Pumping Unit Lubrication

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INTRODUCTION

Lubrication is one of the most important influences on the life of a pumping unit. However, successful operation requires a well balanced program beginning with the careful selection of equipment and lubricants and carried out with a well planned maintenance program.

This paper analyzes the lubricant characteristics required for pumping unit bearings, gear units, electric motor drives, pumping engines, and hydraulic unit fluid. General recommendations are discussed for the maintenance of the lubrication systems of this equipment. Specific examples of the effect of service on the lubricants are reviewed to illustrate the need for a proper oil change frequency.

General principles of the lubrication of the equipment are discussed; however, it is beyond the scope of this paper to cover detailed recommendations for the different models of these units.

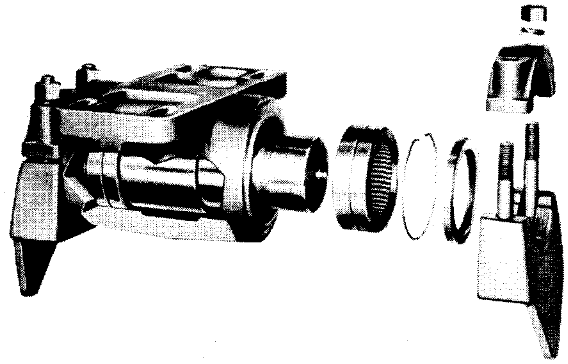

Figure 2. Pumping Unit Saddle Bearing Assembly

PUMPING UNIT BEARINGS

Refinement in design and improvement of bearings has led to the replacement of plain bearings by roller and needle bearings in the pumping unit. Figure 1 shows a typical modern unit equipped with needle and roller bearings. The bearings are provided with pressure grease fittings, and for convenience to the operator the saddle bearing and the equal-

Figure 1. Typical Pumping Unit

izer bearing are equipped with remote fittings to provide easy application of the lubricant.

The saddle bearing assembly shown in Figure 2 is typical of the highly developed precision needle bearing used in the saddle bearing, the equalizer bearing, and the Pittman bearings of modern pumping units. The needle bearing is used in these assemblies in order to increase the magnitude and the velocity of the angular movement of the bearing surfaces generated by the oscillation of the bearing assembly. The higher bearing surface movement of the individual needles builds up a hydro-dynamic film of the lubricant and good load-carrying properties. Of course, at each reversal of the motion, relative movement of the bearing surfaces ceases momentarily, and under these conditions boundary layer lubrication occurs.

Satisfactory performance of this type of bearing under heavy reversing loads demands precision machining of the parts and very close clearances. These surfaces must be protected by a high-quality lubricant, and the bearing must be equipped with a seal, as shown in the figure, to retain the lubricant and to seal out abrasive matter and water. A good seal of the type shown must be protected from accidental damage by the application of excessive pressure when the bearing is greased with a pressure gun. Therefore, bearing housing is equipped with a relief valve to protect the seal.

The wrist pin bearings of this particular unit are equipped with self-aligning roller bearings in a sealed housing fitted with a pressure-grease fitting and a relief valve, as shown in Figure 3. The rollers of this bearing assembly operate at a constant surface speed that provides full hydrodynamic lubrication, but they may be sufjected to considerable load reversal, depending upon the balance of the counter weights, the walking beam, and the well load. The precision roller bearing used in this assembly must be supplied with a high-quality lubricant to carry the heavy loads transmitted through

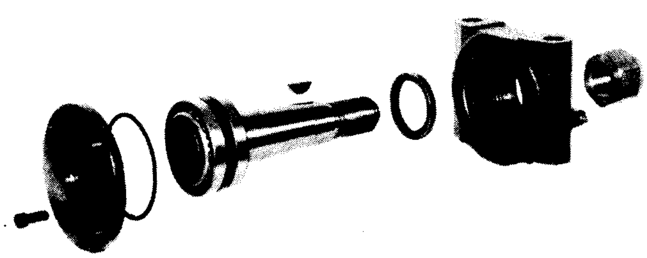

Figure 3. Wrist Pin Bearing Assembly

TABLE I.

PUMPING UNIT GREASE CHARACTERISTICS

PUMPABILITY -	Applicable by hand gun at ambient temperature.
CONSISTENCY -	Above 32 F No. 2 Below 32 F No. 1
LOAD CARRYING -	E.P. Additives not essential. Oil base viscosity above 50 SSU at 210 F.
TYPE OF SOAP -	Not Critical.
MECHANICAL STABILITY -	Good after working at elevated temperature.
TEMPERATURE STABILITY -	Oxidation-inhibited.
RUST PROTECTION -	Rust-inhibited.

the bearing and to protect the bearing surface.

As shown in TABLE I, the pumpability of this grease must permit application with a hand-operated grease gun over the entire winter and summer operating-temperature range. The remote grease fittings with long lines to the saddle bearing demand the use of a grease with good pumpability in cold winter weather. Generally, the No. 2 consistency is satisfactory at all normal operating temperatures. However, below 32 F, No. 1-consistency grease will feed to the bearings more uniformly and is more easily applied through grease fittings. If lower temperatures persist, No. O-consistency grease is desirable.

