MAINTENANCE OF OIL FIELD PUMPING UNITS

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INTRODUCTION

When it becomes necessary to put an oil well on the pump, the operator is usually faced with an investment of many thousands of dollars in some means of artificial lift. By far the most successful and the most generally accepted type of artificial lift is the beam type pumping unit. Many years of research and testing have gone into the design and development of the modern pumping unit. Advancements in metallurgy and the most up-to-date machine tools go into its manufacture. All these improvements in design and technique of manufacture are of little value if the equipment is installed improperly on the well, operated incorrectly, or is poorly maintained.

UNIT SELECTION

Obviously, a pumping unit that is inadequately sized will always give trouble in the form of repeated equipment failures. These failures can be in the form of gear failures or structural failures. Thus, establishing any sort of preventive maintenance on a pumping unit that is too small for the application is an exercise in futility. Most new units are sized by a method recommended by the American Petroleum Institute (API Recommended Practice API-RP-11L). API-RP-11L as published covers only the Conventional Crank Balanced Unit; however, modifications and additions have been made by manufacturers so that API-RP-11L as modified can cover both the air-balanced and Mark II Units as well as the conventional crank-balanced units.

Bear in mind that this predictive method yields only predictions. Although it may size a unit fairly accurately in one case, it may miss the next prediction under similar conditions by a fairly wide margin.

If field results are available in the form of dynamometer surveys, or from a history of successful operations, then, of course, the field results should always be used rather than any sort of predictive method or calculation procedure.

INSTALLATION

Detailed instructions for the assembly and installation of pumping units are given in the instruction manual furnished with each unit. Some of the more important items are covered in this section.

Well Head

Even before the location of the pumping unit foundation is laid out, the precautionary measure of checking the well head is highly desirable. Very often the well head will lean one way or the other to the extent that the stuffing box on a high well head will be off 2 or 3 inches from the well center at the foundation level. The well head should be straightened before the foundation is located with respect to the centerline of the well. Otherwise, excessive polish-rod wear and stuffing-box leaks will result. Also, if the well head is not straightened, it may be virtually impossible to install and operate the pumping unit properly. This precautionary measure of straightening a well head, if needed, is very important before locating the pumping-unit foundation. (It is also a measure that is nearly universally ignored.)

Foundation

An adequate foundation is essential to the satisfactory operation of a pumping unit. Although there are circumstances under which substitutes may be acceptable (see API Recommended Practice API-RP-11G), a reinforced concrete block is still the best foundation for trouble-free operation. Manufacturers' foundation prints will show the location of foundation bolts or hold-downs and suggested outlines of the foundation; however, the actual size and depth of the foundation depends on local soil conditions. Complete bearing of the pumping unit structural base on a concrete block is ensured by grouting. Grout should be worked under all beams for their full width, not just the edges. Before grouting, however, the centerline of the base should be in line with the well. The center of the base should be aligned with a chalkline extending from the center of the well along the center of the foundation.

