GOOD MAINTENANCE CAN EXTEND THE LIFE OF YOUR BEAM PUMPING UNIT

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Introduction

The common beam and sucker rod pumping unit is old technology yet it continues to be part of the most popular artificial lift system in use today for several good reasons. A few of the more important are:

- It is a simple mechanical mechanism that is easily understood and therefore easy to keep in good repair.

- It is a highly efficient part of the beam and sucker rod artificial lift system.

- It can be very ruggedly built resulting in a long useful life.

Because the surface unit has a history of being relatively trouble free, there is generally little attention given to providing really good preventive maintenance to this equipment. Rather the attention is given to some other part of the system that requires more frequent repair. As a result, when a failure occurs in the pumping unit, it is often a surprise and expensive. Exceptional maintenance can add years to the life of the machinery and reduce operating cost. This paper is intended to supplement your existing preventive maintenance program by developing a good understanding of the really important maintenance requirements for a beam pumping unit.

Safety

No paper on maintenance would be complete without a section on safety. A sucker rod pumping unit is a large slow moving piece of machinery that seems safe enough to work around but don't you believe it. Those large slow moving parts can move quietly and with a tremendous amount of force. When performing any type of work around this potentially dangerous equipment, always render it safe before beginning the job. Refer to your company's safety procedures including locking-out and tagging-out the power source prior to getting inside the guards. Always place the equipment in its lowest energy state before working around the unit and then be alert to any potential dangers. Do not depend on the brake alone to prevent movement. Your pumping unit installation manual should have safety guidelines that must be read and understood prior to working around the pumping unit.

Before beginning your inspection of the unit, approach the unit cautiously from the rear looking for any indication of a potentially dangerous situation. The following visual inspections are recommended before getting near the unit:

- Are the counterweights loose on the cranks?

- Are the crank pins tight in the cranks or has one of them been turning in the crank and is it about to fail?

- Look at the center bearing area to confirm that there is no looseness between the bearing and the beam or between the bearing and the Samson post. Look for beam wobble.

- As the unit turns, visually check the clearance between the pitman and the crank. Are they about to hit?

- Check the wireline. Is it about to slip off the head? Is it badly frayed and about to fail?

- Look for any loose or missing bolts. Fretting corrosion caused by loose bolts usually causes a rusty-looking area at the loose joint. Loose bolts will fail in fatigue and are the single largest cause of pumping unit failures.

- Are the belts in good condition? Listen for belt squall.

- Is the brake in good condition? Is the brake drum key tight?

- Is the horsehead safety bar or attachment bolt in place?

- Look for movement and listen for bumping noise at the tail bearing.

- If driven by a slow speed engine, confirm that the flywheel is not about to come off the shaft.

- Listen for unusual noises or vibrations.

If any of the above conditions exist, the unit should be shut down and the problem corrected.

Reducer

The gear reducer is truly the heart of the pumping unit. It is the most expensive part of the unit yet it generally gets the least attention. The modern pumping unit gear reducer has a double reduction gear train usually having two double helical or herringbone gears with mating pinions. The gears are normally made of nodular iron while the pinions are made of an alloy steel. These rotating parts are supported by anti-friction bearings and/or bushings. The reducer gearing is rated by American Gear Manufacturing Association (AGMA) and API Specification 11E for pumping units to carry a given amount of torque as stated on the reducer nameplate. If properly manufactured to the above design criteria and operated within its torque limit, the gearing should have a long trouble free life given good maintenance.

The inspection of the reducer should be focused on the brake, the reducer sheave and belts, the gearing, the bearings and the lubricant.

Brake

The pumping unit brake is not intended as a safety stop but is intended for operational stops only. When operations or maintenance are to be done 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.

The brake should be capable of holding the reducer against rotation both when the well load is connected and when it is not. Without a counterbalancing well load, the cranks and counterweights can create a torque load on the reducer that is well over the gear rating. To hold against rotation, the brake needs to be in good adjustment and clear of any foreign material on the brake linings. If the linings are badly worn, they should be replaced and the brake readjusted to the new lining. If the brake cable is frayed or damaged in any way, it should be replaced. When correctly adjusted, the brake lever should have several ratchet teeth left to engage when the lever is fully and firmly set. The adjustment procedure is fully explained in the pumping unit installation manual available from the manufacturer. Make certain the brake drum key is tight.

Sheave and Belts

The reducer sheave and belt drive allows an operator to easily change the speed ratio between the prime mover and the output shaft of the reducer by varying the size of the sheaves. The important inspection points of a sheave inspection are:

- Check the condition of the "V" grooves in the sheave to confirm they have not become worn with use. The belt and sheave manufacturers can provide plastic templates of the groove sizes which can be placed in the groove to see if the fit is proper. A belt carries load through its sloping sides so a sheave that is worn may allow the belt to touch the bottom of the groove thus reducing its torque carrying capacity. This can be visually seen by looking at the bottom of the "V" groove. If the bottom has a bright finish, it is likely being polished by the slipping belt. See Figure 1.

- Visually inspect the sheave for any broken or damaged areas that may harm the belting or cause concern of impending sheave catastrophic failure. Replace any sub-standard sheaves.

- Check the alignment of the two sheaves by drawing a string across the two faces. The string should touch each sheave two places at their outside diameters. Move the prime mover to achieve alignment. See Figure 2.

- Check the belts for cracking or fraying. Cracking is usually caused by excessive heat due to belt slippage and, if severe, is reason for belt replacement. A belt can also become frayed by running over a damaged sheave or by being damaged during belt replacement. Never use a pry bar to force belts onto the sheave. Always reduce the drive center distance until the belts easily fit into their mating grooves. Never mix new and old belts – they do not share the load equally.

- Check the belts for correct tensioning. Belts transmit torque by depending on friction between the belts and the sheave. Adequate tensioning of the belts is the single most important factor necessary for long satisfactory belt service. If the belt tension is loose, the belts will slip and wear out both the sheave and belts. Also, slipping belts will reduce the pumping unit efficiency. Belts that are too tight can cause excessive loads on the prime mover and gear reducer input pinion bearings and shafts which will shorten their operating life. Fortunately, there is a wide range of tensioning that will yield satisfactory drive performance. The following is a good field procedure for determining the proper belt tensioning at belt installation:

    - After installing the new belts, increase the sheave center distance until the belts are snug and have a live springy action when struck with the hand.

    - Run the unit for several minutes to seat the belts and observe the belt bow on the slack side of the drive as the unit comes under its heaviest load (the torque peaks). A slight amount of belt bow on the unloaded side of the drive indicates proper tensioning. If the belts slip or have excessive bowing, the tension should be increased. If the slack side remains taunt during peak loads, the tensioning is too tight.