Because of the load reversals and the directional reversals of all except the wrist pin bearings, a grease having good load-carrying capacity is needed. However, this does not demand extreme pressure properties and extreme pressure additives. It has been well established by field experience that greases made with a high-quality oil base having a viscosity above 50 seconds Saybolt Universal at 210 F will provide a tough strong film to protect the needle and the roller bearings of a pumping unit through many years of service.

The type of soap with which grease for this application is compounded is not critical as long as the performance characteristics are suitable. Accordingly, good results are obtained with different soap bases, and lithium multi-purpose-type greases properly compounded with other additives are rapidly expanding in these applications, since they are also suitable for electric motor, clutch, and other bearings, making possible the use of one grease on a number of different applications.

Mechanical stability is very important, for a grease must not soften excessively after having worked in these bearings and must not leak past the seals, starving the bearing before it has been relubricated. These requirements demand a grease that is properly formulated and manufactured.

The most desirable type of grease for this service should contain a suitable oxidation inhibitor to prevent severe oxidation of the grease during long periods of hot service. In addition, the grease should contain a rust inhibitor to protect the polished bearing surfaces from rust caused by moisture during the shut-down periods of the unit.

Typical properties of a desirable pumping unit grease formulated from a high-quality oil and a lithium soap base with oxidation and rust-corrosion inhibitors is shown in TABLE II.

Final success in the lubrication of the pumping unit bearings requires frequent application of the grease. A fresh small amount daily is preferable to excessive greasing on a less frequent scale; however, the frequency must be adjusted to the requirements of the operation as a whole and may be weekly.

TABLE II

TYPICAL PROPERTIES OF A DESIRABLE PUMPING UNIT GREASE

CONSISTENCY NLGI	No.2
PENETRATION 77F	
Unworked	280
Worked	290
FLOW POINT F	330
DROPPING POINT F	380
OIL BASE VISCOSITY SUV	
210 F	80
SOAP TYPE	Lithium
ADDITIVES	
Type	Oxidation Inhibitor
Type	Rust Inhibitor

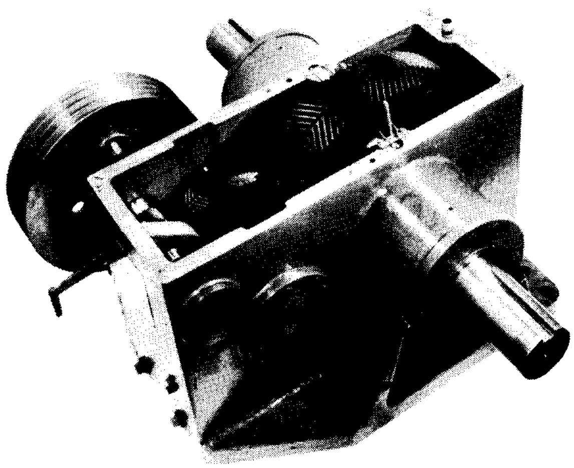

Figure 4. Pumping Unit Gear Set

GEAR UNIT

The herring bone reduction gear set shown in Figure 4 is typical of the modern pump drive unit. The pinion and the intermediate shaft are equipped with roller bearings, and the crankshaft has sleeve bearings.

The load-carrying surfaces of the gears are lubricated by the bath oil reservoir in the base. Scrapers take oil from the crankshaft and intermediate gears through a trough to the bearings. Oil spray from the gears also supplies oil to the roller bearings on the pinion and the intermediate shafts.

The elements critical to lubrication in the gear unit are the loaded gear faces rather than the bearings. However, the bearings require a lubricant having good film strength and oxidation stability. The rubbing surfaces of the gears require oil of the proper viscosity with good film-strength properties.

The American Petroleum Institute has issued a bulletin, RP11G, dated June, 1956, establishing recommended viscosities for gear reducers depending on the oil operating temperature, as shown in TABLE III. The API ranges have been selected so that the viscosity of the oil at the minimum temperature will be low enough to assure adequate oil flow through the oil passages to the bearings. The upper temperature limits have been established to provide satisfactory film thickness for lubrication of bearings and gear faces.

Individual gear reducer manufacturers have established viscosity ranges for units of their manufacture and in some cases may prefer or specify extreme-pressure additive-type gear oils. These extreme-pressure gear oils are superior to non-additive oils where gear tooth loading is high, and they have been very successful where care has been used in the proper selection of the lubricants.

TABLE III

API VISCOSITY RECOMMENDATIONS FOR

PUMPING UNIT GEAR REDUCERS

OPERATING OIL TEMPERATURE F	SAE VISCOSITY NUMBER Engine Oil	Gear Oil
-50 to + 32	5W	75
-40 to + 50	10W	--
-20 to + 80	20W	80
0 to + 100	30	--
+10 to + 125	40	90
+20 to + 135	50	90
+30 to + 155	--	140

A review of desirable characteristics of pumping unit gear oil is presented in TABLE IV. If the viscosity selected is too low, it may prevent sufficient oil from being carried up on the gears and into the bearings. It may also fail to provide an adequate film on the loaded gear faces. On the contrary, if the oil is too high in viscosity or if the pour point is too high, inadequate oil will be carried to the bearings, and a bearing failure may occur.