Erection Of The Unit

1. (Levelness of the unit)-One of the first items to check on any installation is to make sure that the pumping unit is level. This may be done by putting a level across the main base members. Another more accurate method is to place a level on the machined horizontal surface on the gear box. This is done by removing one of the inspection covers and placing a level across the machined surfaces.
2. (Alignment of wireline hanger with well)-On conventional crank-balanced units, the walking beam may be moved forward or backward approximately 3 inches each way to allow for proper alignment with the stuffing box. On air-balanced and Mark II units, the base must be skidded forward or backward to the correct position before the unit is grouted in. After the beam is aligned (See item 4, below), it may be necessary to realign the horsehead by using the adjusting screws on the side of the horsehead.
3. (Alignment of samson post with center of base) - After the base is in the correct position and level, a plumb bob should be dropped from the center of the samson post at the center-bearing connection to the base. The plumb bob should fall at the center of the main base members. If this is not the case, the base will usually be found to be out-of-level. It may be necessary to shim under one or more legs of the samson post under these conditions if the base has already been grouted in.
4. (Beam alignment and alignment of pitmans)-In checking beam alignment, the distance between the edge of one pitman and the end of the crankshaft should be measured and compared with the measurement taken in a similar manner on the other side. This gap should measure approximately the same on both sides. If not, the unit will usually be found to be out-of-level.
5. (Tightness of all bolts and nuts) - It should be obvious that all bolts, nuts, etc., should be *thoroughly* tightened before the operation of the unit is begun. (This is one of the most common causes of structural failure on pumping units.) A bolt that is properly sized for the job it is intended to do should never fail if it is properly tightened. To ensure proper tightness, most manufacturers furnish hammer wrenches with the unit to adequately tighten the large bolts and capscrews. Any bolt or capscrew above 1 inch diameter can seldom be tightened sufficiently except with a hammer wrench or impact wrench of some type.
6. (Correct alignment of V-belt drive) - If properly installed and cared for, modern V-belts are dependable and trouble-free. Sheaves should be aligned with a straight edge or a stretched string between them. If, for example, the engine sheave is offset just one groove with respect to the unit sheave, excessive wear will result; a greater possibility of one or more belts turning over in their groove will also occur.
7. (Correct V-belt tension) - Belts should go on easily without prying or forcing. As the belts are tightened, all belts should be checked for being the same length. If one belt is still very loose while the others are tight, that belt should be replaced with one to match the others. The belts should be tightened until a few pounds finger pressure applied midway between the sheaves will depress a belt one or two inches. Belts that are too tight will shorten the life of the reducer bearings and engine (or motor) bearings. Belts that are too loose may slip or turn over in the groove causing belt damage and, possibly, a fire. After

a set of belts has run twenty-four hours, tightness should be rechecked as outlined above. Check again at the end of one week. No belt dressing should be used on V-belts. Banded type belts should be used for all belt drives with pitch lengths longer than 285 inches.

8. (Correct oil level and correct type of oil in the gear box) - Oil level should be somewhere between the high mark and the low mark on the gear-reducer oil-level gage. Too much oil will cause seal and gasket leaks. Too little oil will not do the job of adequately lubricating the gear teeth and bearings. (There have been cases where units have been started without any oil in the gear box.)
9. (Adjustment of the brake) - The brake should be adjusted according to the manufacturer's instructions so that both shoes grip the drum tightly in the "on" position and are completely free in the "off" position. Proper brake adjustment is essential for the safety of operating personnel, and it also makes it possible to space the well and adjust counterweights.

   The pumping unit brake is not intended as a safety stop but is intended for operational stops only. When operations or maintenance is to be conducted on or around a pumping unit, the position of the cranks and counterweights should be securely fixed in a stationary position by chaining or other acceptable means.
10. (Check for possible air leaks) - Some operators complain that the compressor on an air balanced unit runs too often, yet they never seem to consider what is causing the trouble. Even very small leaks will cause the compressor to work excessively. Invariably, the operator finds that some connection is not made up tight or has been made up without a thread compound. Going over every conceivable source of air leaks with a soap solution will always reveal even the smallest of air leaks.

LUBRICATION

Gear Reducer

For the type of oil to use, manufacturers' recommendations or the API Recommended Practice API-RP-11G should be consulted. This recommended practice states that for installations operating above 0^0 F, an SAE 90 or 90 EP oil is recommended. This corresponds to an AGMA 6 or 6 EP. For operations below 0° F., an SAE 80 or 80 EP (AGMA No. 3 or 3 EP) oil should be used

If foaming conditions become a problem, a very small quantity (approximately 1 teaspoon) of Dow Silicone 200 should be dropped into the gear box. A large amount of Dow Silicone 200 will affect the lubricating qualities of the oil.