    - New belts will stretch some so the belt tension should be checked several times over the first 24-hour period of operation.

Gearing

As gears mesh, the flanks of the teeth roll and slide against each other while transmitting horsepower or torque. At the point where the teeth touch, the gear elements are exposed to high loads which, if not properly addressed, can lead to damage of the teeth. If the gears are designed in accordance to API Specification 11E for pumping units, adequately lubricated, manufactured to high manufacturing standards and operated within their design limits, then the gearing should have a long productive life. It is not uncommon for a reducer to still be working after 40 or 50 years of operation!

As a minimum, the gearing should be inspected semi-annually so that any problems can be corrected before a costly failure develops. The following procedure is recommended:

- Stop the unit with the crank pin at the 6 o'clock position and make the unit safe to move inside the crank guards.

- Remove everything from inside your shirt pockets. It's amazing how often those things inside a shirt pocket will fall through the inspection cover into the reducer sump.

- Remove the inspection covers and, with a good light, study the condition of all the gear teeth. Look on both sides of the teeth, if possible, to find the load side.

- The loading on the input pinion and the intermediate speed gear and pinion will show tooth contact all around the gears; but the low speed gear (bull gear) will show the most loading in those areas where the peak or higher torque loads occur. In general, the peak torque will occur around mid-upstroke and again near mid-downstroke. The 6 o'clock and 12 o'clock crank pin positions will place the approximate area of peak loading on the topside of the bull gear for viewing through the inspection cover. The above is only an approximate way to locate the areas of peak torque; so if not found in those crank locations, it may be necessary to continue to rotate the gearing until they are found.

- As you inspect the teeth, note which side of the teeth is carrying the load. The leading side of both pinion teeth and the trailing side of the driven gears should show evidence of carrying the load. The load-carrying surface will be shiny or brighter than the non-load carrying side. If there is an indication of the back side of the teeth carrying significant load, then the unit may be badly out of balance which causes a torque reversal that loads the back side of the teeth. In a properly balanced pumping unit, there are usually some parts of the torque cycle that contain negative torque, but the peak value of the negative torque is minimal. So while there may be some minor indication of backside loading, it can be readily recognized as normal negative torque.

  On the other hand, if your inspection reveals heavy destructive loading on the back side of the teeth, the counterbalance is nearly always the reason. This is best seen at the two torque peaks on the low speed gear. Here, poor counterbalance will cause the driven side of the tooth to indicate load at one of the torque peaks while the other torque peak will indicate a much lighter load or even back side loading. By noting where in the stroke the torque peaks occur and on which side the teeth are loaded, one can determine if the reducer has too much or too little counterbalance.

There are numerous modes of gear tooth failures; however, for pumping unit type gearing, the more common types can be classified as tooth breakage, surface pitting, wear and plastic flow.

- Tooth breakage is the breaking off of a tooth or a substantial part of a tooth due to shock loading, overload conditions, or the more likely fatigue failure caused by repeatedly loading the tooth material, in bending stress, above its endurance limit.

  In pumping unit gearing, shock loading could be due to pounding fluid excessively or suddenly applying the brake while the unit is turning at its running speed. This shock loading could immediately break off the tooth at the time of the incident or start a crack that later breaks the tooth.

  Overload conditions could be caused by sudden gross misalignment of the gears, a bearing failure that tends to "lock up" the gearing or something large going through the mesh. The fracture surface of this type failure is not smooth but is stringy and looks like the tooth was wrenched apart.

  Fatigue failures occur over a period of time and are caused by repeated unexpected stresses above the endurance limit of the material. The unexpected high stress could be due to some stress concentration factor, operation of the reducer above its API gear rating or from gear misalignment. For example, pumping unit gears are intended to operate with their shafts parallel. If the housing bores are not parallel, or a bearing on one side wears allowing the shafts to get out of parallel, then the gears will mesh such that the load is not carried by the whole tooth but rather by a portion of the tooth thus overloading the teeth. If the load is high enough and the problem is not corrected, the tooth will likely fail in fatigue.

  In some cases, a fatigue failure is the secondary failure. It is not uncommon for a fatigue crack to initiate at the stress riser caused by gear pitting (explained below).

  The more common fatigue failure fracture surface is smooth in texture except for the area where the final fracture occurred. A close examination of the fracture will normally reveal the classic "eye" and "bench marks" found in fatigue failures. See Figure 3.

- Tooth pitting is a type of tooth distress characterized by pits or cavities that form on the loaded flanks of the teeth. Pitting is due to cyclically overloading the surface of the tooth such that the Hertizan sub-surface stresses are above the endurance limit of the tooth material. When this happens, small pieces of the tooth flake out, leaving a void. There are two basic types of pitting conditions, corrective pitting and destructive pitting.

  Corrective pitting is characterized by small pits approximately 1/64 to 1/32 inch in diameter and is caused by localized temporary surface overload conditions. As the pits remove the high stress area by pitting it away, the load spreads out over more tooth area reducing the stress and correcting or redistributing the load. With new pumping unit gearing, the machining operation of the gear teeth leaves small high spots down the tooth flanks that cause high loads in those locations. As the teeth are loaded, these high spots have high surface stresses that may develop corrective pitting. As the pits remove the high spots, the pitting correction spreads the load over a larger area, lowering the stress, and the pitting stops. With time, the pits polish out and disappear. See Figure 4.

With through hardened gearing, corrective pitting can improve minor degrees of tooth misalignment and minor lead errors in the manufacturing process. Tooth misalignment and lead error result in only part of the length of a tooth contacting its mating tooth. As a result, the part in contact carries more load and may be overloaded. If the error is not too bad, corrective pitting will pit away the highly loaded area until the load spreads out over enough tooth length to carry the load. When this correction is taking place, the pitting will start at the wing of one helix and the apex of the other. See Figure 5. With time, it will spread across the tooth length until the length is sufficient to carry the load.

Destructive pitting has more and larger pits than corrective pitting and will usually cause failure if the load is not reduced. See Figures 6 and 7. The concentration of large pits destroys the profile of the tooth and causes even more stresses. The pits are also good places for fatigue cracks to develop. In the end, a broken tooth or a rough sounding reducer will usually cause the pumping unit to be taken out of service.

- Tooth wear is the removal of metal from the tooth flanks in a, more or less, uniform manner. As the teeth mesh, they slide and roll against each other while under a torque load which is conducive to metal removal. Some wear is normal and should be expected; however, the degree of wear can be minimized by following good operation and maintenance practices. Figure 8 illustrates the progressive stages of wear. The more common types of wear in a pumping unit reducer are:

- Tooth-to-tooth contact allowed by poor lubrication. One of the purposes of lubrication is to separate the meshing teeth by a thin film of oil. At best, with pumping unit operational speeds, the oil film is considered to give marginal separation. So to maximize the lubrication effects, the oil needs to be the right lubricant for the job and it should be up to its specifications. The lubricant and its condition are of paramount importance in controlling wear. Unusual wear can often be related to wrong oil viscosity selection.

