Operation, Care and Maintenance of Beam Pumping Units

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INTRODUCTION

The increasing cost of producing oil has caused operators to expend every effort to reduce operating expense. This expense is always increased when an artificial lift is required. The most popular type of artificial lift has been the beam pumping unit. The operation of this type of pumping unit may become very costly without proper care and maintenance of the equipment. Primarily, the responsibility for this operation falls on the field personnel of the oil company. Through training and experience, they have learned the techniques and procedures required for the pumping of individual wells. We would like to discuss the correct techniques and procedures necessary to assure satisfactory operation of this pumping unit.

PROPER INSTALLATION

The majority of pumping unit installations are handled on a local contract basis. The contractor should make the installation according to the manufacturers' recommendations. For maximum performance manufacturers recommend the use of grouting with a solid reinforced concrete block. The soil should have a minimum bearing power of two tons per square foot. The outline dimensions of the foundation may be increased to suit the soil conditions. Upon completion of the block, the contractor will erect the pumping unit. Field personnel will usually assume responsibility for the unit after it has been erected and the well is ready to be placed on the pump. The block must be thoroughly cured before the unit is operated. Correct installation is very important because a large percentage of failures may be traced to incorrect installation. Field personnel in charge of a particular well should personally check the correctness of the installation before operating the unit. The use of the following suggested check list will help assure the accuracy of this inspection:

1. Alignment of the wire line hanger and the polished rod support.
2. Alignment of the unit and the polished rod with the well bore.
3. Alignment of the pitman arms so that they are vertical to the base of the unit.
4. Alignment of the unit and the prime mover sheaves.
5. Vee-belt tension.
6. Alignment of the center line of the samson post with the center line of the base.
7. Tightness of all structural bolts.
8. Tightness of wrist pin nuts.
9. Tightness of counterweights.
10. Tightness of foundation bolts.
11. Gear box oil level.
12. Lubrication of all bearings, the wrist pin, the saddle, and the pitman.
13. Proper brake adjustment.
14. Levelness of the unit.
15. Possible defects of the cement block and the grouting.

An individual will do a better job of inspection if he knows how to make the inspection and the reason for making the various checks. Manufacturers' experience has shown that incorrect installation of certain items will eventually result in certain types of failures. Our check list and reasons have been compiled from this experience.

1. Improper alignment of the wire line hanger and the polished rod support will result in a bent polished rod and in uneven wear on the wire line. To correct these faults, the polished rod support should be parallel to the base of the unit. Most manufacturers have provided the upper seating surface of the hanger so that it will center the well load over the beam and will provide vertical alignment of the hanger over the well.

2. Improper alignment of the unit and the polished rod with respect to the well bore will result in stuffing box trouble, increased polished rod wear, and possible increased load on the unit due to friction. Adjusting screws are provided at the saddle to allow approximately a three-inch longitudinal alignment of the beam. There is usually approximately one-half to one inch between the arc hanger and the walking beam for lateral alignment of the arc hanger to center the polished rod in the tubing. The fit of the bolts in the holes at the saddle and at the pitman top bearing connections is loose enough to allow for some additional adjustment of the beam over the well center. Also the fit of the saddle bearing on the samson post will usually allow for some lateral adjustment.

3. The pitman arms should be vertical to the base of the unit to assure proper alignment of the walking beam to the center line of the base. This alignment of the pitman arms and the walking beam should be made before the pitman bearing bolts and the walking beam have been tightened to the saddle connection to help assure satisfactory performance of the wrist pin bearings.

4., 5. Improper alignment of the unit and the prime mover sheaves and incorrect belt tension will result in poor Vee-belt service, possible clutch and pilot bearing trouble of the prime mover, and, in some cases, gear failure in the gear box of the unit. Too much tension will result in increased loads to the clutch and the bearings, while slipping of the belts will result in reversing the load on the face of the gear teeth, causing a hammering action in the gear box.