Structural Bearings

1. Warm climates: (Where lowest annual temperature is above 0° F) Roller bearings, except tapered roller crankpins bearings, should be relubricated every 6 months. A premium NLGI No. 1 lithium soap base grease with an extreme pressure additive should be used. Soda-soap grease should not be used.

   Bronze bearings (sleeve bearings) and tapered roller crank pin bearings should be relubricated as required to maintain oil level. Use an EP 140 extreme pressure oil with an extreme pressure additive and a pour point of 15° F or lower. If available, a heavier oil (viscosity up to 6600 SUS at 100° F) is recommended.
2. Cold climates: (Where lowest annual temperature is down to- 30^0 F) Roller bearings, except tapered roller crankpin bearings, should be relubricated every 6 months. A premium NLGI No. 0 lithium soap base grease with an extreme pressure additive should be used. Soda-soap grease should not be used.

   Bronze bearings and tapered roller crank pin bearings should be relubricated as required to maintain oil levels by removing fill plug and adding oil until the reservoir is full. An EP 80 or EP 90 extreme pressure oil with an extreme pressure additive and a pour point of -10° F or lower should be used.

Air Counterbalance Cylinder

On air-balanced units, the air cylinder must be lubricated properly to prevent wear and to maintain an adequate air seal. Air balanced units maintain a pool of oil which "rides" the top of the piston and requires no automatic lubricator (as required on earlier air balanced unit models). An oil with a viscosity comparable to SAE 30 motor oil should be used. A detergent type oil should not be used. After initial lubrication, oil should be added every 30 days. The amount of oil added will depend on the size of the unit. Manufacturer's recommendations should be consulted.

Air Compressor

The crankcase should be filled to the oil level indicated. Use compressor oil or high grade non-detergent oil—summer-SAE 30 or 40, winter-SAE 10 or 20. Every six months, or more often if the oil appears dirty or contaminated with moisture, the oil should be changed. The crankcase should be kept filled to the high level.

MAINTENANCE AND ADJUSTMENTS

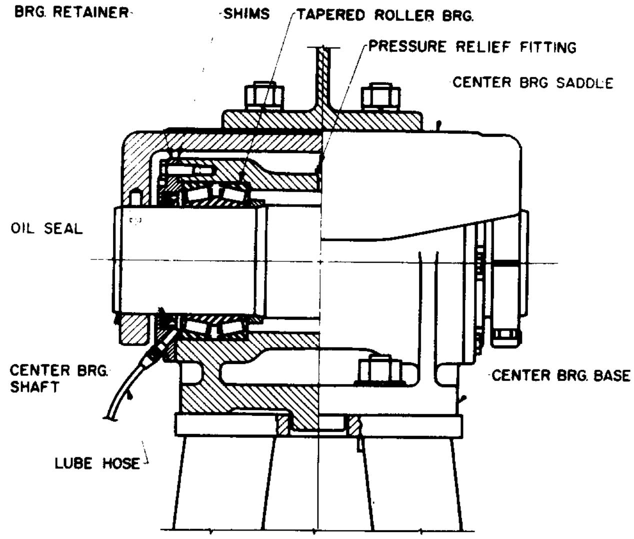
Proper lubrication of bearings is absolutely essential for satisfactory operation of a pumping unit. Since different type bearings are often used by the different pumping unit manufacturers, manufactureres recommendations about the type of lubricant to be used should always be followed.

The use of grease or oil as a lubricant for structural bearings depends on the type of bearing. Oil is, of course, always the best lubricant; however, grease is usually acceptable on most anti-friction type bearings since it is much easier to contain than oil and thus results in fewer seal leaks. As a general rule, grease should not be used on sleeve-type bearings.

Structural Bearings

1. Center bearing - Figure 1 shows a typical center-bearing assembly (sometimes called saddle bearings). It is an anti-friction type employing tapered roller bearings. Most manufacturers furnish this type bearing at the samson post, especially on the larger units. Grease is added at the lubrication hose on the lower left and exits at the pressure relief fitting at top center.

