Dynamometer Testing for Analyzing the Pumping Well Problem

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ABSTRACT

Oil produced by pumping wells is a major source of income to the petroleum industry. The continual increase in operating and repair costs of pumping equipment has required more efficient and economical operation, in order to maintain a satisfactory margin of profit.

Since the pumping well problem is often complicated, accurate analysis requires an exact and complete test procedure, and a thorough study of well data and test results.

In order to facilitate testing of the problem pumping well, an organized dynamometer test procedure is presented. This procedure may serve as a reference guide for the seasoned dynamometer operator and may assist in the training of new and inexperienced personnel. The test procedure is designed to guide the well study from the time the tester is notified of the pumping well problem to the final diagnosis.

Along with problem location and repair, elimination of the cause should be carefully considered. To assist in this phase of study, a summary of the common subsurface problems, causes, and remedies is presented.

INTRODUCTION

As simple as the pumping system may seem, it is actually a complex grouping of equipment. There are numerous points within the system where major and minor problems may exist to cause inefficient and expensive operations. Well capacity, fluid characteristics, foreign material, and gas can cause additional problems. The location, repair and elimination of these problems are among the responsibilities of the production personnel.

The dynamometer and related tests have furnished valuable information which have assisted in maintaining pumping systems at peak operational levels.

This paper is not presented as an introduction to dynamometer application. The organized test procedure is offered as a suggested guide for improvement of pumping well study programs which involve dynamometer work. To the operator without a well weighing program, this paper may offer a review of many of the uses and values of a dynamometer.

DISCUSSION

The organized test procedure was constructed to aid in training and guiding the inexperienced engineer or tester in the field application of the dynamometer. When the test system was used in field work, it was found to be beneficial in other ways. Several of these benefits are listed below.

1. A reference and field test guide.
2. A method of testing that results in problem analysis at the well.
3. A reduced possibility of incomplete test operations.
4. A diagrammatic picture of problems and effects which assists in explaining problems and planning corrective measures with other field personnel.
5. A method of improving the efficiency of field personnel through a better understanding of the pumping operation.

The dynamometer has played, and will continue to play, an important role in the study and operation of pumping wells; but, like any other instrument, it is only as effective as the personnel who use it. The dynamometer tester has relied on memory and experience for test procedure and problem analysis. A procedure based on memory may present two definite obstacles: 1., details of the test may be overlooked, necessitating a retest or resulting in problem misinterpretation; and 2., instructions to inexperienced personnel may be inadequate. The organized test procedure may help in removing these obstacles.

Since the dynamometer furnishes a continuous recording of the polished rod load only, additional well tests not involving use of the dynamometer are recommended throughout the organized test procedure. These special tests must be made if the well test is to be complete.

It must be remembered that problem location and repair would offer only temporary relief if the cause of the problem were not eliminated. Neglecting to locate and remove the cause of the problem is often responsible for unnecessary lifting costs. When a well equipment failure is found, the type of failure should be studied and every reasonable effort made to locate and remove the circumstances that caused such a failure.

The summary of common subsurface pumping problems, causes, and remedies is included in this paper to assist the field personnel in planning operational and mechanical design improvements.

APPLICATION

The application of the systematic approach to pumping well testing will generally be conducted as follows:

1. Gather data and complete preliminary calculations.
2. Install the dynamometer and weigh the well.
3. Classify the dynamometer card and consult the proper test procedure.
4. Test as directed.

A study of the well data and calculated loads will often give a definite insight into the pumping characteristics of the well. With this background, the tester is better prepared to analyze the production operation. Calculations and actual measurements often will not be similar, but the indicated difference can either be explained by the fluid characteristics or can be a guide to the proper approach for problem understanding. A thorough knowledge of well equipment and operation is necessary to organize corrective and preventive action.

The well weighing operation should be conducted carefully and as slowly as may be necessary. In many cases, weight diagrams must be taken for several hours if a true recording of load behavior is to be obtained. Lack of patience during the test operation often is responsible for problem misinterpretation. The systematic approach to a dynamometer study of pumping wells emphasizes the importance of static weight measurements, i.e., the traveling valve and the standing valve measurements. Every precaution should be taken to insure that the dynamometer is utilized to its fullest advantage: this should include the recording of valve measurements on every card.

Problem analysis will be dependent upon a complete and accurate well weighing operation. Field test precautions, such as checking the standing valve below the point of fluid pound, bringing the unit to a smooth stop when making static weight tests, and rechecking valve weights several times to insure accurate recordings are necessary, if dependable measurements are to be obtained. It is recommended that a standard three quarter stroke position be used for the valve checks. Checks at other positions can be made as required. A standard one second interval between load recordings for valve leak checks would be beneficial also. These standards would permit each person involved in the well study to work from the same basis.

The dynamometer card classification, for application to the organized test system, is based on a comparison of the calculated and the measured polished rod loads. The procedure of superimposing the calculated traveling valve and standing valve loads over the actual measured loads on the dynamometer card is recommended. This procedure is shown in Fig. 1. The relationship or variation between the calculated and measured loads will determine the card classification and, in turn, determine the recommended test procedure. The following basic formulae are used in load comparison:

1. Weight of the fluid measured:

$$W_f = W_{rf} - W_r$$

W_f = Weight of the fluid measured, lb.
W_r = Weight of rods measured, lb. (Standing valve measurement)
W_{rf} = Weight of rods plus fluid measured, lb. (Traveling valve measurement)

2. Weight of the rods plus fluid calculated:

$$W_{rfc} = W_{rc} \quad W_{fc}$$

W_{rfc} = Weight of rods plus fluid calculated, lb.
W_{fc} = Weight of fluid calculated, lb.
W_{rc} = Weight of rods calculated, lb.