  - Abrasive wear is wear caused by operating the reducer in lubrication oil that has hard foreign particles suspended in solution so that as the gearing meshes, the particles go through the mesh. These contaminants leave scratches from the root to the tip of the tooth as they wear away the tooth surface. (Since these same particles go through the bearings, they also suffer wear.) See Figure 9. Abrasive wear feeds on itself and adds more contaminants to the lubrication system thus perpetuating the problem.

    The corrective action for abrasive wear is to keep the contaminants out of the lubrication system. Abrasive particles enter the reducer through air breathers, poorly fitting inspection covers, and seals. These areas should be checked periodically to be sure they are not allowing foreign materials into the reducer. Contaminants are also generated through normal tooth wear so it is prudent to either check the condition of the oil on a regular basis or change it out more often.

- Plastic flow is a form of tooth failure caused by extremely high loads that yield the material and cause it to flow in the direction of the rolling and sliding action. This type of failure displaces metal from the tooth flanks and leaves it at the tips of the tooth. The sharp wire edge condition can be felt with the fingertips at the outside diameter or tips of the teeth. See Figure 10. This condition is caused by an overload condition and the correction is to remove the overload.

The above explanation of the type of tooth distress and the cause should help the inspector recognize a problem so that it can be corrected. Since diagnosis of tooth problems and their corrections is such a specialty field, the inspector's role might be to simply recognize that there is a problem and call for help from the pumping unit manufacturer.

Reducer Bearings

The reducer pinion bearings must be free to float axially so that the pinions can line up properly with the low speed gear. The more common bearing used on the pinions is the straight roller type, having no locating shoulder on the inner race. The bearings on the crankshaft must locate the gear train within the gear housing. These bearings or bushings must be capable of taking some locating-type thrust loading. The minimum size or rating of the bearings is specified by API Specification 11E.

Even though bearings have a calculable fatigue life based on speed, load and the catalog rating of the bearing, it is rare that fatigue is the cause of a bearing failure. In a laboratory setting, bearings may fail from fatigue, but in the oilfield, most bearings fail from inadequate lubrication and from trash getting between the rollers and raceways. The secret to long reducer-bearing life is to use the appropriate oil and to keep it clean.

The inspection of the reducer bearings is difficult because of their location. The first indication of a failed bearing is normally the clicking noise it makes as the rollers turn over spalls in the raceway. Once the noise has been identified as a failed reducer bearing, the location of the bad bearing may be desirable. After removing the inspection cover, use a mirror on a wand placed in position to allow one to look for spalls or other damage inside the various bearings. In those situations where the mirror doesn't work, then it may be possible to use a piece of wire such as a paper clip bent into a "L" shape having a short leg and a long leg. This can be used to run between the bearing rollers to feel for a roughness in the raceway indicating spalling has taken place.

Recognizing the noise a failed bearing makes and finding that bearing is not a job for the average pumping unit user. This job is best left to experts in the service business who have had experience in identifying the various noises pumping units make as they turn.

Once the decision has been made to open up the reducer to replace the failed bearing, it makes good sense to change out all anti-friction roller bearings at that time even though some of them may seem to be alright. (A visual inspection of the "good" bearings will not tell you how much life is left in the bearings.)

Oil Lubricant

The purpose of the reducer oil is to provide a film of oil between the sliding and rolling teeth and bearings thus reducing friction and to carry away heat caused by friction. It is very important that the oil specified by the manufacturer is used and that the lubricant is in good condition. A good pumping unit gear oil will have the following characteristics:

- Should be high quality well-refined petroleum oil.
- Possess rust and oxidation inhibitors.
- Possess good anti-foam properties.
- Should have a minimum viscosity index of 90.
- Be non-corrosive to all metals even in the presence of moisture.
- Additives in the oil must not act as abrasives.
- The oil should have an extreme pressure additive.
- The viscosity of the oil may differ by pumping unit manufacturers but LUFKIN Industries requires the oil correspond to that of an AGMA No. 5EP product for ambient temperatures down to 0 degrees Fahrenheit and an AGMA No. 4EP lubricant for ambient temperatures down to –30 degrees Fahrenheit. Synthetic EP oils (such as Mobilgear SHC series) provide the widest temperature range of operation.

Figure 11 gives details of some oils that meet the above specifications.

Never substitute a motor oil for a gear oil. Motor oils contain a detergent which keeps water dispersed in the oil. Engines operate at high temperatures that boil away any water in the oil. Gear reducers do not operate at high temperatures so condensation water collects in the lubricant. In gear oils, it is preferred that the water be allowed to settle out so that it can be drained off. Water content should be less than 1000 parts per million (0.10%).

Check the oil level in the reducer after it is shut down. Too little oil may prevent the "splash" lubrication system from getting oil to the bearings and gear mesh. Too much oil may cause the oil to be churned to the point that it foams excessively. Foam can hinder the lubrication process and cause leaks.

As the oil is used, eventually it will become contaminated or depleted in several ways:

- Wear particles and other debris from internal and external sources will accumulate. Dirt (abrasive silicon) can enter through unfiltered vents.

- As the pumping unit warms up and cools off during its normal operating sequence, water will enter the gear reducer through condensation.

- Unusually hot running gear boxes can oxidize and thicken the oil and result in sludge formation.

As the oil becomes contaminated, its lubricating properties are reduced allowing more wear to take place and thus more contamination until the bearings and gearing begin the final failure process. The root cause of that pitted pinion or spalled bearing might very well have been dirty and/or wet oil.

There are two approaches to lubricant inspection. The first is to take a sample of the oil from the mid-sump level immediately after shutdown and send that sample to a lubricant laboratory for analysis. The analysis will identify any contaminants including water and will confirm if the oil meets its original specification. The key to effective oil analysis lies in the determination of changes over time, rather than just looking at just one test. Therefore, tests must be made at periodic intervals for the program to function properly.

If the analysis is completed on a regular basis and at any time oil is added, a trend of the concentration of each element can be documented and studied. One looks for abrupt changes in concentration levels as an indication of a reducer developing problems. For example, if the iron content is running at 100 PPM (parts per million) over several laboratory checks and suddenly jumps up to 500 PPM, we might look for some sort of problem that adds iron to the oil such as wearing or pitting gears or bearings. A good analysis will also check the oil's viscosity and presence of water so that one can tell if the oil needs changing. See Figure 12.