   Shims are present at the bearing retainer. Center bearings are always adjusted at the factory to remove any looseness as well as adjusted for a very slight preload.



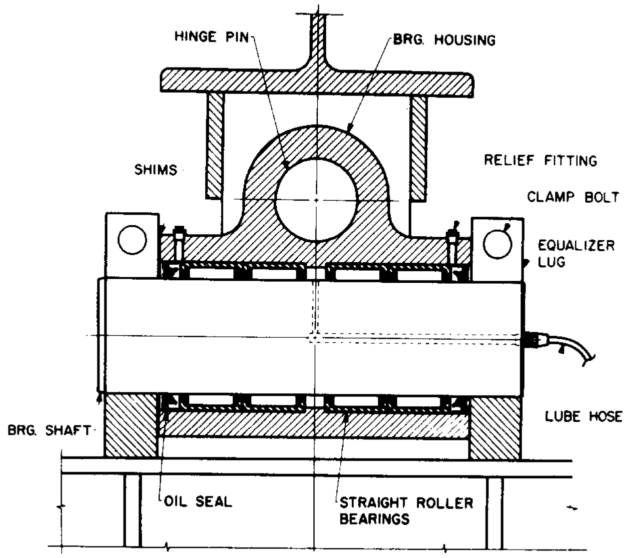
CENTER BEARING ASSEMBLY

FIGURE 1

2. Equalizer bearing - Figure 2 shows a typical equalizer or tail bearing. Usually, equalizer bearings use straight roller bearings of some sort. Here agin, grease is added at the lubrication hose from ground level and exits at the pressure relief fitting at the top of the bearing. On this type of anti-friction bearing where straight roller bearings are used, shims may be necessary between the bearing housing and the equalizer lugs. Shims are added, not as an adjustment to the bearings, but to take out excessive clearance between the housing and the lugs.

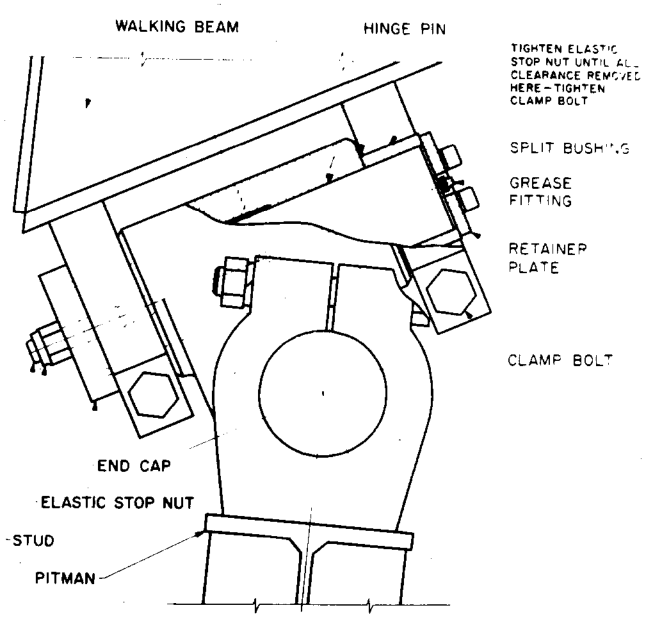
3. Equalizer hinge pin adjustment - Figure 3 shows a section through the hinge pin of a typical equalizer bearing. This hinge pin connection is shown to illustrate the correct method of removing excess clearance. If excessive clearance is not removed, the operator will possibly hear a thump at the top and bottom of the stroke as the equalizer bearing moves between the lugs on the walking beam.

   The clearance mentioned above should be removed by locating the walking beam with the horsehead at the top of the stroke which will place the equalizer bearing (conventional crank-balanced units) at the lowest possible level. In this position, the cranks will be straight down. With the hinge pin clamp bolts loose, the elastic stop nut shown should be tightened so that the split bushing (shown at the upper right-hand side) is moved inward until it contacts the surface of the center bearing housing. At this point, the clearance has been removed and both clamp bolts should be retightened.