Some operators have been concerned that the additives used in extreme-pressure lubricants may become corrosive to the gear faces in the presence of moisture, and there has been some evidence of this, particularly with bronze gears and active chlorine compounds. However, extreme-pressure additives of the sulfur fatty-oil type, the lead-naphthen type, and similar compositions have established excellent long-service records.

The oxidation stability of gear oil is very important because of the long time of operation between oil changes. Normally, the oil temperature of the gear units may be expected to be not over 25 F above the oil temperature, but in severe service the temperature of the oil may be considerably higher. Unstable oil will oxidize rapidly, forming organic acids which form sludge and water emulsions, rendering the oil unsuitable for service. Resins are formed by the oxidation process which coats the gears with a tacky lacquer-type substance that upon further oxidation becomes hard lacquer. Oxidation products also increase the viscosity of the oil, making it unsuitable for the operating temperature range.

TABLE IV

DESIRABLE CHARACTERISTICS OF

PUMPING UNIT GEAR OIL

VISCOSITY -	Selected to meet manufacturer's recommendation and operating temperature.
POUR POINT -	Preferably 5 to 20 F below minimum air temperature.
FILM STRENGTH -	Good oiliness properties and may have extreme-pressure additives.
STABILITY -	Due to heat and long service the oil should have good resistance to oxidation.
WATER SEPARATION -	Separates rapidly from water.
RUST PREVENTION -	The oil should adhere to the bearing and the gear surfaces to prevent rust.

These gear reducers are usually exposed to the weather, the exposure resulting in some contamination of the oil by water and airborne grit and dirt. Accordingly, it is desirable that the oil separate rapidly from water and contaminants.

Since many pumping units operate intermittently, the oil should provide rust protection during the inoperative as well as the operating period. Therefore, the oil should be surface-active and should adhere to the bearing and the gear surfaces while they are inoperative to prevent rust and to displace moisture from these surfaces.

After the proper lubricant has been selected, it must be protected from contamination as well as possible and must be changed at a reasonable frequency. During the normal service period, the oil level must be properly maintained, and any visible water or contaminant should be drained from the bottom of the reservoir.

Occasionally, operators permit an oil charge to stay in service for too long a period. TABLE V shows the analysis

TABLE V

E.P. TYPE SAE 90 GEAR OIL

FROM PUMPING UNIT

AFTER 5 YEARS' SERVICE

VISCOSITY SUV, SECONDS	
At 100 F	1536
Increase	334
NEUTRALIZATION VALUE ASTM D974	
Total Acid No.	1.26
Increase	1.10
WATER AND SEDIMENT: %	0.1
INSOLUBLE MATTER: %	
Normal Pentane	2.7
Benzene	0.1
Resins	2.6

of a sample of extreme-pressure-type SAE 90 Gear Oil, after the excessively long period of five years. Oxidation has caused the viscosity to increase 334 seconds above the original value, making the viscosity undesirably high. The oxidation process has generated acid, as will be noted by the acid number increase of 1.10. Water and sediment have accumulated in the system in the amount of 0.1%. The total insoluble matter, 2.7% normal-pentane insoluble, has become excessive. Solid contaminants such as grit and dirt are represented by the benzene insolubles of 0.1%. Severe oxidation has occured from the excessively long period of service, as shown by the resin content of 2.6%. This deterioration makes the oil unsuitable for further service. The resins and acid can be removed only by active filters that would remove the extreme-pressure additives; therefore filtering this oil will not make it suitable for service.

The best service can be obtained from the gear sets by selection of the proper lubricant. The oil should then be maintained at the proper level and should be changed regularly. The oil should be changed semi-annually if temperature conditions require different viscosity oil for winter and for summer; otherwise the oil should be changed annually or more frequently if severe contamination occurs or if there is other evidence of deterioration.

ELECTRIC MOTOR DRIVE

Normally, electric-motor-driven units are operated by 220- or 440-volt a-c 900- or 1200-rpm motors. These are usually operated on three-phase current; however some of the small 7 1/2-hp motors are single phase.

Maintenance and lubrication of these electric motors requires very little time. Some are equipped with an oil reservoir and may be lubricated with a high-quality turbine-type oil. It is desirable to use an oil having a viscosity of 200 to 300 seconds Saybolt Universal at 100 F for temperature ranges above freezing. If sub-freezing temperatures prevail, the lower end of the range should be used. If extremely cold temperatures of O F or lower occur and the operation is intermittent, a special oil should be selected, the selection being based on the minimum temperatures encountered.

The oil used for lubrication of the motors should separate from water readily and should be oxidation-/and rust-inhibited to resist deterioration by oxidation and to prevent rusting of the bearing surfaces during the inoperative periods.

The oil-lubricated electric motor should be inspected regularly to make certain that the oil is being maintained at the proper level in the reservoir. Usually weekly inspection is frequent enough; however, the inspection should be adjusted to the operating time. The reservoirs should be inspected for water or other contaminants and should be thoroughly cleaned on a semi-annual basis or whenever contamination is observed.