The second approach to lubrication inspection is to take a sample of the new oil when it is put in the empty reducer and keep it in a clear container to be used as a comparison to the reducer oil at a later time. Every 6 months draw a sample of oil from the reducer and place it in a clear container for visual comparison against the unused sample. Let the oil set for 24 hours; then a visual inspection will expose possible dirt, sludge, water or other types of contamination. If present, take the following action:

- An acid or burnt odor would indicate oxidation of the oil to the point that it needs to be replaced.

- If sludge is found in the sample, the oil should either be replaced or filtered through a maximum of 10-micron filter medium and a laboratory check completed to see if it is still in specification. If not, replace the oil. Sludge is usually found in reducers that have not had their oil changed in a long period of time.

- If water is found in the sample, the water should be completely drained from the sump or the oil replaced if the water has formed a tight emulsion with the oil. The presence of water in oil can be detected by heating a drop or two of it on a metal surface. Bubbling and spattering (like frying bacon) will occur with as little as 0.1% of water present in the oil. If water is detected, a sample should be sent in for a laboratory check to determine the quantity. More than 0.1% water is too much for good lubrication. Anti-friction bearings and gear teeth life can be significantly reduced by the presence of water in the lubricant.

Every 18 months the oil should either be replaced or a laboratory check made to confirm the oil's lubricating quality is within specifications.

Lubrication of Structural Bearings

The structural bearings on a modern pumping unit are lubricated with grease because grease is less difficult to seal and keep in place than oil. Grease is made up of a mixture of base oil and a soap thickener which serves as a storehouse for the oil. Successful application of grease depends on a relative small amount of mobile lubricant (the oil bled out of the thickener) to replenish the small amount of lubricant needed to lubricate the bearing.

Greases are identified by thickener (material and stiffness) and by the properties of the oil in the grease. For pumping unit bearings, use lithium soap base grease. The thickener stiffness is graded by the National Lubricating Grease Institute (NLGI) in numbers ranging from 000 to 6 with 000 being the softest. For temperatures down to 0 degrees Fahrenheit, use NLGI No. 1 grade and for temperatures down to –30 degrees, use NGLI No. 0 grade.

The base oil in the grease should be highly refined and contain rust and oxidation inhibitors and extreme pressure additives. For temperatures down to 0 degrees Fahrenheit, use AGMA No. 7 base oil (414-506 cSt. at 40° C.) and for temperatures down to –30 degrees, use AGMA No. 5 base oil (198-242 cSt. at 40° C). Figure 13 identifies several brand names and manufacturers of greases that meet the above specifications for greases recommended for use in pumping units.

To ensure a good grease maintenance program, follow the relubrication steps listed below:

- Relubricate grease lubricated anti-friction bearings every 6 months.

- Use the proper lubricant – not only should one use the grease specification identified above, but different types or brands of greases should not be mixed unless the compatibility of the two greases has been checked out by the lubricant supplier. Some greases are not compatible and should not be mixed. These incompatible mixes usually result in drastically reduced performance and a substantial softening of the mixture which may allow the grease to run out of the bearing housing. It is also possible for incompatible greases to harden when mixed, preventing good oil mobility.

- Prior to introducing new grease into the grease cavity, clean the lubrication fitting of any dirt so that it is not pumped into the bearing. Note the condition of the bearing assembly seals. If they are allowing the grease to escape and trash to enter the bearing housing, replace the seals.

- Slowly pump grease into the bearing cavity until grease comes out of the vent. Be sure the vent can function – is it free of paint? Be careful; pumping too fast may damage the bearing seal.

- Inspect the grease that comes out the vent for indication of bearing problems. If the bearing is badly spalled, the grease may have small bits of bright metal in the vent grease.

Inspection of Structural Bearings

The key to long life of structural bearings is to lubricate the bearings as discussed above, keep trash out of the assembly and to minimize or eliminate "pounding fluid" which causes shock loads on the bearings.

It is difficult to catch a structural bearing during the beginning of its failure because it moves slowly and therefore does not make a noticeable noise or generate much heat until later in its failure. About the only way to catch an early failure is through inspection of the grease. As the bearing spalls, metal flakes can be seen mixed in the bearing grease. It is wise to inspect the vent grease during relubrication for signs of early bearing failure. The following are suggested ways of inspecting bearing assemblies:

- Crank pin assembly

    - Remove the bearing end cap and inspect the grease for signs of metal.

    - Inspect the bearing cage for signs of damage or failure.

    - Since the cap removal allows access to the inner bearing, this bearing can be inspected with a "L" shaped piece of wire slipped between the rollers and against the raceway to look for a rough area that would indicate a spalled race.

- A crank pin bearing that is well into its failure will make a clicking noise while running and will feel warm or hot to the touch immediately after shutdown.

- Check the seal for leaks. Be sure that you do not mistake grease coming out of the vent for seal leakage. The vent location on some units is on the backside of the crank pin assembly near the seal area.

This is also a good time to inspect the crank pin for looseness in the crank. Look on both sides of the crank where the pin enters and comes out of the crank for any sign of looseness such as wear or rust stains coming out of these joints. Any rust found is due to fretting corrosion that is caused by a small movement between the pin and the crank. Another way to check for looseness in this joint is to match mark the crank pin nut and crank with paint or a chisel so that one can see if there is any movement between the two. If left unchecked, the wear and movement will grow allowing high crank pin stresses that may cause the pin to break and result in a major pumping unit wreck. If rust or movement is found, the pin should be removed and the pin and crank inspected for wear. There should be good contact (70% of area at each end – the middle 1/3 of pin length can be less) between the pin and crank. If wear is excessive, replace the crank pin and rebore and sleeve the crank bore.

Most crank pins get loose because they were not correctly tightened or were installed in a crank pin hole that was not clean. Be sure both the pin and hole are clean and free of any burrs before installation. See your installation manual for details.

- Equalizer bearing assembly
  - Look for metal flakes in the grease.
  - Stand behind the unit and look for looseness or a drop down appearance in the bearing housing indicating a failed bearing on one side.
  - Listen for clicking bearing sounds coming from the bearing housing.
  - A failed bearing will feel warm or hot to the touch immediately after shutdown.
  - Check for leaking seals.
- Center bearing
  - Look for metal flakes in the grease.
  - Look for looseness or a drop down appearance in the bearing housing indicating a failed bearing on one side. To confirm the drop down, measure from the top plate of the Samson post to the center bearing shaft or shaft retaining strap on both sides. A 1/8 to 1/4 inch difference would suggest a possible bearing failure. A dropped

down center bearing shaft would cause the wireline bridle to become misaligned to the horsehead which would be a clue to a possible failed center bearing.

