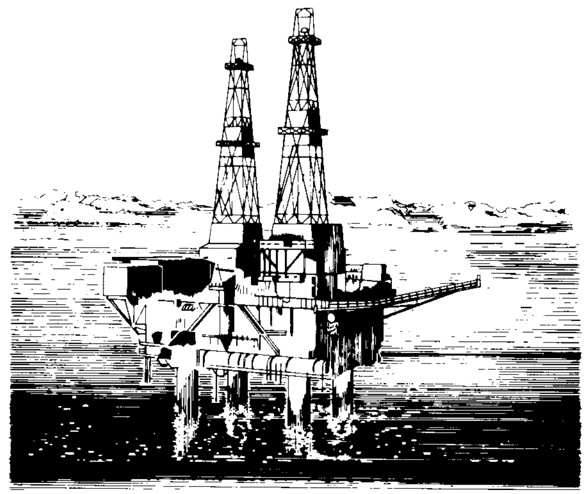
WOODWARD

Reference Manual



Oils for Hydraulic Controls

Manual 25071J

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IMPORTANT DEFINITIONS

WARNING—indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.

CAUTION—indicates a potentially hazardous situation which, if not avoided, could result in damage to equipment.

NOTE—provides other helpful information that does not fall under the warning or caution categories.

Revisions—Text changes are indicated by a black line alongside the text.

Chapter 1. General Information

Introduction

This manual serves as a general guide for anyone involved in the selection of oils for use in Woodward governors or actuators.

One of the primary functions required of an oil is to stand up to high loadings and high temperatures, while remaining a good lubricant. Oil, as it emerges from the refinery process, is a slippery liquid, but it lacks additives vital to its intended functions.

These additives turn a liquid into a lubricant that fights heat, cold, contamination, corrosion, rust, wear, and other environmental and mechanical hazards. Lubricant additives are grouped into three general categories according to the functions they perform:

- protect the lubricated surface
- improve lubricant performance
- protect the lubricant

Surface protective additives include anti-wear agents, corrosion and rust inhibitors, and detergents and dispersants. Performance additives include pour point depressants, seal swell agents, and viscosity index improvers. Lubricant protective additives cover anti-foamants, anti-oxidants, and metal deactivators.

Oil Characteristics

There are four important characteristics to be considered in an oil: viscosity, pour point, shear stability, and thermal stability.

Viscosity

All natural lubricants thin as they warm, and thicken as they cool. The magnitude of this change is measured by the Viscosity Index (VI). The higher the VI number, the less effect temperature has on viscosity change. An oil with a VI of 200 is very good in this respect.

Pour Point

The pour point of an oil is a measure of its low temperature suitability. Chemical compounds, called pour point depressants, are used to allow the oil to flow even at low operating temperature when the oil has thickened.

Shear Stability

Oil viscosity can also change due to shear. Actual mechanical shearing of long chain polymers in oil will act to lower both the actual viscosity at any given temperature and the Viscosity Index.

Thermal Stability

Oil viscosity changes will also occur with long-term operation at high temperatures. In this case, the oil will thicken due to oxidation and evaporation of the lighter molecules.

Multi-viscosity oils extend the operating temperature range while still maintaining proper viscosity. However, they have relatively poor thermal and shear stability resulting in shorter useful life. A good alternative is synthetic oils, since they have good temperature viscosity characteristics. Synthetic oils are covered in Chapter 2.

Oil Lubrication Properties

Oil lubrication properties are greatly improved by the addition of a variety of chemical compounds such as anti-wear agents, corrosion and rust inhibitors, and detergents and dispersants.

If information is needed about the additive contents of an oil, it may be advisable to check with an oil company representative.

Anti-wear Agents

Mechanical wear from metal-on-metal rubbing or abrasives is normally prevented by hydrodynamic lubrication with an oil film thick enough to keep the parts separated. But under certain conditions such as high load, low speed, and low lubricant viscosity, the lubricant film may rupture and allow metal-to-metal contact. This condition may exist between thrust bearing surfaces or between closefitting pump gears and gear pockets.