6. To assure correct positioning of the samson post and proper alignment of the unit and to prevent uneven loads on the saddle bearings, a plumb-bob should be dropped from the center of the samson post to the top of the centerline of the unit base. However, when the pitman arms are equidistant from the cranks and the arc is aligned over the well, good alignment is assured.

7. Loose structural bolts will result in fatigue failure of that member of the unit.

8. Insufficient tightening of the wrist pin nuts will result in a wrist pin failure. The tightening of these nuts is the responsibility of the field personnel, and this failure will usually result in costly damage to the unit.

9. To prevent slipping, careful attention must be paid to the tightness of the counterweight nuts. The field personnel responsible should always personally check the nuts before starting the unit.

10. Improper tightness of the foundation bolts will result in fatigue failure of the unit base and possible damage to the foundation.

11. The gear box oil level must be correct to prevent damage to the gears and bearings. Insufficient oil will not lubricate the bearings properly. Too much oil will cause gasket and oil seal leakage problems. There are actual cases where units have been operated without oil, thus producing extensive damage.

12. Operation on improperly lubricated bearings, even for a short time, will damage the bearings.

13. Proper brake adjustment is necessary for the operating personnel's safety. Spacing of the well and adjustment of the counterweights require satisfactory operation of the brake.

14. A level should be used to check the base of the unit. A base that is not level will result in misalignment of the unit with the well and in uneven distribution of the well load.

15. The cement block and the grouting should be checked for cracks and also contact with the unit base. Poor base contact can cause fatigue failures in the base and in the foundation bolts.

The unit should be rechecked after two weeks of operation to disclose any loosening of the bolts caused by vibration. The well conditions then should be more stable and the counterbalance can be rechecked.

PROPER COUNTERBALANCE

The heart of the pumping unit is the gear box. The service of the gear box depends largely upon proper counterbalance. Manufacturers give gear boxes torque ratings in inch pounds. The torque exerted on a gear box is primarily determined by the uncounterbalanced load. The uncounterbalanced load is equal to approximately one half of the fluid load, plus the effect of impulse factors, inertia, vibratory and frictional forces.

Fundamentally, the load on the upstroke is the weight of the sucker rods plus the fluid column being lifted. On the downstroke the load is the weight of the sucker rods only. Both of these loads are influenced by impulse factors, fluid friction, buoyancy, pump friction, inertia forces, etc., and these must be considered in the making of an accurate calculation. The average load throughout the cycle is equal to approximately the rods plus one-half the fluid. Therefore this is the portion of load that is counterbalanced. On the upstroke when the unit load is equal to approximately the rods plus the fluid and the counterbalance is equal to approximately the rods plus one-half the fluid, the net load to the gear reducer is the result of the uncounterbalanced load created by one-half of the weight of the fluid. On the downstroke when the unit load is equal to approximately the weight of the rods and the counterbalance is again equal to the weight of the rods plus one-half the weight of the fluid, the net load to the gear reducer is the result of the uncounterbalanced portion of the load created by one-half the weight of the fluid. Obviously this is an equal load on the gear reducer on the up and down strokes.

If the operator counterbalanced the weight of the sucker rods only, on the downstroke where the unit load is equal to approximately the weight of the sucker rods only, his unit would be exactly balanced out with no uncounterbalanced load going to the gear reducer. However, under these conditions on the upstroke where the unit load is the weight of the rods plus the weight of the fluid, the uncounterbalanced load going into the gear reducer would be the result of all of the fluid load. This under counterbalanced condition causes the gear reducer to carry no load during one-half of the cycle and twice the normal expected load during the other half of the cycle. Over counterbalancing will produce the same result but in reverse order. Therefore it is important that the proper counterbalance be maintained so that the loading on the gear reducer will be as even as possible throughout the cycle and will be kept at a minimum.

Now that we have established the fact that the counterbalance is essential to satisfactory gear box service, we must examine the various methods for determining if our unit is correctly counterbalanced.