The grease-lubricated motor bearings are usually fitted with pressure-grease fittings for lubrication during service; however, some may have hand-packed bearings that are lubricated only after disassembly and cleaning on an annual basis or other frequency established by the manufacturer. Pressure-gun greasing of these bearings may be weekly or monthly, depending on the service experience of the particular unit. Caution must be observed to prevent supplying the bearings with excessive amounts of grease, which will cause the bearing to overheat and which may damage the windings by coating them with excess grease. Applying a small amount of fresh grease at frequent intervals is the most desirable practice.

If a high-quality oxidation-and rust-corrosion-inhibited grease is used on the pumping unit bearings, it may also be used on the electric motor bearings. This is the most desirable practice, for it assures a high-quality grease and minimizes the number of required grades and the possibilities of accidental mixing of the greases. Either sodium-base or lithium-base multi-purpose greases may be used. In initially applying the lithium-base grease to bearings previously lubricated by other grease, there may be some softening of the mixture and temporary high consumption. This phenomenon disappears as the old grease is replaced with the new grease and normal consistency and consumption return.

PUMPING ENGINE

Modern 2-cycle single-cylinder and 4-cycle multi-cylinder gas pumping engines have been designed with close clearances and highly finished parts to generate power efficiently and to render long service. The successful operation of these units is based on a careful choice of the design and the power requirement of each particular unit, in addition to the proper mechanical and lubricating-oil-system maintenance.

The lubrication system of the 2-cycle single-cylinder engine differs substantially from that of the 4-cycle multicylinder engine. Normally, the 2-cycle-engine crankcase is sealed from the cylinder and the scavenging system by means of a packing which prevents cylinder-lubricant and fuel-combustion products from entering the crankcase system. The crankcase lubrication may be either by splash or by the full-pressure system to the crank pin, the connecting rod, and the main bearings. Usually, the oil in this system is not subjected to the extreme temperatures adjacent to the combustion space. Accordingly, the crankcase system of these 2-cycle single-cylinder engines does not impose severe oxidation requirements on the lubricating oil.

The cylinder is usually lubricated by a separate drip-feed or force-feed lubricator driven by the engine, and the lubricant is supplied from a separate oil reservoir. The oil feed rate to the power cylinder may be adjusted by regulation of the lubricator pump. This adjustment should be made with considerable care in order to avoid scuffing the rings or the cylinder because of insufficient lubricant. Conversely, if excessive amounts of cylinder oil are fed through the force-feed lubricator, carbon-deposit accumulations within the combustion space, the intake, and the exhaust ports may necessitate more frequent maintenance and cleaning. Normally, the oil feed rate to the power cylinder is from one-half pint to one quart per cylinder per day. The exact amount depends on the operating conditions and on the general engine design. The manufacturer's recommendations should be carefully followed during the initial operation of the engine until adequate experience has been obtained in each instance. The feed rate may then be adjusted to compensate for the particular load at which the engine is operated.

The force-feed lubricators used on these engines are generally equipped with the plunger-type pump, that forces the oil through a sight-drip or sight-fluid where it is then forced through a check valve to the cylinder. The sight-fluids normally used are a 50/50 mixture of glycerin and water;

however, in some instances where there is interference with this fluid by additives in the oil, other solutions may be used. In any event, it is necessary to clean the lubricator reservoir at intervals of approximately six months, and if on these occasions the sight-feed fluid is observed to be cloudy or discolored, it should be replaced.

Normally the multi-cylinder 4-cycle engines are full-pressure and splash-lubricated from the crankcase system. The pressure oil system may also be arranged so that oil is sprayed or splashed on the under side of the piston crowns to improve the cooling of the piston ring belt. In this type of engine the operator has no control over the lubricating oil consumption rate other than through proper maintenance of the oil rings. Worn oil-control rings will result in high oil consumption, and worn compression rings will permit excessive blow-by of combustion products into the crankcase oil.

In the 4-cycle multi-cylinder engine there is also a tendency to contaminate the crankcase oil by the liquid components and sulfur from gas containing any excessive amounts of these materials. These combustion contaminants cause rapid deterioration of the crankcase oil, particularly at elevated temperatures. In this type of engine, crankcase temperatures in the order of 160 to 200 F are frequently experienced, and they further accelerate the deterioration of the crankcase oil. Under extremely cold operation the combustion products and moisture from both combustion and breathing may contribute to a rapid accumulation of sludge. Care used in the selection of the lubricating oil and proper oil changes, along with an adequate filter element, will significantly improve the operating condition.

Characteristics of the general types of lubricating oils used in pumping engines are shown in TABLE VI. The viscosity is independent of the general type of oil. The pour point may be influenced by the type of oil or by the possible use of pour-point depressants. In general, oils refined from naphthene-base crude have a lower pour point than those refined from the more paraffin-type crude.

The oxidation stability of a non-additive-type oil is limited to the inherent properties of the crude and to the degree to which it is refined. Oxidation stability is improved by additives in the inhibited type of oil or in the detergent type of oil which normally contains both a detergent and an oxidation inhibitor. The inhibitor additive retards the oxidation process of lubricating oil at elevated temperature and has a significant effect on reducing the rate at which the viscosity of the oil increases because of oxidation and of the rate at which acids are formed in the oil. Even with the addition of these fortifying additives, an oil subjected to high temperatures or to normal engine temperatures for an excessive period of time will develop oxidation products which will materially affect its performance and will render it unsatisfactory for further service.