To prevent wear due to metal-to-metal contact, anti-wear additives found in most lubricants form a coating which will yield under the shear stress imposed by minimum lubrication. However, heat from friction between mating surfaces provides energy for a chemical reaction between the additive and metal surfaces that result in a protective coating.

Corrosion and Rust Inhibitors

Another important lubrication property of an oil is that it must be able to resist rust and corrosion and be compatible with seal material.

If a lubricating oil becomes contaminated with moisture, corrosion can develop. In the case of governors using engine oil, the oil may become contaminated with the acidic products of combustion.

Detergents and Dispersants

Detergents are compounds used to control deposits at high temperature, while dispersants are used to control the formation of sludge at low temperature. Dispersants absorb contaminant particles and keep them in suspension so they cannot agglomerate and form sludge.

Performance Additives

Oil performance characteristics also can be greatly improved with additional compounds such as pour point depressants, seal swell agents, and Viscosity Index improvers.

If information is needed about the additive contents of an oil, it may be advisable to check with an oil company representative.

Pour Point Depressants

Pour point depressants are compounds which allow the oil to flow even at low operating temperature when the oil has thickened. These natural properties of oil are determined by the crude itself and by the refinery process.

Seal Swell Agents

A number of seals are used throughout a governor to keep the dirt out and the oil in. Seals are made of many compounds including nitrile and silicon. Currently, the trend in seal material is to Viton which can withstand prolonged temperatures to 204 °C (400 °F).

Viscosity Index Improvers

The rate at which mineral oils thin out is described by a mathematical relationship between their viscosities at 100 °F (38 °C) and 210 °F (99 °C), which is referred to as Viscosity Index (VI).

Oils with a high VI exhibit less viscosity change with temperature than oils with a low VI. A lubricant that is expected to perform over a wide temperature range must usually have a high VI. The VI of oils has received much attention because ease in starting the engine requires low viscosity at low temperatures, and normal operation requires an adequate oil film at normal operating temperature.

Wide temperature-range viscosity requirements of oils has been met by treating the oil with an additive known as a VI improver. VI improvers also improve shear stability.

Polymeric VI improvers are more likely, however, to be broken apart by shear forces between moving surfaces. Once this type of permanent shear has occurred, the polymer contributes less to high-temperature thickening. Therefore, high VI oils using polymeric VI improvers require a polymer that will continue to provide adequate thickening at high temperature.

Lubrication Protective Additives

Special additives also are used to increase the lubrication protection given by oils. Such additives include anti-foamants, anti-oxidants, and metal deactivators.

If information is needed about the additive contents of an oil, it may be advisable to check with an oil company representative.

Anti-Foamants

When subjected to sufficient agitation, all oils will entrap air and produce foam. This, in turn, causes more problems. Oil reaction increases exposure of the oil to oxygen, which increases the rate of oxidation.

Air and foam also reduce lubricant efficiency as a coolant and as a hydraulic fluid. Retained air changes oil to a compressible fluid and may cause operational problems. To eliminate foaming, additives with a lower surface tension than the oil, and low solubility in the lubricants are used. This weakens and ruptures the oil film surrounding the bubbles.

Anti-Oxidants

The oxidation process is complex and is highly undesirable. Often, additives that reduce oil oxidation also reduce corrosion.

Decomposition of the oil may also occur, forming a variety of compounds such as aldehydes, alcohols, and acids. These compounds may further oxidize and react with each other to form more compounds. Some of these compounds may be soluble in oil, resulting in a viscosity increase; others may be insoluble and form varnish or sludge.

Oxidation is affected by many factors: temperature, lubricated materials, crude source, and refining process. The choice of the anti-oxidant agent used is based on tests of a particular oil.

Metal Deactivators

Additives that are used as corrosion and rust inhibitors form coatings on metal surfaces which also act as metal deactivators. Metal deactivators also inhibit oxidation by coating metals such as lead, copper, and iron, which could act as oxidation catalysts.

Chapter 2.
How to Select an Oil

General Information

There are several important factors to consider in the selection of an oil for proper governor operation. Following is a list of those factors and how they affect governor operation.

Viscosity

In governor applications, a change in viscosity can seriously affect performance. If the oil is too thin, the governor can become unstable. If the oil is too thick, the governor will become sluggish and unresponsive.