EQUALIZER BEARING ASSEMBLY

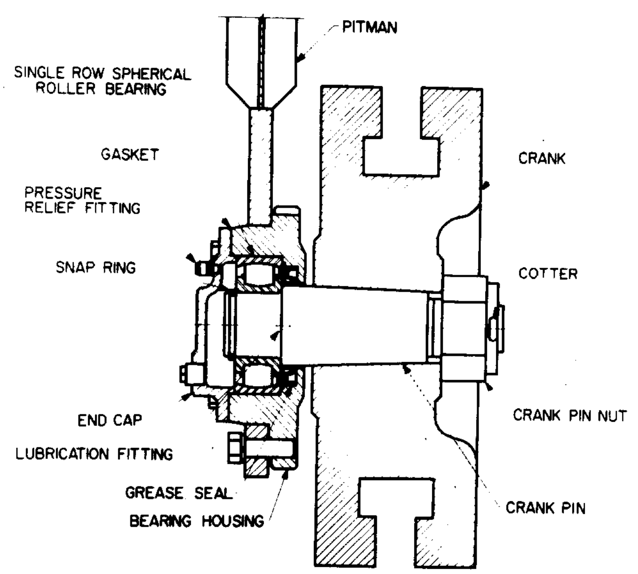
FIGURE 2



EQUALIZER HINGE PIN CONNECTION

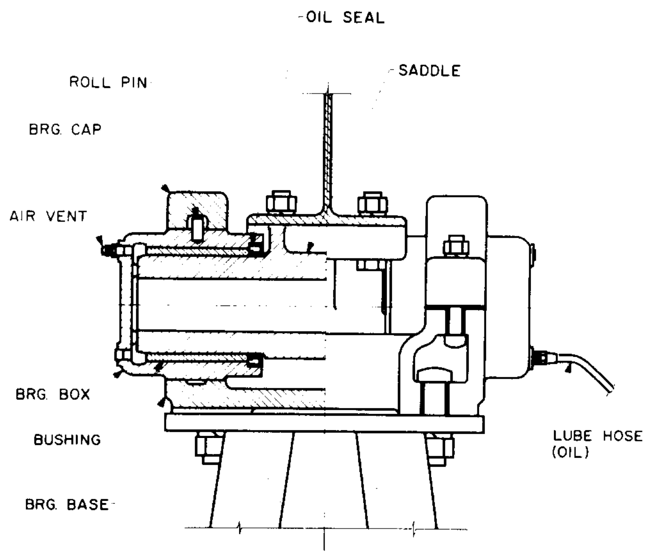
FIGURE 3

4. Crank-pin bearing
   a. Spherical roller bearings - Figure 4 shows a typical crank-pin bearing (or wrist-pin bearing as it is sometimes called). Figure 4, of course, shows a crank pin of the single-roll, spherical type. Grease is added at the rear of the bearing housing. The pressure relief fitting is located on the top of the bearing retainer on the outside so that it can be observed when the bearing is being filled with grease. There is no adjustment on this type bearing although there would be adjustments on two tapered roller bearings as are used on air-balanced units.
   b. Tapered roller bearings - In making adjustment on tapered-roller bearings on crank-pin assemblies, shims should be added or removed so that a small preload (10-15 in-lbs.) is obtained.
   c. Sleeve bearings - On smaller crank-balanced units and many beam-balanced units, sleeve-type bearings are often used at the center-bearing, equalizer-bearing, and crank-pin locations. Figure 5 shows a typical center bearing assembly using sleeve-type bearings.