- Listen for clicking bearing sounds coming from the bearing housing.
- A failed bearing will feel warm or hot to the touch immediately after shutdown.
- Check for leaking seals.

Inspection of Structural Joints

Most structural joints on a pumping unit are made up with bolts. Bolts that are not thoroughly tightened may experience a varying load that will cause them to fail in fatigue. Most pumping unit manufacturers publish bolt tightening torque values. However, service companies do not use torque wrenches to tighten bolts. Rather they hammer tighten bolts until the hammer blows feel solid. This seems to work well because bolts will sooner fail in fatigue from inadequate tightening rather than from being pulled into from excessive tightening. If you are experiencing bolt breaking problems, look for loose bolts or a joint that is not fitting up metal-to-metal. A loose joint will usually undergo fretting corrosion that will stain the joint with a rust-like appearance which is a sure indicator of looseness. If the joint is not fitting metal-to-metal as it should, it may be necessary to shim the joint to get a tight fitting joint that will not cause fatigue of the bolts.

One way to check a bolted joint for small movement is to flood the joint with light oil. As the pumping unit runs, the varying loads will make a loose joint move or breathe which can be better seen by the movement of the oil in and out of the joint. Any movement is too much.

Foundation Inspection

The pumping unit foundation supports the pumping unit base and provides an anchor place for the pumping unit so that it can lift the well load. Ideally, the base would be flat and level and heavy enough to keep the unit from rocking while under operation. If the concrete base settles to the front enough, it is possible that the oil troughs in the reducer will not properly lubricate the reducer bearings on the high end. If not flat, the steel base will not be supported in the valley and as the well load comes and goes, the varying loads can cause steel base breakage where it is not supported. In addition to good concrete support under the steel beams, it is important that the foundation bolts be tight to keep the base from moving under load. Any significant movement will likely cause a base crack in the area of flexing. Inspection of the foundation should include the following:

- Check the base for level – if out of level more than 3/8 inch in 4 ft. down the length of the base, then the base should be releveled. Across the base, the unit may be out of level no more than 1/4 inch in 4 ft. If the base is badly out of level, the polished rod will not fall in the center of the stuffing box which will cause bending of the polished rod and wear of the stuffing box rubbers.

- Check the foundation bolts for tightness and check for any movement between the base and the concrete. Shim, if necessary, to remove any looseness or movement.

- If the concrete base is cracked to the point that the two halves move independently, then that concrete base should be replaced.

- In the case of Mark II bases, the two pads should be spaced as shown on the foundation plan. If they are set too close together, it is possible for the steel base to "see" higher loads than it was designed to accommodate. If the concrete pads were improperly set, the spacing can be corrected by shimming under each end of the steel base as is shown in the foundation plan.

Pumping Unit Alignment Inspection

The pumping unit can be both internally and externally aligned. The internal alignment is the alignment of the several parts of the unit to itself. A pumping unit that is internally misaligned will cause unnecessarily higher loads to the structural parts that will shorten the useful life of those parts and the turning parts may even hit. To check the alignment of the unit, stop the unit with the pitman located just off the end of the crankshaft so that the distance from the end of the shaft to the pitman can be measured. See Figure 14. The distance should be the same on each side of the pumping unit. If the distance differs more than 1/4 inch from side to side, the unit should be realigned. Refer to your installation manual for alignment details.

The alignment of the pumping unit to the well is considered external alignment. If the external alignment is significantly off, the polished rod and stuffing box rubbers will suffer. To check the alignment, stop the unit at several spots in the stroke and use a level to check the plumbness of the polished rod. This should be checked in two planes (at right angles to the unit and in the plane of the unit). To correct a misalignment, move the unit as required. Another way to check this type alignment is to check that the polished rod is centered in the pumping tee at the top and bottom of the stroke. If not, realign the pumping unit to the well.

Wireline Bridle

The API Specification 11E for pumping units requires that the wire rope used for bridles has a safety factor of 5 when applied to the breaking strength of the wire rope. It is rare that a wireline fails from having been pulled into; rather it fails from wear or fatigue.

- Wear

  The wear may be internal or external to the rope. As the wireline wraps around the horsehead, external abrasive wear takes place between the two parts that can be seen at the outside diameter of the line. See Figure 15.

The bending and stretching action, caused by both the wireline wrapping around the horsehead and the load variation during the pumping cycle, forces the individual wires to move relative to each other. This movement produces internal wear between the wires in the rope.

- Fatigue

The wire rope bending action around the horsehead and any vibration bending movement of the wireline during the pumping cycle due to pounding fluid or "floating the rods" contribute to rope fatigue failure. All wirelines will eventually fail in fatigue if some other type of failure does not happen first. Wires that fail with square ends and show little surface wear have usually failed from fatigue.

To combat fatigue failures, use a flexible wire rope made up of many small diameter flexible wires (as opposed to a few large diameter wires) and reduce vibration movement of the rope. The 6 X 37 classification of wire rope, having an IWRC (independent wire rope center), made of improved plow steel, is a good compromise for wear and fatigue characteristics.

Wire Rope Inspection

A good time to inspect the wireline is when the horsehead has been taken off the pumping unit for well work. During this time frame, some care should be taken to keep the bridle out of the dirt so that abrasive materials do not become imbedded in the rope. Inspect for the following:

- Corrosion

A light rust discoloration indicates a need for rope lubrication. To lubricate the rope, first clean it with a wire brush; then paint on a wire rope lubricant. Severe rusting that causes pits leads to premature fatigue failures and is reason to replace the wireline.

- Kinks

A kink will significantly weaken the rope and is reason for replacement.

- Broken wires

  - If two or more wires are found broken in a valley (where the fracture occurs between strands), the rope should be replaced.

  - When a rope shows more than one broken wire next to an end fitting, the rope should be replaced.

- Three or more broken wires in one lay are reason to replace the wireline.

Conclusion

I am convinced that good maintenance programs more than pay for themselves in reduction of lost production and in less expensive repairs when they are required. It is my hope that this paper will yield a better understanding of the cause and effect of pumping unit operational problems and that this knowledge will encourage more frequent and thorough maintenance programs.