The higher the VI (Viscosity Index) number, the less effect temperature has on viscosity change. Our recommended range of viscosities for proper governor operation is from 50 to 3000 SUS with a nominal 150 SUS being ideal. With this in mind, proper oil selection would be that with 150 SUS at operating temperature and a high VI

WARNING
A loss of stable governor control and possible prime mover overspeed may result if the viscosity exceeds the 50 to 3000 SUS range. An overspeeding and/or runaway prime mover can result In extensive damage to the equipment, personal Injury, and/or loss of life.

Pour Point

We recommend an oil with a pour point 8 to 11 Celsius degrees (15 to 20 Fahrenheit degrees) below the lowest starting temperature anticipated. This avoids possible pump cavitation and slow response. In arctic conditions, it may be necessary to install an oil heater. Contact Woodward for information concerning the specific requirements of your installation.

Shear Stability

In applications where severe service is expected or long spans between oil changes are required, an oil with a high shear stability should be selected. Check with an oil company representative for information regarding the shear stability of a particular oil.

Thermal Stability

For service conditions expecting long-term high-temperature operation, an oil with high thermal stability should be selected. Multi-viscosity oils extend the operating temperature range while still maintaining proper viscosity. However, they have relatively poor thermal and shear stability, resulting in shorter useful life. A good alternative is synthetic oils. These products have good temperature viscosity characteristics and good thermal and shear stability.

A heat exchanger can be used to lower the operating temperature of a governor.

Corrosion and Rust Inhibitors

Another important factor in the selection of an oil for proper governor or actuator operation is that it must be able to resist rust and corrosion.

Corrosion is a particular problem in governors because the oil may become contaminated with moisture. In the case of governors using engine oil, the oil may become contaminated with the acidic products of combustion.

Sludge Dispersion

Dispersants are especially useful in protecting engines that rarely reach normal operating temperature. This type of service leads to the formation of sludge, which coats parts and can block internal oil passages in the governor.

Seal Compatibility

Oils used in governors must be compatible with these materials. While significant shrinkage or softening of seals cannot be tolerated, a slight swelling is often desirable. If the base oil cannot cause sufficient swelling, a seal swell agent may be used.

Oil Oxidation

When subjected to sufficient agitation, all engine/governor oils will entrap air and produce foam. This, in turn, causes more problems. Oil reaction increases exposure of the oil to oxygen, which increases the rate of oxidation. Air and foam also reduce lubricant efficiency as a coolant and as a hydraulic fluid. Retained air changes oil to a compressible fluid and may cause a perfectly adjusted governor to become unstable. To eliminate foaming, additives with a lower surface tension than the oil and low solubility are added to the lubricant used. The additives weaken and rupture the oil film surrounding the bubbles.

Anti-wear Additives

Oils containing anti-wear additive packages provide more protection during periods of boundary lubrication, when true hydrodynamic lubrication is not possible, due to high loads, low speed, excessive temperatures, etc. This additional lubrication is possible due to the formation of protective films on metal surfaces.

Zinc dialkyldithiophosphates (ZDPs) are often used as anti-wear additives and are found in many common hydraulic and engine oils. Governors do not normally require anti-wear additives, but under certain marginal lubrication conditions may benefit from their use.

CAUTION
ZDP is corrosive to silver and tends to attack it. Oils with a ZDP anti-wear additive are not recommended for use in the PGEV governor with an oil-filled side plate. The PGEV governor contains a load-control resistor with silver contacts. Increased silver contamination of the oil and wear of the load-control resistor contacts may result from using an oil with a ZDP anti-wear additive. PGE governors and PGEV governors without an oil-filled side plate may continue to use oils with a ZDP anti-wear additive, as the oil does not come into contact with the silver contacts.

Proper Oil Selection

There are two essential factors that need to be considered in the selection of an oil for proper governor operation. The first one is the SUS viscosity range of the oil, and the second one is the operating temperature of the governor in its ambient environment.

Oil Viscosity Range

The recommended range of viscosities for governor operation is from 50 to 3000 SUS at normal governor operating temperature.