Many engines, and particularly multi-cylinder 4-cycle engines, are equipped with copper-lead bearings or other types of bearings that may be corroded by acids developed in the oxidation products of lubricating oil. A non-additive type of oil is poor in this respect and may, under severe operating conditions, rapidly become acid and corrosive. The addition of inhibitors used in both the inhibited- and the detergent-type oils provides these products with good resistance to the formation of corrosive material that would attack copper-lead or other sensitive bearing metals.

The lacquer-prevention characteristics of an oil are particularly desirable under high-temperature operating conditions, and the non-additive-type oil is limited in this characteristic to the degree of refinement that can be obtained with the base stock. Naturally, this characteristic can be greatly improved by inhibiting the oil. Further improvement can be obtained by the use of a detergent-inhibitor combination so that lacquering under hot operating conditions will be held to minimum, provided that the oil is changed at reasonably frequent intervals.

Cold sludge accumulation is usually the result of a mixture of oxidation products, oxidized lubricating oil, and moisture. Both the non-additive-type oil and the inhibited-type oil are limited on cold sludge performance characteristics since they do not contain a depressant or a detergent type of compound that will assist in suspending the sludge and in carrying it to the oil filter. Therefore, the detergent oil has a marked advantage under these operating conditions, and it has been found that oils containing the higher concentration of detergent additive are especially effective in minimizing cold sludge formation.

Corrosion and corrosive wear frequently occur when high-sulfur and high-liquid-content gas is used. The non-additive and inhibited oils lack the required characteristics to combat this attack. The detergent-type oil and particularly oils of a high detergency content with good alkalinity properties have shown a significant improvement in minimizing corrosion and wear in engines consuming gas having high sulfur or liquid components.

TABLE VI

ENGINE LUBRICATING OIL

CHARACTERISTICS

	LUBRICATING OIL TYPE		
	Non-Additive	Inhibited	Detergent & Inhibited
VISCOSITY	Available in desired range		
POUR POINT	Available in desired range		
OXIDATION STABILITY	Limited	Excellent	Excellent
BEARING CORROSION PREVENTION	Poor	Good	Good
LACQUER PREVENTION	Limited	Good	Excellent
SLUDGE PREVENTION	Limited	Limited	Excellent
SULFUR - CORROSION PREVENTION	Poor	Poor	Excellent
RUST PREVENTION	Limited	Limited	Fair

Rust prevention in an engine crankcase and in the cylinder assembly is particularly important in pumping units that are operated intermittently. The rust-prevention properties of non-additive and of inhibited oils are limited to the performance of their oleaginous properties in displacing moisture on the metallic surfaces during such shutdown periods. The effectiveness of a detergent oil is somewhat better because of the ability of the detergent additives to displace the moisture more readily and to adhere to the metal surface during the inoperative periods. If an engine is to be operated only on a very limited basis with long inoperative periods, consideration should be given to securing a special type of oil designed particularly for rust prevention of engines during storage and provided with adequate detergent and inhibitor characteristics for intermittent use.

Currently available are oils of approximately three detergency-content levels with each higher level an approximate double of the lower level. The effectiveness of these detergent-additive levels can be evaluated only by specific engine tests; however, the three ranges of activity may be classified in general by the additive-ash level. Normal heavy-duty detergent oils have ash contents of approximately 0.5%. The Supplemental I oils have an ash content of approximately 1.0% and the super-duty-type oils generally have an ash content in excess of 2%.

The Saybolt Universal viscosity temperature relationship in comparison with SAE numbers of oils is shown in TABLE VII. It will be noted that the SAE control limits for the 20-, 30-, and 40-SAE ranges are shown at 210 F, and any oil meeting this classification has a viscosity between these limits at 210 F. The SAE 10W oil has a control limit of 6000 to 12,000 Saybolt Universal seconds at 0 F in order to assure good oil flow characteristics at low temperature.

This particular table shows the range in viscosity that may occur at other temperatures such as 100 F and 30 F of oils meeting a particular SAE Number. This table has been prepared by using a Viscosity Index range of from 50 to 100. The Viscosity Index range in this instance has been chosen to cover normal temperature viscosity characteristics for oils used in pumping engines. The 100-Viscosity-index oil represents typical viscosity temperature characteristics for a highly solvent, refined paraffin-type oil. The blended type of oil made from paraffin and naphthene-type stock is illustrated by the lower limit of 50 viscosity index.

TABLE VII

SAYBOLT VISCOSITY - TEMPERATURE

VS

SAE NUMBERS

FOR 50 - 100 VI OILS

APPROXIMATE SAYBOLT UNIVERSAL VISCOSITY SECONDS FOR 50-100 VI OILS

SAE NO.	210 F	100 F	30 F
10W	40 - 47	120 - 200	1300 - 2500
20	* 45 - 58	175 - 540	1750 - 16000
30	* 58 - 70	390 - 900	6000 - 37000
40	* 70 - 85	600 - 1330	11000 - 65000

* SAE Control Limits. SAE 10W control 6000-12000 SSU at 0 F.