For classification purposes, dynamometer cards are divided into five general catagories. These catagories are listed below.

1. Valves good, fluid weight satisfactory.
2. Valves good, fluid weight less than satisfactory.
3. Indicated valve leaks.
4. Only one valve recorded.
5. Abnormal load.
   a. Indicated by valve measurement.
   b. Indicated by card shape, valves good, fluid weight satisfactory.

The last catagory, abnormal load, is divided into two sections in order to include vibration and speed problems in the test system which is based primarily on static weight measurements. Hundreds of dynamometer cards were checked and without exception, each card was classified in one of the five catagories. Due to the complexity of pumping systems and the possibility that additional classifications may be required, the test diagram has been arranged to permit additions when warranted. Several cards have indicated dual problems and these problems have been processed in order of their importance.

The following examples illustrate several types of dynamometer cards and the method of classification.

Card A, Fig. 1

Visual inspection indicates that there is little difference between the calculated and measured polished rod loads. The measured loads do not indicate valve leakage since the static measurement remains constant. This card is classified as "valves good, fluid weight satisfactory".

Card B, Fig. 2

This card diagram shows that the static polished rod load on the downstroke is approximately equal to the calculated load; but the spread between the upstroke polished rod load and the calculated rod plus fluid load is great enough to be considered unsatisfactory. This load variation represents the difference in the

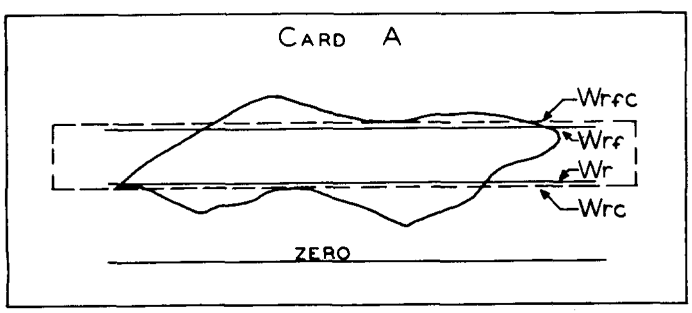


FIG. 1

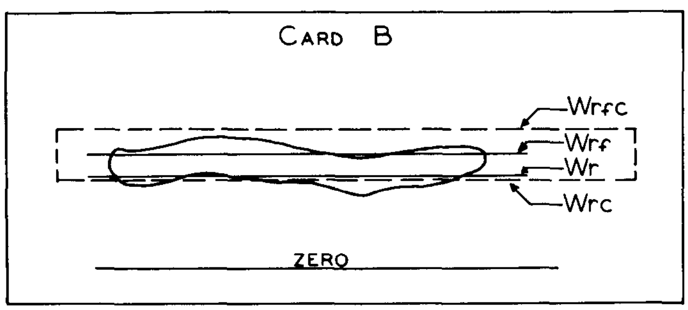


FIG 2

calculated and the measured fluid weight. Since there are no load changes to indicate valve leaks, the card is classified as "valves good, fluid weight less than satisfactory."

If this well were tested and the light fluid load were attributed to a cause such as gas production or high fluid level, adjustments in calculations on successive test operations could be made and the light fluid weight would be considered satisfactory.

Card C, Fig. 3

This card indicates a load loss during the traveling valve weight check. The load loss indicates a leak, and the card is classified as having an "indicated traveling valve leak."

Card D, Fig. 3

The diagram indicates the traveling valve and standing valve recorded by the same weight line. Close observation will reveal that an indicated traveling valve leak was recorded on the card by a near vertical weight loss line. This leak was severe enough to result in an instantaneous load change, and the card is classified as having an "indicated traveling valve leak." The need for accuracy in the dynamometer test operation is again emphasized in the classification of this card. If the dynamometer stylus had not remained in the recording position during the valve check, the instantaneous load loss would not have been recorded and the proper classification of the card might have been difficult.

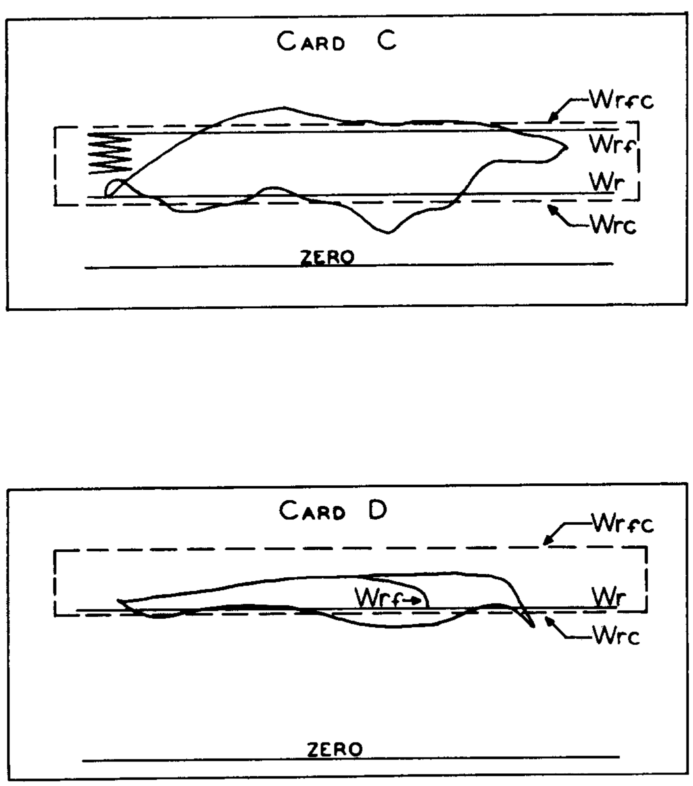


FIG. 3

Card E and F, Fig. 4

The two example cards depict situations in which the polished rod load remains constant throughout the stroke. Both the traveling valve and standing valve measurements are recorded on the same weight line. These cards are classified as "only one valve recorded". Calculation comparisons determine whether the recording indicated the continuous load to be either the rod weight or the rod plus fluid weight.