This range is shown in the "Legend" (at the bottom of the Oil Chart) and in the Oil Chart as the "Acceptable Operating Range". The higher the viscosity number, the less effect temperature has on viscosity change.

Woodward governors are designed to give stable operation with most oils if oil viscosity at the operating temperature span is within a range of 50 to 3000 SUS. The ideal range of viscosities for governor operation is from 100 to 300 SUS at normal governor operating temperatures. The governor oil operating temperatures are shown on a scale from –40 to +116 °C (–40 to +240 °F) on top of the Oil Chart. This range is represented by the white sections in the legend and in the Oil Table as the "Ideal Operating Range".

Governor Operating Temperature

The recommended oil temperature for continuous governor operation is 60 to 93 °C (140 to 200 °F). Measure the temperature of the governor or actuator on the outside lower pan of the case. The actual oil temperature will be slightly warmer, about 6 Celsius degrees higher (10 Fahrenheit degrees higher). The ambient temperature range is –29 to +93 °C (–20 to +200 °F).

WARNING
Governor operation must not be attempted below the pour point of the oil as the governor can become sluggish and unresponsive. Seizure of governor internal parts can also result, causing loss of governor control with resulting damage to equipment and/or personal injury.

How to Read the Oil Chart

(Figure 2-1)

The cross-hatched sections to the left of the white section in the legend and in the Oil Chart designate the low temperature limits acceptable for operation for limited periods of time only.

The hatched sections designated “Pour Point” in the legend and in the Oil Chart indicate the temperature range where oil gets progressively thicker to reach its pout point. The approximate pour point is represented by the low temperature end of the hatched section (left-hand end).

If the oil is too thick, the governor can become sluggish and unresponsive. An oil with a pour point 8 to 11 Celsius degrees (15 to 20 Fahrenheit degrees) below the lowest starting temperature anticipated is recommended.

The cross-hatched sections to the right of the white sections in the legend and in the Oil Chart designate the high temperature limits acceptable for operation for limited periods of time only. The right-hand end of these sections represents the approximate degradation temperature of the oil.

Prolonged use at temperatures above this point, without frequent oil change, may result in governor failure. To avoid governor operation close to the point of oil degradation, change to an oil more temperature resistant or lower the governor operating temperature with a heat exchanger, or both.

Under extreme ambient operating temperatures, such as tropical or arctic operating conditions, it may be necessary to install a heat exchanger or an oil heater. Contact Woodward for information concerning the specific requirements of your installation.

Automatic Transmission Fluids

Automatic transmission fluids, such as AT FLUID TYPE F, AT FLUID TYPE A, OR DEXRON II, are suitable for governor use. Automatic transmission fluid can be used at temperatures lower than most petroleum oils and at temperatures to 149 °C (300 °F) for short periods. However, at elevated temperatures, internal governor leakage may develop. Any transmission fluid approved by a transmission manufacturer should be suitable in a governor, providing viscosity requirements are met.

Synthetic Oils

Most synthetic lubricants are excellent for governor use, provided they meet viscosity requirements. Synthetics provide better lubrication than conventional oils under severe demands, particularly at high speeds or broad temperature ranges. They are not generally recommended as an alternative to straight mineral oil in standard applications.