It will be noted from the data shown in this table that at low operating temperatures of 100 F it is possible for one SAE 20 oil to be as viscous as another SAE 30 oil. Also, considerable difference in viscosity may occur at low starting temperatures such as 30 F between two oils of the same SAE Number. From these particular data it will be noted that the viscosity variation of SAE 30 oil may be from 6000 to 37,000 seconds at 30 F for a range of 100 to 50 Viscosity Index.

These data indicate the importance of securing the proper viscosity and the proper viscosity index relationship for an oil that is to be used in intermittent operation at low temperatures to minimize starting difficulties and to assure proper oil flow to engine parts under cold conditions.

Pumping unit engine oil recommendations, as shown in TABLE VIII, must be modified depending on the design of the engine, the manufacturer's recommendations, operating conditions, and the oil supplier's knowledge of the performance of his particular product. Accordingly, the viscosity ranges shown are only in a general category. The pour point of the oil, of course, should be sufficiently below the air temperature to permit a ready flow of the oil in the engine system when it is cold. Once the oil begins to absorb engine

TABLE VIII

PUMPING UNIT ENGINE OIL

RECOMMENDATIONS

	ENGINE TYPE	
	Single-Cylinder 2-Cycle	Multi-Cylinder 4-Cycle
VISCOSITY, SAE NO.		
Below 32 F	10-20	10-20
Above 32 F	20-30	30-40
POUR POINT	10 to 20 F below ambient	
PREFERRED OIL TYPE FOR:		
Light-Load Cold Operation		
Dry and Low Sulfur Gas	Non-additive or Detergent	Inhibited or Detergent
Wet or High Sulfur Gas	Detergent	Detergent
Heavy-Load Hot Operation		
Dry and Low Sulfur Gas	Non-additive or Inhibited	Inhibited or Detergent
Wet or High Sulfur Gas	Detergent	Detergent

heat the pour point has little significance; however, it is particularly important in the handling of the oil and the oil feed through force-feed lubricators at initial engine-starting temperatures.

Light-load cold operation of either 2-cycle-or 4-cycle-type engines obviously minimizes oxidation requirements. With dry and low-sulfur-content gas a non-additive oil will be entirely satisfactory in a 2-cycle engine. If the temperatures are particularly low and mositure is at a high concentration, it may be desirable to use a detergent oil in the crankcase system to minimize sludge accumulation. Under light-load conditions with clean gas the 4-cycle engine will perform very satisfactorily on an inhibited oil unless cold sludge accumulation indicates the need of a detergent-type oil. Under light-load operating conditions wet gas or high sulfur gas is inclined to increase piston ring belt deposits and corrosive wear. Detergent oil will improve this condition in both the 2- and the 4-cycle-engine power assemblies.

Heavy-load, hot operation generally produces higher engine circulating-oil-system temperatures with the resultant tendency for oxidation. However, in the 2-cycle engine the crankcase may still remain adequately cool to permit the use of a well refined non-additive oil. If the temperature of the crankcase is high, an inhibited-type oil would be more desirable. In the case of the 4-cycle engine, it is preferable to use either an inhibited oil or a detergent oil under these operating conditions to minimize oxidation and resultant lacquer and varnish formation.

If either a 2-cycle engine or 4-cycle engine is operating under heavy-load, hot operating conditions and using wet or high sulfur gas, lacquer deposits and corrosive wear may be alleviated by the use of detergent oil. General field experience has shown that under critical conditions detergent oil of the Supplemental I category is most effective in minimizing ring sticking and in reducing corrosive wear for applications of this type. It is rarely necessary to use the extremely high additive concentration available in the super-duty type of oil for gas-engine applications.

The choice of the proper type of lubricant and good operation are alone not enough in establishing a well balanced program to secure desirable engine availability and low maintenance. The effect of pumping-engine service on detergent oil, as shown in TABLE IX, illustrates the results of normal service and of excessive service. The viscosity rise for the normal service period is reasonable; however, it will be noted that the viscosity rise that occured from excessive service has resulted in an SAE 30 oil increasing to the upper limit of an SAE 50 oil. Concurrently, there has been an accumulation of 0.1% water in the crankcase system. This is not a high concentration of water if the engine had been inoperative for some time before the sample was taken in a rather humid atmosphere. However, in this instance, the engine had been operating with this concentration of water. The presence of sodium shown in the ash analysis in the amount of 80 parts per million indicates that this engine has a water leak which comes either from water-soluble salts or from water-treating inhibitor compounds used in the cooling system.

The carbon residue of the oil has increased excessively in the case of the over-extended period of operation to 6.2%, indicating that any of this oil which is burned will form a significantly larger amount of deposits than the same oil at the end of a normal service period would form.