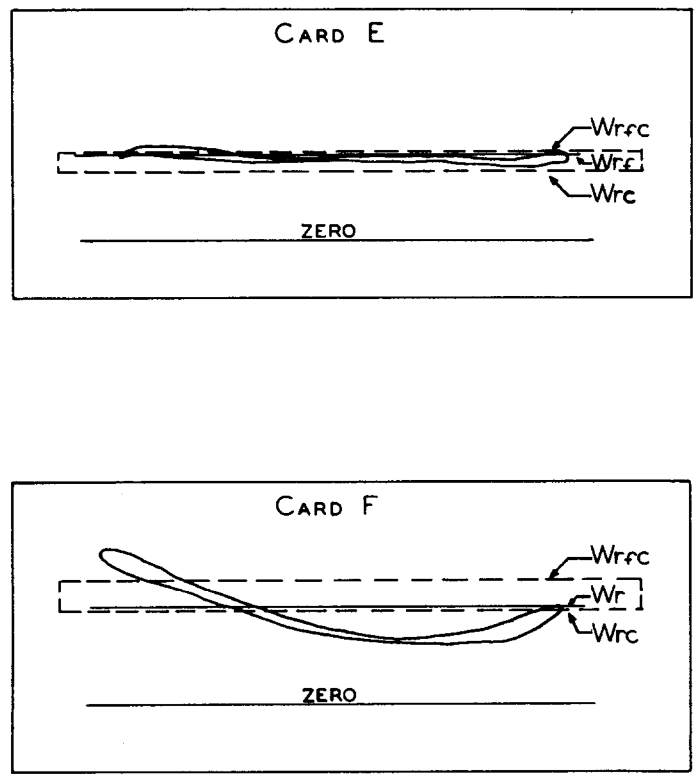


FIG. 4

Card G and H, Fig. 5

These two cards indicate situations in which abnormal loads exist. Abnormal loads are defined as loads where either the recorded rod load is questionably less than the weight of rods calculated, or the rod plus fluid load is considerably greater than the calculated rod plus fluid load. Comparison of the calculated and measured loads on these cards indicate that both the cards are classified as "abnormal loads, indicated by valve measurements."

Card I, Fig. 6

This card presents an example of a situation in which the valve and static weight measurements compare with the calculations, but the peak loads, indicated by the card shape, are irregular. This card is classified as an "abnormal load, indicated by the card shape, valves good, fluid weight satisfactory."

After the dynamometer card is classified, the proper test procedure covering the particular classification is consulted, the additional tests and calculations are

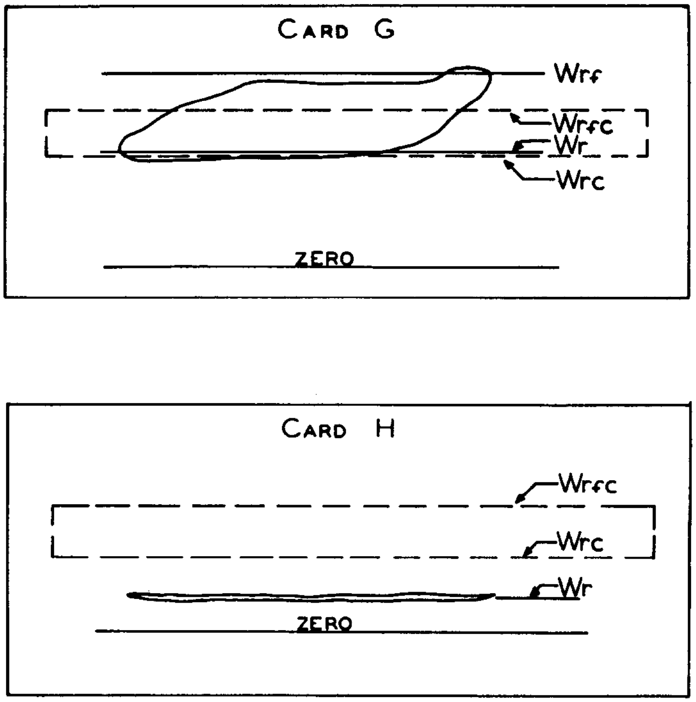


FIG. 5

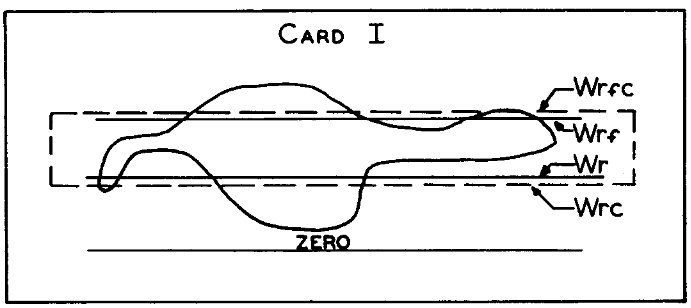


FIG. 6

completed as directed. Frequently the equipment design must be considered and the reference to mechanical design concerns a review of rod, pump, tubing and other equipment sizes and reactions to the existing loads. The reference to operational design pertains to a review of stroke length, stroke speed, pumping time and other operational conditions.