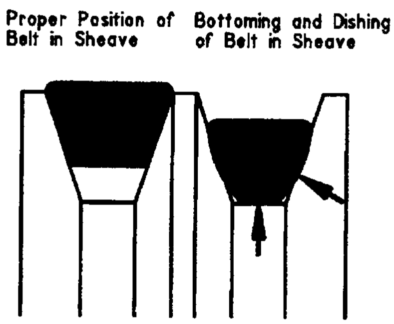

Figure 1

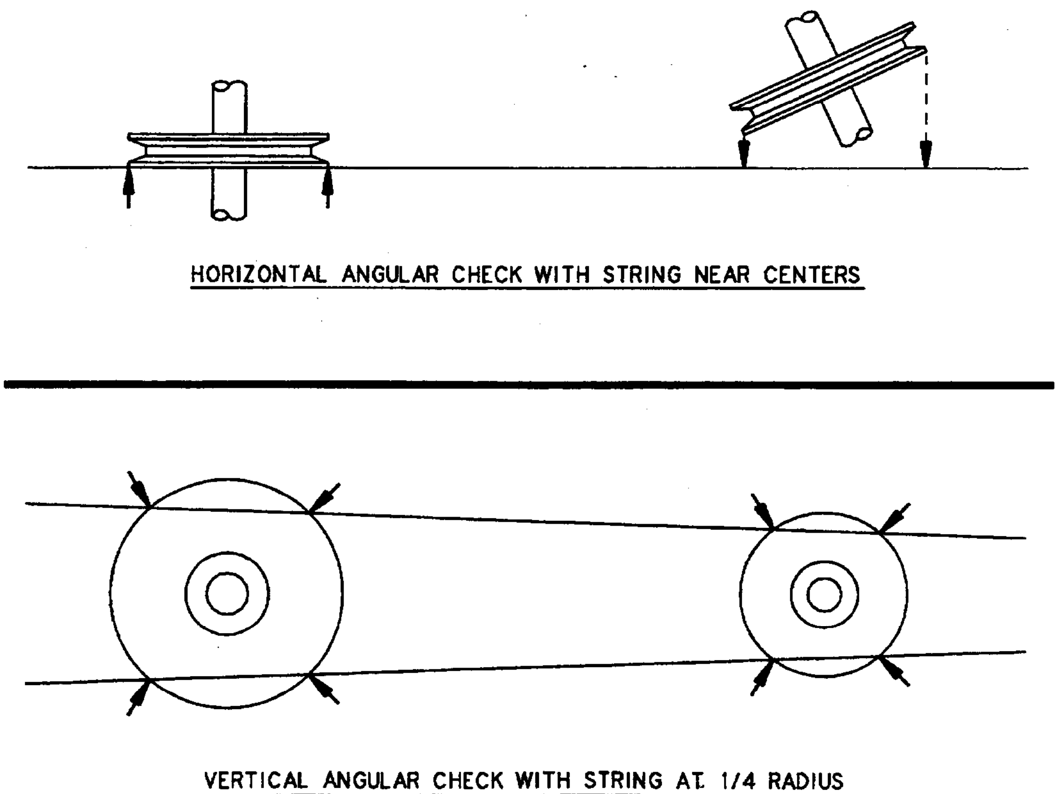

Figure 2 - Sheave Alignment

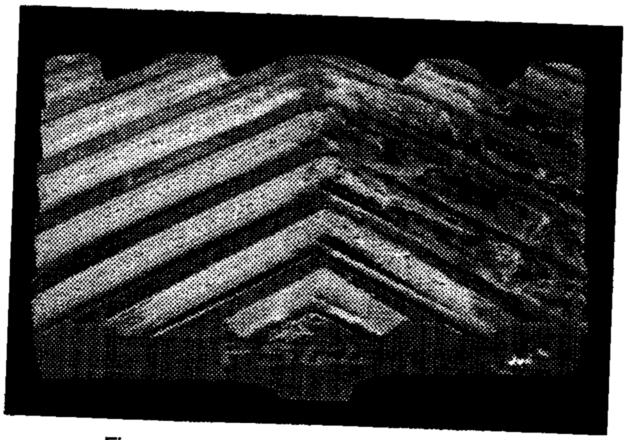

Figure 3 - Broken Teeth Due to Fatigue

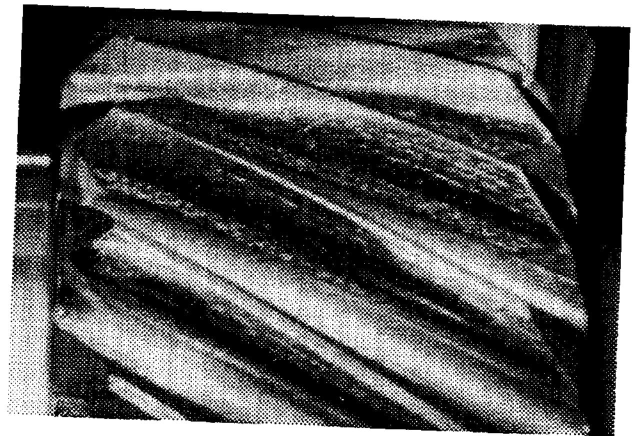

Figure 4 - Initial or Corrective Pitting

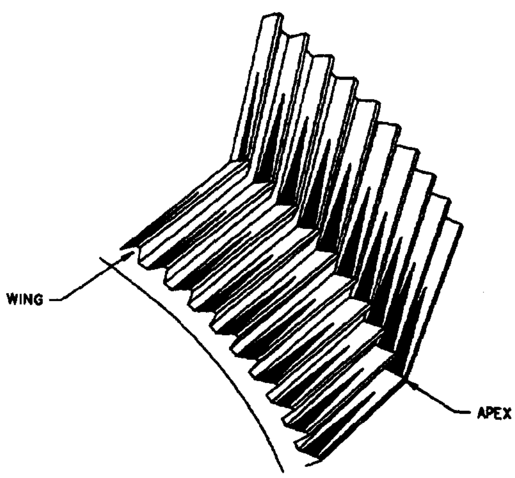

Figure 5 - Wing and Apez Loading

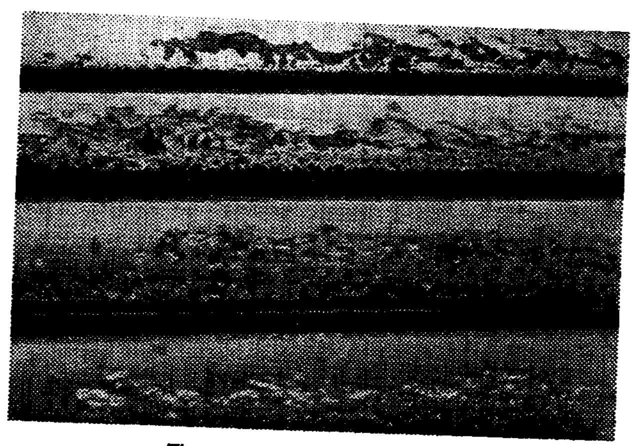

Figure 6 - Destructive Pitting

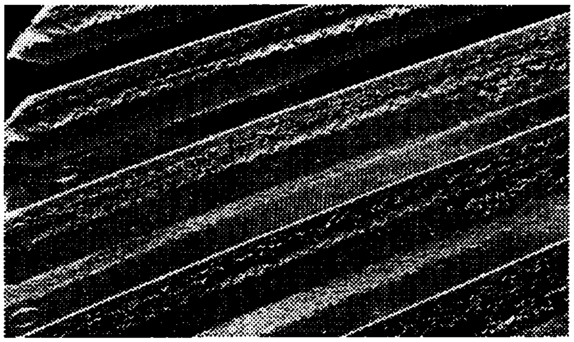

Figure 7 - Destructive Pitting in Ductile Iron

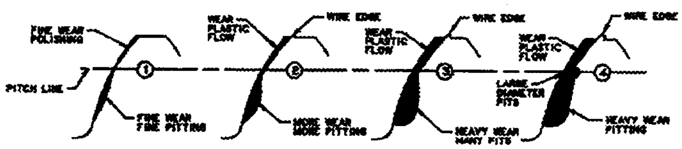

Figure 8 - Profile Wear - Progressive Stages of Wear

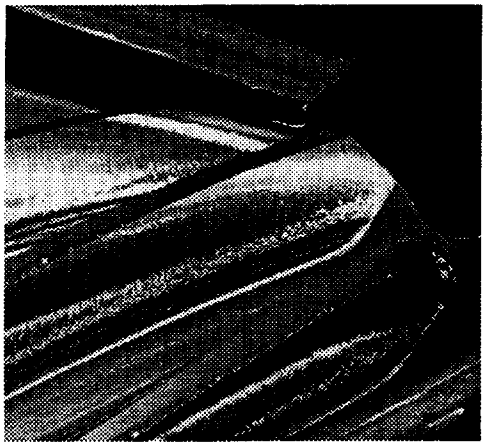

Figure 9 - Abrasive Wear

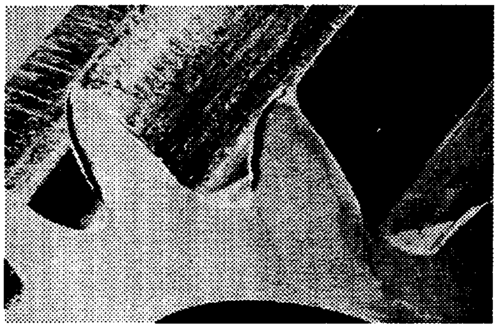

Figure 10 - Plastic Flow

	EXTREME PRESSURE (MILD) GEAR OILS				
	AGMA NO. 3EP ISO VG 100	AGMA NO. 4EP ISO VG 150	AGMA NO. 5EP ISO VG 220	AGMA NO. 6EP ISO VG 320	AGMA NO. 7EP ISO VG 460
AMOCO	PERMAGEAR EP 100	PERMAGEAR EP150	PERMAGEAR EP 220	PERMAGEAR EP 320	PERMAGEAR EP 460
CASTROL	ALPHA SP 100	ALPHA SP 150	ALPHA SP 220	ALPHA SP 320	ALPHA SP 460
CHEVRON	GEAR COMP. EP 100	GEAR COMP. EP 150	GEAR COMP. EP 220	GEAR COMP. EP 320	GEAR COMP. EP 460