The accumulation of insoluble matter in the oil at the end of a normal service period as compared with that at the end of an excessive service period is very important. The normal-pentane insoluble matter represents the total insolubles including fuel soot, airborne contaminants, wear metals, and resins made up of oxidized lubricating oil and fuel components. In this instance, the high benzene insolubles of 1.80% indicate an accumulation of a significant amount of fuel soot, airborne contaminants, and wear metals. The resin content of 4.1% is extremely critical, since this oxidized matter from lubricating oil and fuel is a potential source of lacquer and varnish that may promote rapid ring sticking or crankcase lacquering. Concurrently with the

TABLE IX

EFFECT OF PUMPING ENGINE SERVICE

ON DETERGENT OIL

	NEW OIL	NORMAL SERVICE	EXCESSIVE SERVICE
VISCOSITY, SUV: Sec			
100 F	550	679	1407
210 F	66	75.5	109
COLOR, ASTM UNION	5	Dark	Dark
WATER % BY WT	Nil	Trace	0.1
CARBON RESIDUE, %	1.3	2.7	6.2
INSOLUBLE MATTER, %			
Normal Pentane	Nil	0.20	5.90
Benzene	Nil	0.19	1.80
Resins	Nil	0.01	4.1
NEUTRALIZATION VALUE			
ASTM D 974	0.15	1.2	4.0
ASH, %	0.9	1.0	.8
SPECTROGRAPHIC ANALYSIS PPM			
Barium	8000	7500	6000
Calcium	500	300	250
Iron	———	50	700
Copper	———	4	30
Tin	———	10	90
Silicon	———	3	100
Sodium	———	6	80

generation of the insoluble matter, there has been a rapid rise in acidity of the crankcase oil, as indicated by the neutralization value. These numerical values are not directly indicative of the corrosiveness of the used oil to bearing metals, but in a general way they indicate the accumulation of acids which may attack bearing surfaces.

The spectrographic ash analysis shown in parts per million illustrates the decline of the barium and calcium employed in the oil additives with the period of service. This illustrates loss in additive content and, hence, performance effectiveness where operating time is excessive. It will also be noted that there is an accumulation of iron, copper, and tin which has become significantly high in the engine after excessive service. The accumulation of these wear metals may have been somewhat accelerated by sand carried into the engine crankcase system through the breather, as indicated by 100 ppm silicon in the analysis.

This illustrates the necessity of proper oil change frequencies and proper filter maintenance in order to maintain the oil in the engine system in good condition. The engine oil filter, if properly maintained and changed at a reasonable frequency, will perform very satisfactorily in minimizing the accumulation of gritty matter and fuel soot. These filters are not designed to remove resinous material and acids, nor will they significantly affect the viscosity. These characteristics can be improved by filtration of the oil with an active filter media, such as fullers' earth, but this would be inadvisable since it will also remove the detergent and the oxidation inhibitor additives used in this type of oil. Accordingly, the best practice is to maintain the engine filter properly and to change the oil at a reasonably frequent period, which must be adjusted to suit the particular operation, depending on the type of service and on the nature of the gas fuel employed. If the gas is wet or high in sulfur content, more deposits will accumulate in the 4-cycle multi-cylinder engine crankcase, necessitating a more frequent oil change. The change frequency must be established with operating experience and may be at a weekly, bi-weekly, or monthly interval. In the case of the single-cylinder 2-cycle engines which minimize the accumulation of combustion deposits in the crankcase and do not subject the crankcase oil to as high temperatures, it is possible to operate for periods of up to six months or more without an oil change.

When the oil in pumping engines is changed, it should be done while the oil temperature is hot so that the oil and deposits will rapidly drain down from the engine surfaces. If excessive accumulations are noted, it is desirable to flush the engine with a good grade of flushing oil before a new charge of oil is installed.

HYDRAULIC PUMPING UNITS

A number of designs of modern hydraulic pumping units are now in service in producing oil wells throughout the United States. One of the most critical elements of the pumping units is the hydraulic fluid which transfers the horsepower from the pump driven by the prime mover to the well. Therefore, the selection of the proper hydraulic fluid, with consideration of the pumping unit design, the atmospheric temperatures, and the cycle of operation, is particularly important.

The desired characteristics of pumping-unit hydraulic oils are shown in TABLE X. The viscosity of the hydraulic oil used in this service is generally specified by the manufacturers. It will be noted that three different viscosities of oil are specified by each of three different builders, covering a range from 100 to 225 seconds SUV at 100 F. These viscosities have been established by the manufacturers, depending upon mechanical clearances and lubrication requirements of their particular pumping unit for selected load and temperature conditions. Depending on the viscosity index of the lubricants selected and on the operating temperatures, it is possible that very little viscosity difference will actually occur at the operating temperatures. For example, if two oils having viscosity indices of approximately 100 are selected, one with a viscosity of 100 and the other, 225 SSU at 100 F, their respective viscosities at an operating temperature of approximately 185 F are 44 and 56 SSU.

With reference to the discussion of TABLE VII on viscosity-temperature relationships of oils, the actual operating viscosity of a hydraulic oil in one of these systems may differ substantially from cold-weather to hot-weather operation. It will be noted that the viscosity index range of 20 to a minimum of 97 allows a significant variation in viscosity-temperature relations. This range in viscosity index is the result of the selection of a minimum pour of -40 F by one manufacturer and a minimum of + 10 F by another. With further reference to the table and to the discussion, it will be noted that even though an oil may be of the naphthenic, low-pour type, it may have a particularly high viscosity at low operating temperatures. The resultant high viscosity may produce poor performance in the hydraulic system. Accordingly, it is desirable to use care in the selection of an oil for these hydraulic systems which has the proper viscosity-temperature relationship for the specific installation. The oil supplier is well informed on these characteristics of his product and can very readily recommend the proper viscosity range for operating conditions.