Processing the problem through the test procedure consists of following a routine of special test and calculation reviews in a prescribed sequence. As an example, the dynamometer card shown in Fig. 1 is used. This card is classified as "valves good, fluid weight satisfactory," and the test procedure shown on Page A is followed.

Initial test operations include taking weight recordings to determine whether or not the well will pound fluid. If it will not pound fluid, special measurements and valve checks are made to determine if a worn pump barrel or damaged balls and seats are causing a problem. If these troubles do not exist, the mechanical and operational designs are checked. Proper adjustments are made as required. A pressure test of the tubing would be conducted, if necessary, to check the possibility of a tubing leak.

Should the test procedure be completed without indication of mechanical problems, adjustment of operational design or compensation for gas handling procedures would then be recommended.

Other test procedures may be consulted and used in a similar manner. The card classification determines the test procedure to be used and the problem may be located by a process of elimination. A review of the preliminary data and calculations is suggested at various intervals throughout the test program.

SUMMARY

The dynamometer and related tests, when applied properly, can assist the production personnel in locating and solving pumping well problems. An organized pumping well test procedure is offered to aid in improving well test operations involving dynamometer application. This test program will offer special assistance to the new and inexperienced engineer or tester.

The removal of the cause of a problem is just as important as the location and repair of a problem. A summary of pumping well problems, causes and remedies is included in this paper to assist the production personnel in planning operational and mechanical design improvements.

ACKNOWLEDGEMENTS

Merryman, C. J. and Lawrence, K. D., "Systematic Approach to Problem Pumping-Well Testing." proceedings of the Spring Meeting of the Southwestern District API, (March 12-13-14, 1958). Paper No. 906-3-H.

Acknowledgement is made to Sun Oil Company for permission to present this paper.

A SYSTEMATIC APPROACH TO PROBLEM WELL TESTS

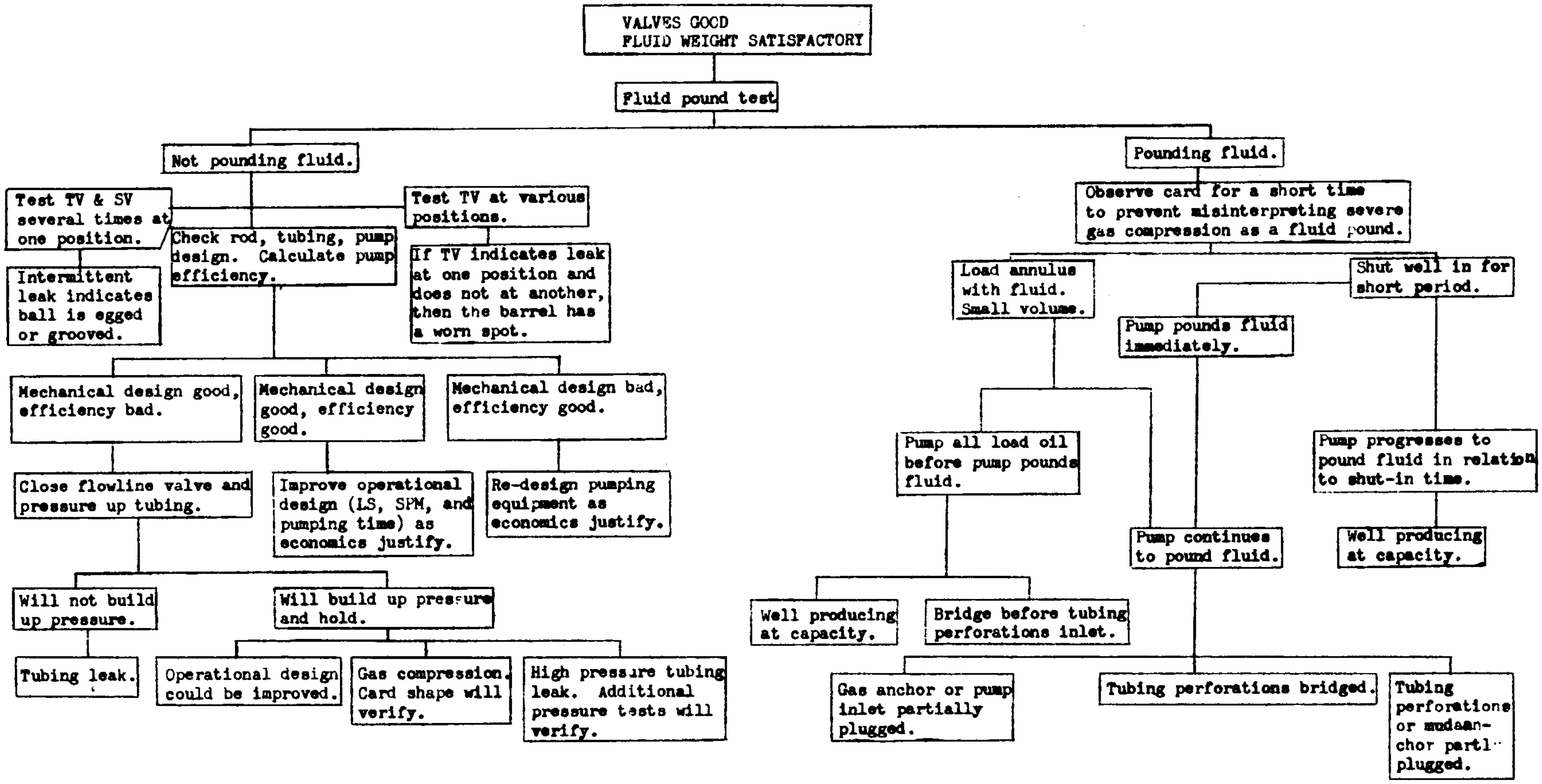
Information to be collected prior to weighing operation:

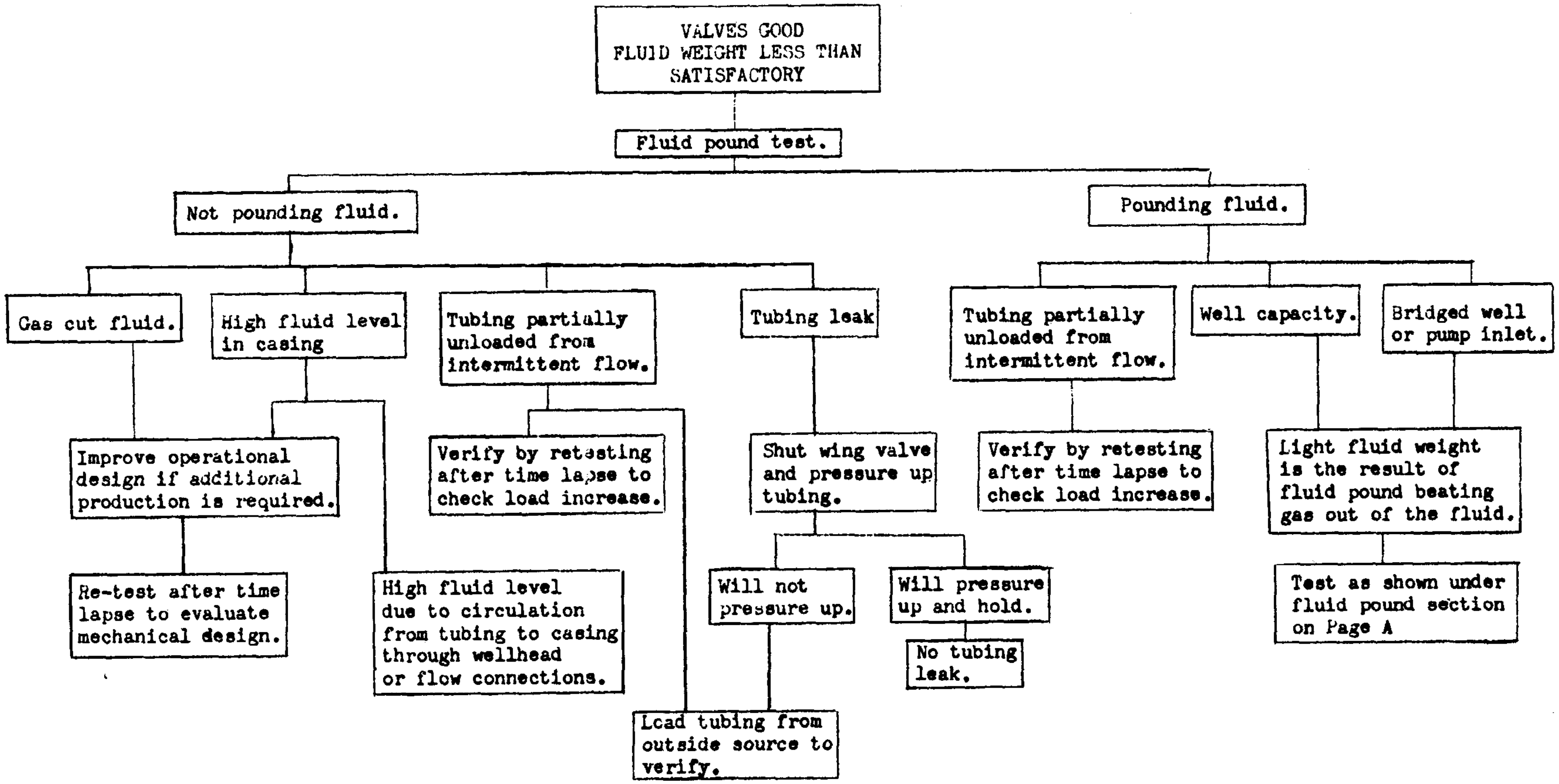
1. Production: daily oil, wtr, gas, and allowable.
2. Pump: size and type.
3. Rods: size and type, length of each size string.
4. Tubing: size, type and seat.
5. Mud anchor: size and type.
6. Gas anchor: size and type.
7. Producing interval and TD or PBTD.
8. Motor or engine: size.
9. Fluid: specific gravity.
10. Auxiliary equipment.
11. LS and SPM.
12. Pertinent well treating data.
13. Daily pumping time and schedule.
14. Power consumption.
15. Calculations: Rod weight in air.
    Rod weight in fluid.
    Fluid weight on pump(pounds).
    Volumetric pump capacity(bbls/day).