Polished Rod Dynamometer

The polished rod dynamometer is the surest device for accurately determining the correct counterbalance. It will show the counterbalance line cutting the center of the dynamometer card when correct and cutting the card too high or too low when incorrect. From the dynagraph one may also determine how much the unit is out of counterbalance. Some operators prefer to lead or to lag their counterweights in order to bring the counterbalance in phase with the peak load of the pumping cycle. The dynagraph will indicate the correct position for the counterweights.

Recording Tachometer

The recording tachometer will help determine counterbalance by indicating variations in engine speed during the up and the down strokes. In the determination of over or under counterbalance, notations must be made of the crank positions on the graph. The margin for error with this method comes on single-cylinder engines with heavy flywheels that store enough energy to carry the counterbalance through with little change of speed. If an engine operates with a sensitive governor, it should be tested while on hand throttle to prevent the governor from giving the false impression of a constant speed. If the counterbalance is correct, the variations in engine speed will be the same on both the up and the down strokes. A nonrecording tachometer may be used by simultaneously observing the crank positions and the tachometer readings.

Clutch Slipping

The clutch-slipping method is another means in the determination of proper counterbalance. The accuracy of this method depends upon the ability of the operator. With a constant clutch lever pressure, which should be just enough to prevent slipping, the cranks should be watched for slowing down at the three and the nine o'clock positions. If the slowing down is equal at both positions, the well is in proper counterbalance. If the crank slows down more on the up stroke than on the down stroke, the well is under-counterbalanced. If it slows down on the down stroke more than on the up stroke, then the well is over-counterbalanced. The increased load at these two points causes slippage of the clutch, from which the method name was obtained. This method is very practical because it does not depend on expensive instruments or knowledge of their operation; however, it is subject to human error.

Fall Of The Counterweights

Some operators check the counterbalance by watching the fall of the counterweights. Many factors involved in this method can create a false impression. The operator must use extreme caution before arriving at a conclusion. In using this method on a crank counterbalanced unit, the operator will allow the weights to coast to a stop at the mid point of the upstroke. If the unit is properly counterbalanced, the weights will have a tendency to rise slowly to the top-dead center, the assumption being that the traveling valve is closed, signifying that the well load is greater than the counterweight effect. When the counterweights are allowed to come to a stop at the middle of the down stroke, the weights will have a tendency to drop to bottom dead center. This time the traveling valve should be open. By both of the above tests, the unit would be considered satisfactorily counterbalanced. When the counterweights accelerate too rapidly or fall in the incorrect direction, the well is probably incorrectly counterbalanced. In a gaseous well, the action of the traveling valve must always be considered, as it will very often cause a false observation. With beam-weighted units, the walking beam will remain stationary if the well is in counterbalance. On wells with light fluid and rod loads, the counterweights on the crank-balanced units tend to remain stationary because of friction in the system. This method requires a thorough understanding of the well conditions.

Sound Of Prime Mover

An operator may determine correct counterbalance by listening to the exhaust explosions of the prime mover. With an electric motor, a "whine" will serve the same as exhaust explosions. In the case of fully loaded, two-cycle heavy flywheel engines, the exhaust will be on a regular cycle in synchronism with the crank. If the unit is improperly counterbalanced, the engine will miss exploding at a certain point in the cycle and will pick up at another point. With multicyclinder engines and electric motors, the operation differs because there is no heavy flywheel to carry the engines through the peak loads. For a correctly balanced unit there will be two even variations in the exhaust for each revolution of the crank. If there is a very definite difference in these variations, the unit is improperly counterbalanced. This system has a higher degree of accuracy if the prime mover is loaded 75% or more. The judgment of the operator is again the important factor.

Ammeter

The ammeter is an accurate device for checking electric motor installations. It will show the variations in amperes during the cycle. A peak variation will occur at approximately the middle of the up stroke and at the middle of the down stroke. If this variation is the same, the unit is in proper counterbalance. If more amperes are required on the down-stroke, the unit is over-counterbalanced. If more amperes are required on the up-stroke, the unit is under-counterbalanced.