The flash point is sometimes specified; however, this characteristic is not particularly significant, since the well refined oils generally used in this type of hydraulic system all have suitably high flash temperatures.

Generally, it is desired, or frequently required, that the hydraulic oil used in these systems be oxidation-and rust-corrosion-inhibited. Oxidation inhibition is particularly desirable in systems operating at higher temperatures to minimize the tendency for the formation of resins which results in lacquer accumulation and tends to stick valves and plunger mechanisms. These oxidation products also coat the inner surface of coolers used in the systems and reduce their effectiveness, thereby increasing the temperature and promoting further oxidation. Since many pumping units are operated on an intermittent basis, it is desirable that the hydraulic oil contain a suitable rust-corrosion inhibitor to prevent rusting of highly polished plunger surfaces by the accumulation of moisture during a shutdown period. The addition of this inhibitor greatly improves the rust-corrosion characteristics of the oil and does not detract from its performance characteristics.

In some systems, the entire charge of hydraulic oil is circulated at the rate of up to four times a minute, allowing very little time in the reservoir for the separation of water and entrained air that promotes foaming. Accordingly, it is desirable that the oil have good initial emulsion-test characteristics indicating its inherent property to separate quickly from water. Of course, if the oil is not well maintained and is permitted to oxidize or to become contaminated, it will readily lose quick-water-separation characteristics. Hydraulic oils generally designed for this service contain an additive to minimize the foaming characteristics. This is particularly desirable in systems with as rapid a circulating rate as that cited above, since there is little opportunity for foam-collapse time in the reservoir. The addition of the proper anti-foam-type additive materially improves the foam-collapse characteristics of the oil, minimizing foaming difficulties.

Generally, hydraulic oils which contain oxidation and rust inhibitors, in addition to an anti-foam agent, are used in the hydraulic pumping units. In some instances because of elevated temperatures under severe operating conditions, detergent-type oils have been preferred. These oils have the added effect of detergency to assist in maintaining clean systems and in preventing lacquer deposition. In addition, these oils

TABLE X

CHARACTERISTICS OF PUMPING UNIT

HYDRAULIC OIL

	Manufacturer's Approximate Specifications
VISCOSITY, SUV: Sec - 100 F	100 - 150 - 225
VISCOSITY INDEX -	Range from 20 to 97
POUR POINT -	Range - 40 to + 10 F
FLASH O.C. F -	400 Min
OXIDATION - INHIBITED -	Desired or required
RUST - CORROSION - INHIBITED -	Desired or required
EMULSION TEST -	Quick water separation
FOAMING TEST -	Desired or required

contain an inhibitor and an anti-foam agent and have inherent rust-prevention properties. In most instances, the lower-detergency-level oils are selected for this particular type of application, since there is no heavy concentration of contaminants such as is experienced in engine lubrication, necessitating a high concentration of dispersive additive. High-quality normal-detergency-level oils have proved very successful in some instances and have established long periods of service.

The effect of normal service life on a detergent type of pumping unit hydraulic oil is shown in Table XI. It will be noted that the oxidation stability of this oil has resisted viscosity rise and resin formation, as indicated by only a slight increase in viscosity of the oil and the formation of only 0.05% resins after an extended period of service. The change in viscosity index, flash, and fire has no particular significance. The darkening of color is normal for the type of oil and this period of service. However, the accumulation of 0.2% water is abnormal and indicates that a significant amount of moisture has been permitted to enter the oil reservoir. Under these conditions, it is particularly desirable to have the rust-preventive properties which are entirely satisfactory in the used oil. It will be noted that there has also been a normal increase in the neutralization value for this period of service. In general, the oil is in very good condition except for contamination by water. It is quite possible that a significant amount of the water could be removed by allowing the oil to settle in the reservoir, by draining the water and the sediment from the bottom of the tank, and by returning the oil to the proper level by the addition of new oil.

The hydraulic oil in pumping units may be maintained in satisfactory condition for extended periods of service of two years or more. However, the success of this service depends on careful maintenance of the hydraulic system with proper care in keeping coolers clean, in preventing contamination of the system by water or other contaminants, and by changing the filters at frequent intervals, as determined by the appearance of the oil, based on the accumulation of solids or other contaminants.

The general success in the lubrication of both beam-type and hydraulic-type pumping units rests largely upon the ability of the operator to provide the proper lubricants and maintenance and to protect the equipment from overload or operating conditions for which it was not designed.

TABLE XI

EFFECT OF NORMAL SERVICE ON

PUMPING UNIT HYDRAULIC OIL

	NEW OIL	USED OIL
VISCOSITY, SUV: Sec		
100 F	170	171.8
210 F	44.6	45.1
VISCOSITY INDEX	99	106
FLASH, O.C., F	420	385
FIRE, O.C., F	475	450
COLOR, ASTM UNION	4.25	4.25 dil
WATER, % BY WT	Nil	0.2
INSOLUBLE MATTER %		
Normal Pentane	Nil	0.12
Benzene	Nil	0.07
Resins	Nil	0.05
RUST - PREVENTIVE TEST	Passes	Passes
NEUTRALIZATION VALUE	0.42	0.88