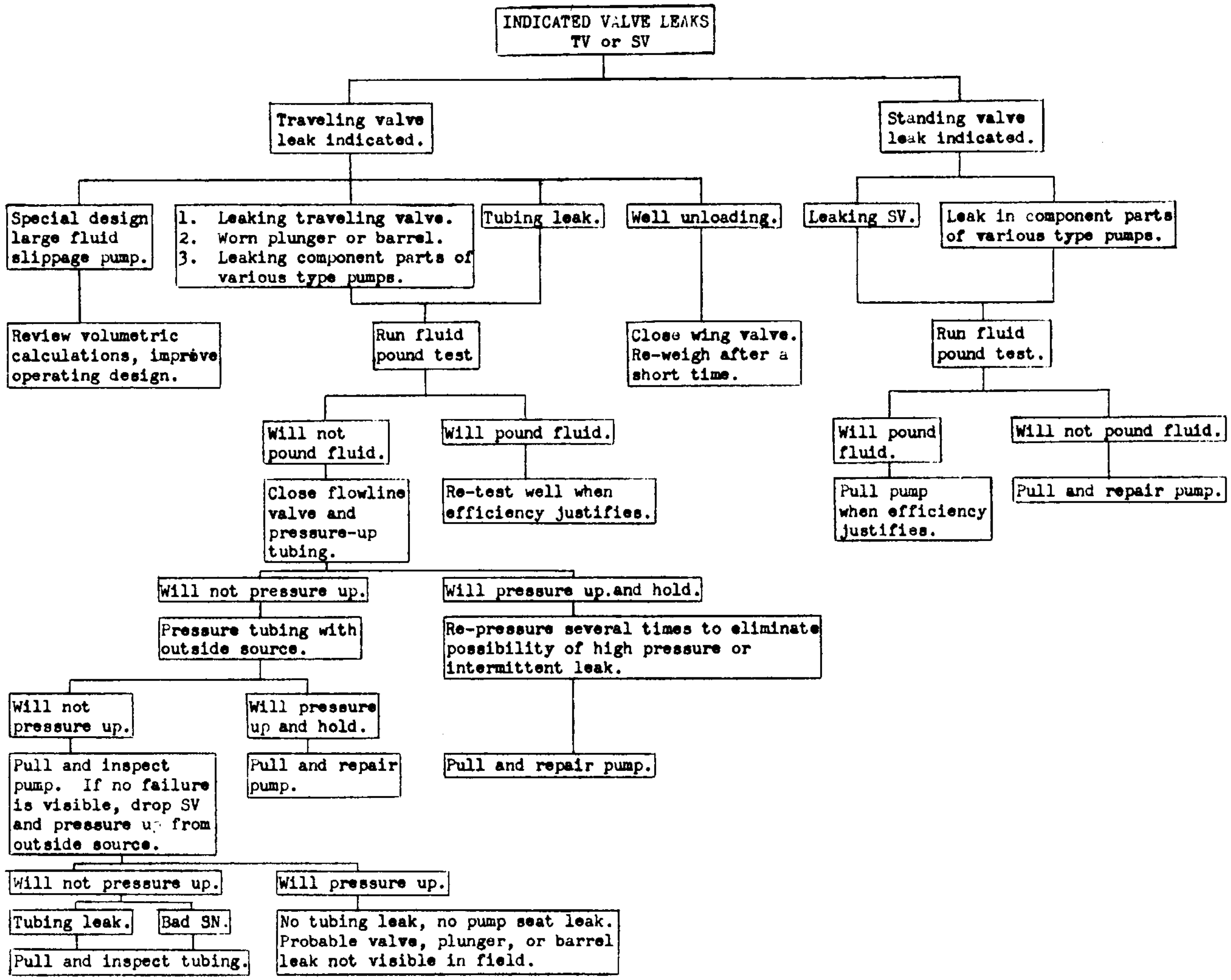
Weigh well, record load diagram, and make traveling valve and standing valve tests.

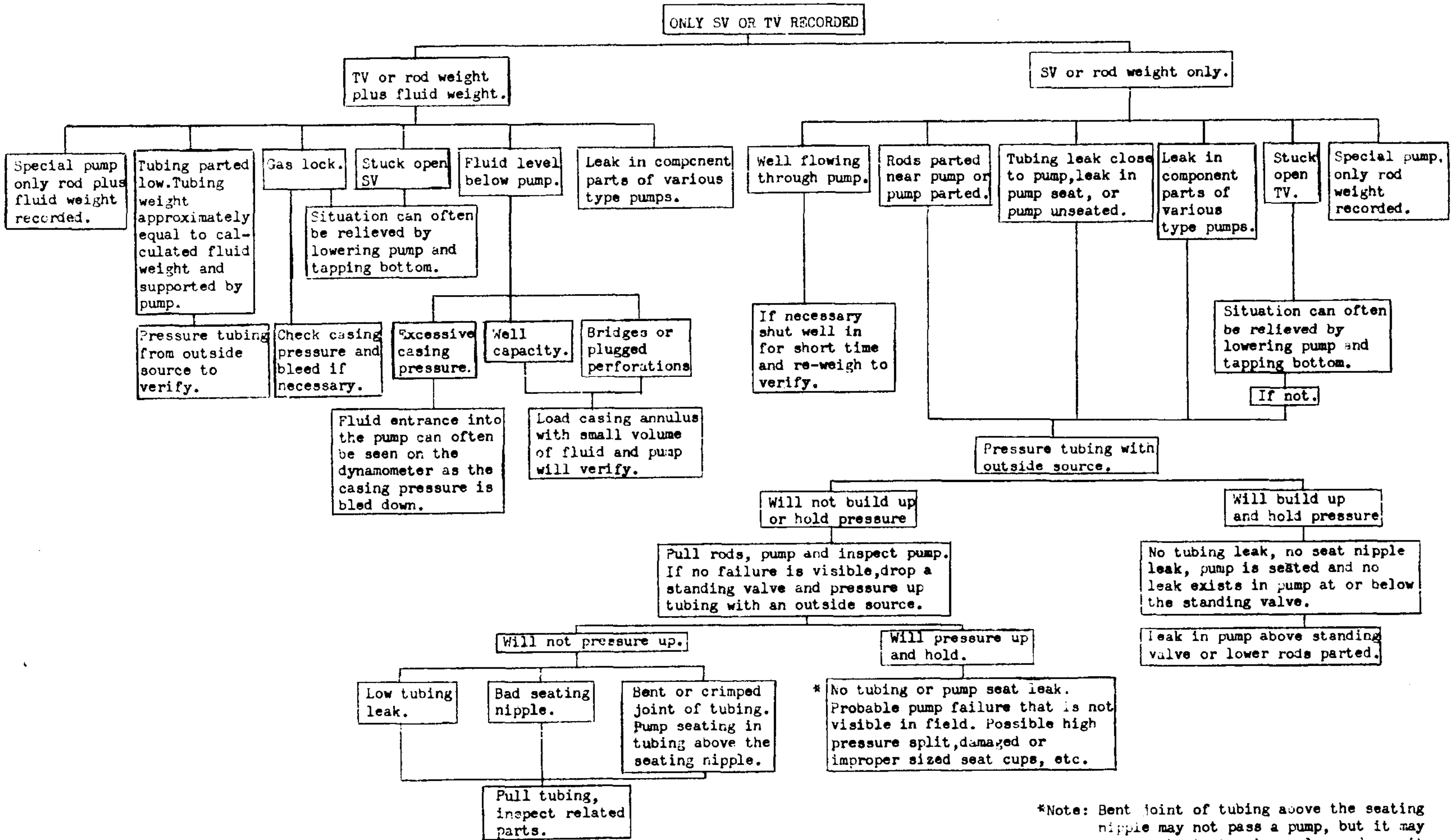
Classify card.