CRANK PIN BEARING ASSEMBLY

FIGURE 4



CENTER BEARING ASSEMBLY
(BUSHING TYPE)

FIGURE 5

COUNTERBALANCE

No phase of pumping-unit operation is more important than correct counterbalancing. Since the early days of artificial lift, much has been said and written about the importance of proper counterbalance of the loads involved. Unfortunately, little has been done in the oil industry towards systematic checking pumping units to ensure that the best counterbalance possible is maintained. As a result, the oil industry and the nation lose heavily every year. Energy is needlessly expended and equipment is damaged by overloading.

Counterbalance Defined

Counterbalancing may be defined as the means to offset the weight of the sucker rod string and a portion of the fluid load in order to minimize the net unbalanced load on the gear reducer, thereby minimizing the load on the gear box and the prime mover. Whether the unit is crank counterbalanced, beam counterbalanced, or air counterbalanced, the importance of this phase of unit operation cannot be over emphasized. A recent survey has shown that the average out-of-counterbalance condition on all beam type pumping units produced an increase in force of 20 percent exerted on the gear reducer; this force would not have been exerted had units been properly balanced.

Changing loads are imposed on the polished rod and pumping-unit structure by the well. These changing loads, of course, apply a changing torque load on the pumping unit gear box.

On the downstroke of the conventional crank-balanced pumping unit, the primary polish-rod load exerted on the polished rod is simply the weight of the sucker rod string. Similarly, the polish rod load on the upstroke is the weight of the rod string plus approximately the weight of the fluid column plus the force necessary to accelerate the rod string. These are not the only loads imposed on the polish rod, but they are by far the largest in magnitude and the only ones to be considered here.

Thus, the difference between the up and down polish-rod loads is the weight of the fluid column plus the load required to accelerate the rods. If the operator is able to counterbalance one half this difference in addition to the weight of the rod string, then the maximum torque load on the prime mover as well as the gear reducer will be approximately equal on the up and down stroke.

If the operator counterbalanced the weight of the rod string only, there would be no load on the gear reducer on the downstroke. On the upstroke, however, there would be twice the normal expected load. If the unit were overcounterbalanced to the same extent, the same would be true on the downstroke. These abnormal loads on the gear teeth would cause premature wear and pitting on the few teeth that are in contact at this maximum load point. Unfortunately, this maximum load point comes in the same place on the gear on every stroke of the conventional crank-balanced unit, and it is this point on the slow-speed gear that will receive 90 percent of the wear.

On the other hand, if the unit is properly counterbalanced, this abnormal loading will be distributed between two load points of equal magnitude, one on the upstroke and one on the downstroke.

For a gear reducer to give a satisfactory service life, it must be properly counterbalanced. There are some practical methods for determining whether the unit is correctly counterbalanced.

Adjustment of Counterbalance

1. Sound of prime mover - Perhaps the most widely practiced method of determining the correct balance of a unit is merely by listening to the prime mover. If the unit is driven by an electric motor, this is an especially good method in that the whine of the motor will vary in intensity on the up and down strokes if the torque peaks are not the same. This method is also good on gas engines where the flywheel effect is not too great and when the engine is loaded 75 percent or more.
2. Ammeter method - For units with electric motor drives, this is perhaps the best method for counterbalancing the pumping unit. This method uses an ordinary ammeter to measure the motor current through the cycle; the ammeter clearly shows the position and relative magnitude of the torque peaks. This is a very accurate method of counterbalancing a unit.
3. Observation of V-belts - Observation of the slack side of the V-belt drive and the amount of dip of the belts at the low points of the up and down strokes shows the relative torques on the gear reducer. If the dip is the same on the upstroke and downstroke, then the unit is fairly well counterbalanced.
4. Polished rod dynamometer - The polished rod dynamometer is an instrument that measures and records the well load at all points throughout the pumping cycle. A dynamometer card in conjunction with torque factors of the pumping unit and the pumping unit counterbalance data provides data for a very accurate torque analysis. This analysis will show any out-of-counterbalance condition and effective measures to correct the counterbalance. Most manufacturers have computer programs that can make this analysis if a dynamometer card is available. While the other three methods mentioned above will all balance the gear reducer to varying degrees of accuracy, the polished rod dynamometer and a resulting torque analysis will do a much more accurate job.