In a review of the discussion of counterbalance, we find three methods using instruments and three methods depending on the judgment of the operator. The best results will be obtained when the operator uses two or more methods to check against each other. Counterbalancing the rods properly is relatively easy, but the problem comes in correctly counterbalancing for the fluid load, as this is usually a variable.

Once the unit has been correctly counterbalanced, the operator must continue to observe the operation, as a number of factors can throw the unit out of counterbalance. A change in the well conditions can increase or decrease the load on the unit. Changing the rotation of the unit will result in a change of the amount of counterbalance required. When changing the stroke length, he must remember that the counterbalance effect will vary in inverse proportion to the change of the stroke. In other words, on crank-counterbalanced units, increasing the stroke length will decrease the available counterbalance effect, while decreasing the stroke length will increase the available counterbalance effect. Consequently, the pumping unit must be re-counterbalanced after a stroke change. Taking these factors into consideration, any operator would be wise to establish a system of periodic checks on the counterbalance, depending on the local field conditions.

Manufacturers recommend the correct procedure for adjusting the counterweights on the units. With the present day crank-counterbalanced units, following this procedure is a relatively simple one-man operation.

PROPER LUBRICATION

Improper lubrication is usually the result of failure to follow manufacturers' recommendations. Manufacturers always recommend the type of lubricant required and the correct procedure for lubrication. The majority of manufacturers recommend changing gear oil twice a year or more often if the oil is found to be contaminated. Gear oil should be inspected every three months. The presence of water, metal cuttings, dirt or sand may be discovered by analyzing a small sample of oil taken from the gear box. A sample taken by removing the drain plug at the bottom of the unit will indicate the presence of any water. The presence of even a small amount of water can result in emulsification which destroys the lubricating properties of the oil. In the check for metal cuttings, dirt or sand, the sample should be obtained from the highest oil level, as this is the pick-up level where dirty oil will cause damage to gear teeth and bearings. Immediately after the unit has been stopped, a small sample should be taken through the inspection plate at the top of the gear box. This sample should be diluted with 50% gasoline and centrifuged. Any water or foreign matter will settle in the bottom of the test tube.

The majority of gear boxes are equipped with sediment chambers in the bottom of the case to collect condensation and foreign particles. The box is easily cleaned by removal of various drain plugs. Some operators are using a filtering service to clean the gear box and to filter the oil. It is startling to see the amount of water and foreign material these people find. We have checked with most of the major operators in West Texas, and the majority report that they do not even inspect the oil, much less change it. They also report that they have very little gear and bearing trouble, a fact which accounts for their failure to make the recommended oil changes. We must remember, however, that improper lubrication will not necessarily cause immediate failure, but rather will accelerate the wear and will reduce the expected life of the equipment. In a fully loaded unit, this acceleration may be very rapid, and extra care should be given these units.

All manufacturers provide recommendations for the lubrication of bearings. A transmission lubricant of the straight mineral type, which is approximately SAE 250, is commonly used for bearings. Climate and operating conditions should influence choice of a lubricant. Customarily, only four bearing lubrication points will require lubrication only once a month: the wrist pin bearings, the saddle bearings, and the pitman bearings. The principal types of bearings are self-aligning roller bearings, needle bearings, bronze bushings or sleeve-type bearings, and a rubber bearing which does not require lubrication. Proper lubrication for bearings is determined by the type of bearing and the type of application for which the bearing is used. Since all manufacturers do not use the same types of bearings, it is not necessarily true that what is satisfactory for a unit of one manufacturer will be satisfactory for a unit of another manufacturer. A typical mistake is to lubricate the pumping unit with the same lubricant as that used for the prime mover.