Valves good fluid weight satisfactory	Valves good, fluid weight less than satisfactory	Indicated standing valve(SV) or traveling valve(TV) leak	Only TV or SV recorded	Abnormal load
Page 215	Page 216	Page 217	Page 218	Page 219

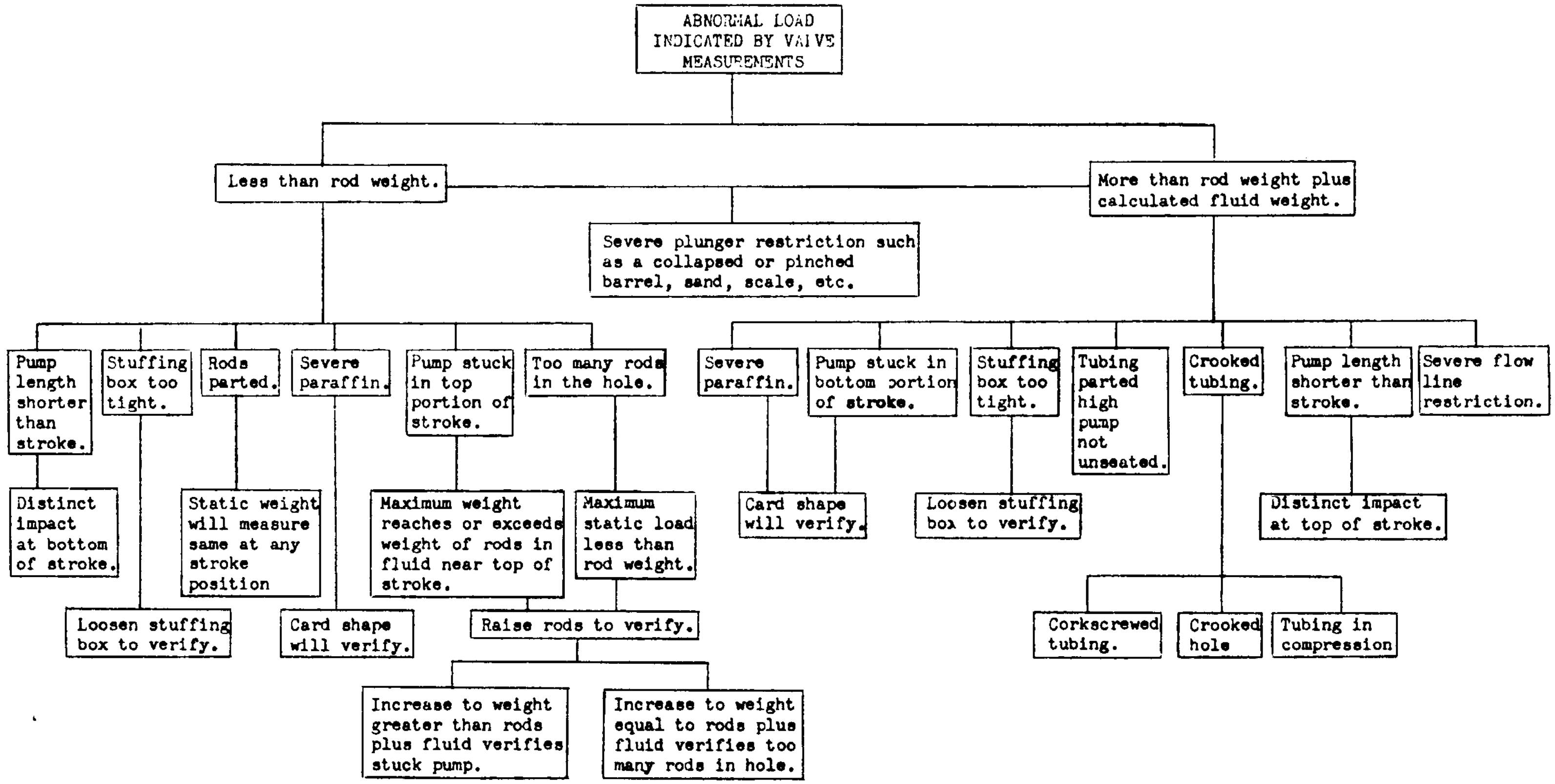

VALVES GOOD
FLUID WEIGHT SATISFACTORY
Fluid pound test
Not pounding fluid.
Test TV & SV several times at one position.
Check rod, tubing, pump design. Calculate pump efficiency.
Test TV at various positions.
Intermittent leak indicates ball is egged or grooved.
If TV indicates leak at one position and does not at another, then the barrel has a worn spot.
Mechanical design good, efficiency bad.
Mechanical design good, efficiency good.
Mechanical design bad, efficiency good.
Close flowline valve and pressure up tubing.
Improve operational design (LS, SPM, and pumping time) as economics justify.
Re-design pumping equipment as economics justify.
Will not build up pressure.
Will build up pressure and hold.
Tubing leak.
Operational design could be improved.
Gas compression. Card shape will verify.
High pressure tubing leak. Additional pressure tests will verify.
Pounding fluid.
Observe card for a short time to prevent misinterpreting severe gas compression as a fluid pound.
Load annulus with fluid. Small volume.
Shut well in for short period.
Pump pounds fluid immediately.
Pump all load oil before pump pounds fluid.
Pump progresses to pound fluid in relation to shut-in time.
Pump continues to pound fluid.
Well producing at capacity.
Well producing at capacity.
Bridge before tubing perforations inlet.
Gas anchor or pump inlet partially plugged.
Tubing perforations bridged.
Tubing perforations or mudanchor partly plugged.

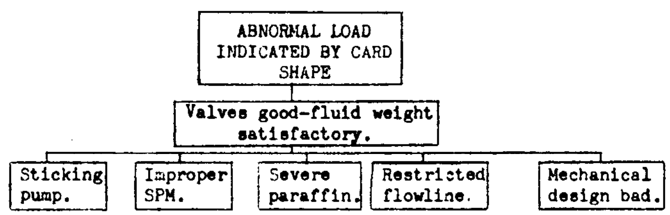

VALVES GOOD
FLUID WEIGHT LESS THAN SATISFACTORY
Fluid pound test.
Not pounding fluid.
Pounding fluid.
Gas cut fluid.
High fluid level in casing
Tubing partially unloaded from intermittent flow.
Tubing leak
Tubing partially unloaded from intermittent flow.
Well capacity.
Bridged well or pump inlet.
Improve operational design if additional production is required.
Verify by retesting after time lapse to check load increase.
Shut wing valve and pressure up tubing.
Verify by retesting after time lapse to check load increase.
Light fluid weight is the result of fluid pound beating gas out of the fluid.
Re-test after time lapse to evaluate mechanical design.
High fluid level due to circulation from tubing to casing through wellhead or flow connections.
Will not pressure up.
Will pressure up and hold.
No tubing leak.
Test as shown under fluid pound section on Page A
Load tubing from outside source to verify.


INDICATED VALVE LEAKS TV or SV