CITGO	EP COMPOUND 100	EP COMPOUND 150	EP COMPOUND 220	EP COMPOUND 320	EP COMPOUND 460
CONOCO	GEAR OIL 100	GEAR OIL 150	GEAR OIL 220	GEAR OIL 320	GEAR OIL 460
EXXON	SPARTAN EP 100	SPARTAN EP 150	SPARTAN EP 220	SPARTAN EP 320	SPARTAN EP 460
LYONDELL LUBRICANTS	—	PENNANT NL 150	PENNANT NL 220	PENNANT NL 320	PENNANT NL 460
MOBIL	MOBILGEAR 627	MOBILGEAR 629	MOBILGEAR 630	MOBILGEAR 632	MOBILGEAR 634
PACER	GOLTEX IND. GEAR OIL 100	GOLTEX IND. GEAR OIL 150	GOLTEX IND. GEAR OIL 220	GOLTEX IND. GEAR OIL 320	GOLTEX IND. GEAR OIL 460
PENNZOIL	SUPER MAXOL EP 100	SUPER MAXOL EP 150	SUPER MAXOL EP 220	SUPER MAXOL EP 320	SUPER MAXOL EP 460
PHILLIPS	—	PHILGEAR 150	PHILGEAR 220	PHILGEAR 320	PHILGEAR 460
PRIMROSE	514 FLEX-O-LUBE XHP 3EP	514 FLEX-O-LUBE XHP 4EP	514 FLEX-O-LUBE XHP 5EP	514 FLEX-O-LUBE XHP 6EP	514 FLEX-O-LUBE XHP 7EP
SHELL	OMALA 100	OMALA 150	OMALA 220	OMALA 320	OMALA 460
SUN	—	SUNEP 150	SUNEP 220	SUNEP 320	SUNEP 460
TEXACO	MEROPA 100	MEROPA 150	MEROPA 220	MEROPA 320	MEROPA 460
UNOCAL	EXTRA DUTY NL GEAR LUBE 3EP	EXTRA DUTY NL GEAR LUBE 4EP	EXTRA DUTY NL GEAR LUBE 5EP	EXTRA DUTY NL GEAR LUBE 6EP	EXTRA DUTY NL GEAR LUBE 7EP

