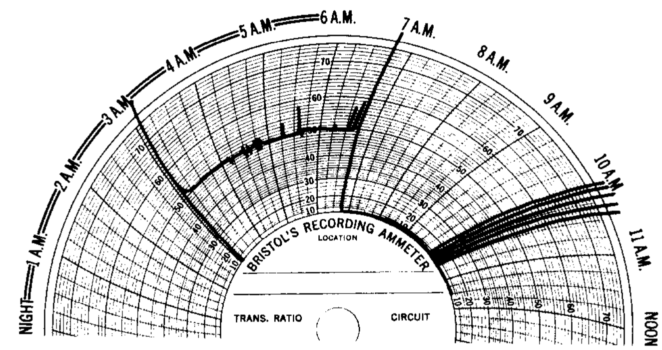

FIG. 14—ILLUSTRATION OF AMMETER RECORDING WHEN EXCESSIVE MANUAL RESTARTS ARE ATTEMPTED

EXCESSIVE MANUAL RESTART ATTEMPTS—FIG. 14

Figure 14 shows a relatively normal chart until power fluctuation kicks are noticed. The unit dropped off line due to overload. Manual restarts were attempted. If a single manual restart attempt fails under these conditions, the unit should be checked by a pump company representative. In this case a power fluctuation, such as lightning, caused the unit to shut down. When the unit did not start, the cause of the failure should have been sought elsewhere. If, for example, a primary line disconnect has been burned, the unit will attempt to restart under single-phase conditions, immediately shutting down. This type restart attempt will eventually destroy the equipment.

ERRATIC LOADING CONDITIONS—FIG. 15

Figure 15 exhibits an unpredictably varying plot. This type plot 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 would not automatically restart. Manual restart should not be attempted until the unit is thoroughly checked by a vendor serviceman and the cause of the problem solved.

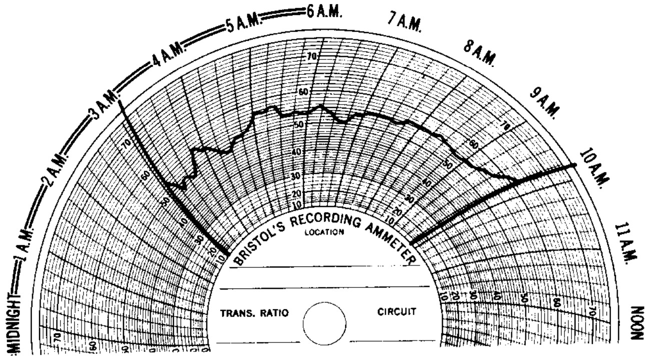

FIG. 15—AMMETER RECORD ILLUSTRATING ERRATIC PUMP LOADING CONDITIONS

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).

SUMMARY

The previous discussion has developed, by the use of examples, certain guidelines for the interpretation of submersible pump ammeter charts. Not all configurations can be described in detail and related back to component causes. However, those which can may be used by the alert individual to avoid premature unit failure.

It is hoped that through the proper inspection of ammeter charts longer and more profitable runs can be realized for electrical submersible pumps.