The majority of bearing housings are provided with a relief fitting to prevent over-lubrication. The relief fitting helps prevent damage to the oil seals, which results in a leaking bearing. A common practice with an oil seal leak is to lubricate more often than usual, thus further exaggerating the leaking. Usually an oil seal leak can be eliminated by examining the oil seal for damage or by relieving excess pressure in the bearing housing.

When units are to be shut down for long periods of time, the bearings should be protected from moisture. Collection of water will pit the bearing and will cause an early failure when the unit is placed in operation. A coating of cosmoline will provide good protection, and the bearing may be relubricated before the unit is started.

CHANGING STROKE LENGTH

Changing the stroke length requires removal and installation of the wrist pin on most crank-counterweighted units. Most manufacturers employ a tapered pin and hole arrangement for the wrist pin connection to the unit crank. The wrist pin serves as the fulcrum for converting rotary motion to reciprocal motion, and it is extremely important that the installation be correct because wrist pin failure usually results in extensive damage to the unit. For assurance of satisfactory installation and ease of removal, all of the well load should be removed from the unit.

In the removal of the wrist pin, the objective is to break the taper lock. This is usually accomplished by hammering the wrist pin, being careful not to injure the threads. A knock-out nut is desirable on a stubborn pin. Some manufacturers provide a hydraulic method which utilizes a high-pressure Alemite gun.

When the wrist pins are installed, two factors are essential: First, the wrist pin hole and the wrist pin should be perfectly clean. Any amount of rust, paint or dirt remaining will act to loosen the connection during operation, and eventual failure will occur. Second, some units are furnished with a locking nut arrangement; others, with a cotter pin and castillated nut or an elastic stop nut. This nut should be thoroughly tightened and rechecked after the unit has operated for approximately one week.

OVERLOADED UNITS

After several years of operation, a unit may be badly overloaded. This condition is usually brought about by unexpected changes in pumping conditions of a well. This overload is very important as the manufacturers' experience has proved that an overload condition will greatly reduce the expected service life of the unit. Tests have indicated that the life of bearings and gears is approximately inversely proportional to the cube of the load. If a unit were overloaded 50%, or operated at 150% of its rating, the expected life would be reduced by 70%.

Experience has indicated that all of the gear teeth are not necessarily subject to this overload condition. Usually, a comparatively small percentage of the teeth in the crank gear are in contact during that part of the pumping cycle when the unit is overloaded. Also another small section of teeth are in contact during periods of load reversal on the gear teeth. These areas will be the first to experience tooth failure. This overload can be distributed to other teeth by changing the pumping cycle - reversing the direction of rotation or changing counterbalance, stroke lengths, or pumping speeds. A careful inspection of the gear box will reveal when load distribution is necessary, and at the same time damaged gears and bearings may be changed before failure occurs.

From the standpoint of maintenance, operators should be exceptionally careful to see that a unit is operated in strict accord with manufacturers' recommendations.

In some instances reducing the well loads and still maintaining allowable production is possible. The engineer should investigate well conditions when considering changes in pump bore, sucker rod design, and pumping speeds. He may use a smaller pump at a greater speed, shorter stroke lengths with faster pumping speeds, redesigned rod string to increase efficiency of production, etc. A complete dynamometer analysis will help the operator select the most advantageous over-all installation procedure.

ASSOCIATION BETWEEN MANUFACTURER AND OPERATOR

The most satisfactory unit operation will result when mutual co-operation exists between the operator and the manufacturer. Manufacturers are willing and ready to provide operators with the service and information necessary to locate and solve any problems that might occur in the operation of equipment. For the manufacturer's representative to arrive intelligently and accurately at a satisfactory solution, the operator's responsibility is to provide him with accurate information. When this close association exists, the operator will receive the most economical and trouble-free operation of pumping equipment.

SUMMARY

We attempted to present a program of operation, care, and maintenance that will assure operators of satisfactory performance of beam-pumping-unit equipment. For this program to be successful, it must be placed into practice and administered under careful supervision.