Traveling valve leak indicated.
Standing valve leak indicated.
Special design large fluid slippage pump.
1. Leaking traveling valve.
2. Worn plunger or barrel.
3. Leaking component parts of various type pumps.
Tubing leak.
Well unloading.
Leaking SV.
Leak in component parts of various type pumps.
Review volumetric calculations, impreve operating design.
Run fluid pound test
Close wing valve. Re-weigh after a short time.
Run fluid pound test.
Will not pound fluid.
Will pound fluid.
Will pound fluid.
Will not pound fluid.
Close flowline valve and pressure-up tubing.
Re-test well when efficiency justifies.
Pull pump when efficiency justifies.
Pull and repair pump.
Will not pressure up.
Will pressure up.and hold.
Pressure tubing with outside source.
Re-pressure several times to eliminate possibility of high pressure or intermittent leak.
Will not pressure up.
Will pressure up and hold.
Pull and inspect pump. If no failure is visible, drop SV and pressure up from outside source.
Pull and repair pump.
Pull and repair pump.
Will not pressure up.
Will pressure up.
Tubing leak.
Bad SN.
Pull and inspect tubing.
No tubing leak, no pump seat leak. Probable valve, plunger, or barrel leak not visible in field.



*Note: Bent joint of tubing above the seating nipple may not pass a pump, but it may pass a short standing valve and permit the tubing to hold fluid and pressure.


ABNORMAL LOAD INDICATED BY VALVE MEASUREMENTS
Less than rod weight.
More than rod weight plus calculated fluid weight.
Severe plunger restriction such as a collapsed or pinched barrel, sand, scale, etc.
Pump length shorter than stroke.
Stuffing box too tight.
Rods parted.
Severe paraffin.
Pump stuck in top portion of stroke.
Too many rods in the hole.
Severe paraffin.
Pump stuck in bottom portion of stroke.
Stuffing box too tight.
Tubing parted high pump not unseated.
Crooked tubing.
Pump length shorter than stroke.
Severe flow line restriction.
Distinct impact at bottom of stroke.
Static weight will measure same at any stroke position
Maximum weight reaches or exceeds weight of rods in fluid near top of stroke.
Maximum static load less than rod weight.
Card shape will verify.
Loosen stuffing box to verify.
Distinct impact at top of stroke.
Loosen stuffing box to verify.
Card shape will verify.
Raise rods to verify.
Corkscrewed tubing.
Crooked hole
Tubing in compression
Increase to weight greater than rods plus fluid verifies stuck pump.
Increase to weight equal to rods plus fluid verifies too many rods in hole.


ABNORMAL LOAD INDICATED BY CARD SHAPE
Valves good-fluid weight satisfactory.
Sticking pump.
Improper SPM.
Severe paraffin.
Restricted flowline.
Mechanical design bad.