For example, by the ammeter method, an operator may balance the torque peaks perfectly, but he still doesn't know whether these two equal peaks represent 50 percent of the rating of the gear reducer or whether they represent a 100-percent overload. The dynamometer gives him this information as well as the actual polished-rod loads and polished-rod horsepower. Thus, the dynamometer is used principally to determine whether or not a unit is overloaded. Normally a torque analysis disregards the inertia of the rotating and articulating masses. It is possible, of course, to take these variables into account if these accelerations can be accurately measured. This can be done with recording tachometers from which speed changes can be calculated. From these speed changes and the known inertia of the various masses mentioned above, a correction to the previously calculated peak torques can be made. If this more refined method of computing torque shows that the counterbalance needs to be changed, then the counterweights should be moved and the whole procedure repeated since a change in the counterweights will affect the speed change of the counterbalance cranks as well as the articulating masses.

Perhaps the greatest mistake made in counterbalancing of beam-type pumping units is that of attempting to counterbalance the unit under certain conditions as the operator finds them at the time; yet, the well may be one of the type that tends to vary considerably throughout its pumping period each day. When a new unit is started, the counterbalance weights should be placed in such a position that the unit will operate satisfactorily without overloading the prime mover, but no attempt should be made to achieve perfect counterbalance. After the well has pumped long enough to settle down to very uniform conditions, accurate and close counterbalancing may be attempted. Even then, the well should be checked two or three times a day for the next 30 days of operation in an attempt to determine whether or not the fluid level is dropping, or whether other conditions are present which affect the counterbalance requirements. A pumping unit may be perfectly counterbalanced when started up, yet at the end of an 8-hour period the unit may be so badly out of balance that the prime mover is on the verge of stalling. Such a well cannot be counterbalanced throughout the pumping period but must be overbalanced in the beginning with the result that it will be perfectly balanced about midday through the pumping cycle and definitely underbalancd by the end of the period. There are thousands of such wells, and it is very probable that they cause the bulk of equipment overload.

FLUID POUNDS

When a well is pumped faster than the fluid enters the bottom hole pump from the formation, a fluid pound results. The pound occurs when the pump plunger hits the fluid on the down stroke. This causes a severe shock load which is transmitted to all components of the pumping system. This includes the rod string, the pumping-unit structure, all structural bearings, the gear reducer, and even the pumping-unit foundation.

Pumping units that are operated continually with a severe fluid pound can be expected to have early equipment failures in the form of structural breakage and gear-tooth breakage.

Units operating with severe fluid pounds should either be slowed down or have their stroke length shortened.

DESIGN FACTOR OF SAFETY

Pumping unit manufacturers are often asked the question, "What factor of safety should be designed into a gear box?" There is no good or accurate answer to that question. Gear reducers for pumping units are designed per Specification API-11E, which is derived from AGMA Standard 422.02. This specification is basically one that limits the loading on gear teeth so that premature and progressive tooth pitting (or excessive wear) does not occur. API-11E also states that the pumping unit manufacturer "shall assume responsibility for selecting a tooth pitch (tooth size) sufficiently coarse to provide adequate tooth strength."

Both of these standards were derived from empirical formulas which were developed from a history of satisfactory field experience. Factors of safety are not mentioned in either standard.

Progressive pitting will result in stress concentrations in the teeth that will accelerate gear-tooth breakage. This acceleration rate is most difficult (actually impossible) to pin down.

The net result is that Standard API-11E establishes a stress level of gear-tooth loading that the manufacturers feel they can stand behind under warranty conditions. Any loading above this stress level cannot be expected to give normal pumping-unit gear-reducer life.