Figure 11 - Extreme Pressure Gear Oils

Make ---> LUFKIN
Model ---> C640-305-144 (Reduction Gear)
Well ----> 123

SAMPLE DATA		WEAR METALS AND ADDITIVES (In parts per million)																	CONTAMINANTS				PHYSICAL TESTS		
		ALUMINUM	CHROMIUM	COPPER	IRON	LEAD	TIN	NICKEL	SILVER	SILICON	SODIUM	POTASSIUM	BORON	MAGNESIUM	MOLYBDENUM	CALCIUM	PHOSPHORUS	ZINC	WATER %	% GLY	Soot	% FUEL	VIS. 40c	TAN	VIS. 100c
Sample Date:	3/1/91	-4	-4	21	46	0	0	0	0	4.1	.6	.5	.2	0	0	0	422	1.5	<.10	N/A	N/A	N/A	219	.24	N/A
Sample No.	100015	N	N	N	N	N	N	N	N	N	N	N	N	-	-	-	-	-	N	N			N		
Lab No.	999049																								
Total Mi./Hrs.	250	ALL WEAR METAL LEVELS WITHIN NORMAL LIMITS FOR SERVICE SINCE OVERHAUL. GEAR UNIT WEAR RATES AND CONTAMINANT LEVELS SATISFACTORY. ELECROMAGNETIC SCANNING DETECTED NO VISIBLE FERROUS METAL PARTICLES. RESAMPLE NEXT SERVICE INTERVAL TO FURTHER MONITOR. -ANALYST PM (REC'D: 3-4-91)																							
Mi./Hrs. on Oil	250																								
Mi./Hrs. on Flt.	? Hours																								
Sample Date:	2/1/91	1.4	.7	179	489	0	0	.9	0	4.3	.6	.6	.3	0	0	0	420	1.1	<.10	N/A	N/A	N/A	234	.30	N/A
Sample No.	100014	N	N	A	S	N	N	N	N	N	N	N	N	-	-	-	-	-	N	N			N		
Lab No.	999048																								
Total Mi./Hrs.	16085	RELATIVELY SHARP INCREASE IN BEARING/GEAR WEAR INDICATED. ADDITIONAL WEAR PARTICLE ANALYSIS REVEALED A LARGE AMOUNT OF MEDIUM SIZE VISIBLE FERROUS METAL PARTICLES. ADVISE INSPECT FOR SOURCE OF WEAR. CHANGE OR FILTER OIL. CHECK FOR VISIBLE METAL PARTICLES. RESAMPLE AT 1/2 NORMAL INTERVAL TO FURTHER MONITOR. (REF. PHONE CALL, 2-6-91) -ANALYST PM (REC'D: 2-5-91)																							
Mi./Hrs. on Oil	2000																								
Mi./Hrs. on Flt.	? Hours																								
Sample Date:	1/1/91	1.0	.3	76	138	0.4	0	.8	0	7.5	.7	.4	.2	0	0	0	423	0.9	<.10	N/A	N/A	N/A	229	.28	N/A
Sample No.	100013	N	N	N	N	N	N	N	N	N	N	N	N	-	-	-	-	-	N	N			N		
Lab No.	999047																								
Total Mi./Hrs.	14085	INCREASE IN GEAR UNIT WEAR RATES NOTED. ADDITIONAL WEAR PARTICLE ANALYSIS REVEALED A LIGHT AMOUNT OF FINE SIZE VISIBLE FERROUS METAL PARTICLES. CHECK FOR VISIBLE METAL PARTICLES. RESAMPLE AT 1/2 NORMAL INTERVAL TO FURTHER MONITOR. -ANALYST PM (REC'D: 1-6-91)																							
Mi./Hrs. on Oil	2000																								
Mi./Hrs. on Flt.	? Hours																								
Sample Date:	12/1/90	1.6	.8	48	108	0.6	0	.6	0	6.6	1.0	.8	.1	0	0	0	421	1.0	<.10	N/A	N/A	N/A	224	.27	N/A
Sample No.	100012	N	N	N	N	N	N	N	N	N	N	N	N	-	-	-	-	-	N	N			N		
Lab No.	999046																								
Total Mi./Hrs.	12085	GEAR UNIT WEAR RATES AND CONTAMINANT LEVELS SATISFACTORY. ELECROMAGNETIC SCANNING DETECTED NO VISIBLE FERROUS METAL PARTICLES. RESAMPLE NEXT SERVICE TO MONITOR AND ESTABLISH WEAR TREND. -ANALYST PM (REC'D: 12-4-90)																							
Mi./Hrs. on Oil	2085																								
Mi./Hrs. on Flt.	? Hours																								

LUFKIN INDUSTRIES, INC.
ATTN: ENGINEERING LAB MANAGER
601 S. RAGUET
LUFKIN, TX 75901

System Capacity ---> 70 GALLONS
Oil Make and Type -> AGMA #5EP
History/Remarks ---->

LEGEND:

N	=	Normal
A	=	Abnormal
S	=	Severe
>	=	greater than
<	=	less than
Neg	=	Negative
Nil	=	Negligible
N/S	=	Not Applicable

Figure 12 - Example of an Oil Analysis

GREASES FOR PUMPING UNIT STRUCTURAL BEARINGS

SUPPLIER	SOUTHERN CLIMATE (DOWN TO 0° F.)	NORTHERN CLIMATE (DOWN TO -30° F.)
CASTROL	MOLUB-ALLOY 860/460 #1	MOLUB-ALLOY 860/220 #0
CHEVRON	ULTI-PLEX GREASE EP 1	ULTI-PLEX GREASE EP 1
CITGO	LITHOPLEX RT	LITHOPLEX MP-1
CONOCO	MILUBE GREASE 2100	EP CONOLITH GREASE #1
EXXON	RONEX EXTRA DUTY 1	UNIREX EP 1
LYONDELL LUBRICANTS	LITHOLINE COMPLEX EP-1	LITHOLINE COMPLEX EP-1
MOBIL	MOBILGREASE HTS	MOBILGREASE HTR
PENNZOIL	PENNLITH ULTRA EP 1	PREMIUM LITHIUM COMPLEX #1
PHILLIPS	HI TEMP EP-1	HI TEMP EP-1
TEXACO	STARPLEX PREMIUM 1	STARPLEX 1
UNOCAL	- -	MULTIPLEX RED #1

Figure13 - Greases for Structural Bearings

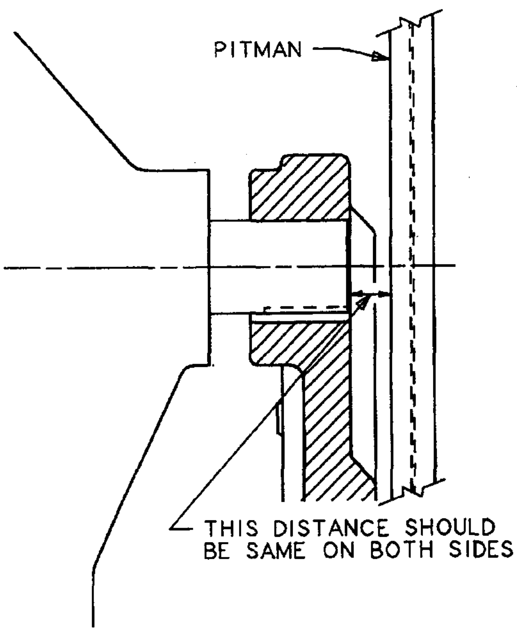

Figure 14 - Pitman to Crank Alignment

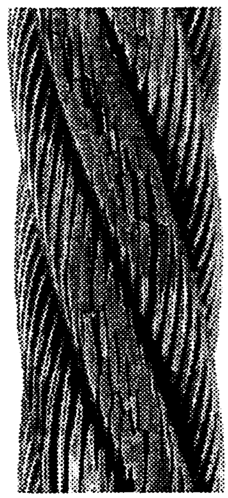

Figure 15 - Wear in Wire Rope