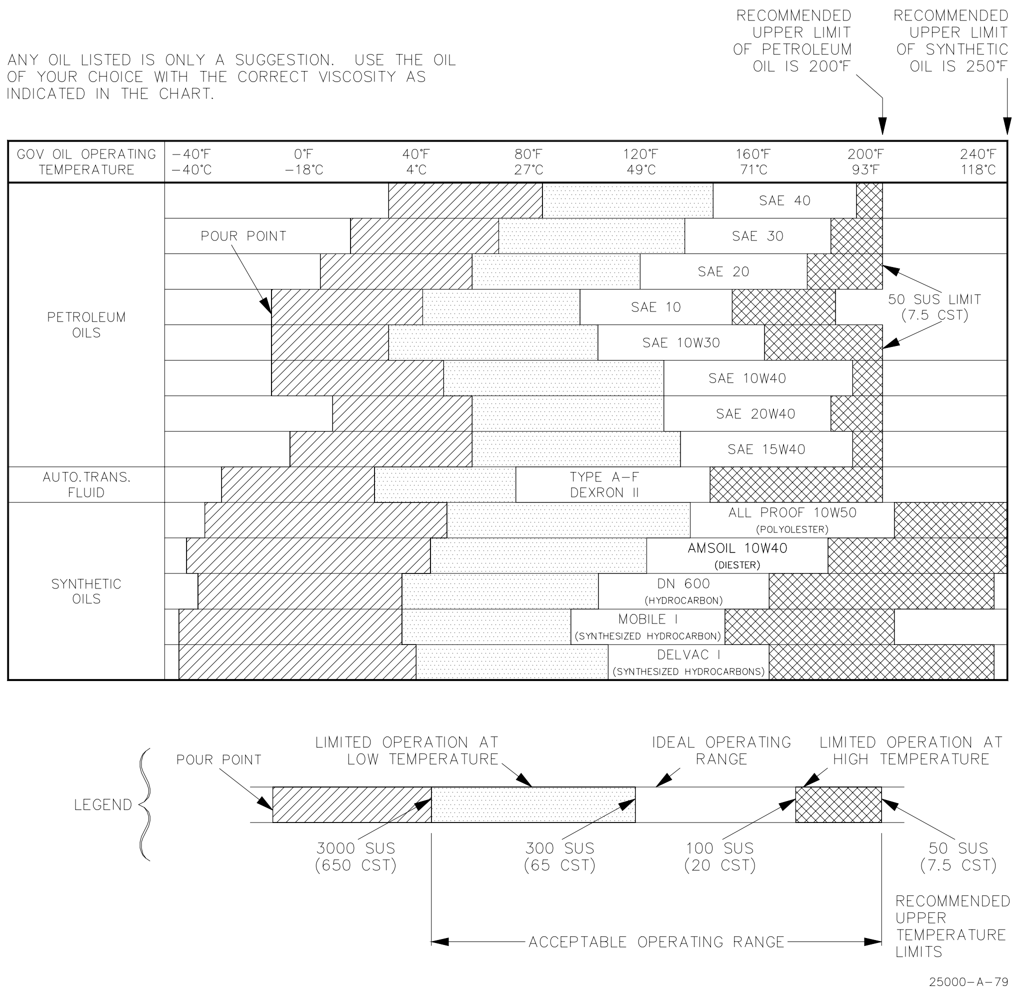

Figure 2-1. Oil Chart

VISCOSITY COMPARISONS				
CENTISTOKES (CST, CS OR CTS)	SAYBOLT UNIVERSAL SECONDS (SUS) NOMINAL AT 100F	SAE MOTOR (APPROXIMATE)	SAE GEAR (APPROXIMATE)	ISO
15	80	5W		15
22	106	5W		22
32	151	10W	75	32
46	214	10	75	46
68	310	20	80	68
100	463	30	80	100
150	696	40	85	150
220	1020	50	90	220
320	1483	60	115	320
460	2133	70	140	460

250−087

Figure 2-2. Viscosity Comparisons

The major advantages of the synthetic family of oils over straight petroleum oils in governor applications are a wider temperature range, a high resistance to oxidation, and a very low volatility. The disadvantages are cost and more limited availability in some areas. As with any oil, it is not recommended that these be mixed with each other or with petroleum oils.

CAUTION
Some classes of synthetic oils may not be compatible with diaphragms, gaskets, and seals. Serious damage to diaphragms, gaskets, and seals can result, requiring replacement of parts. If in doubt, contact Woodward for specific recommendations.

Synthetic lubricants are classed according to chemical source: for example, the silicones, the polyglycols, the synthesized hydrocarbons, and the organic esters.

Silicone Lubricants

The name "silicones" has been broadly applied to several different base fluids, and they are available in a wide range of viscosities.

The main advantage over petroleum oils comes from the formulations that provide very high viscosity index (usually in the 200 to 300 range), high resistance to oxidation, and very low volatility.

Polysulfide additives have greatly improved the load-carrying capacity and anti-wear properties of silicone lubricants. Silicone oils have little effect on most rubbers, but this is not the case with other oils. Systems previously lubricated with other oils should be cleaned and flushed.

Silicone oils are used in high temperature, high pressure hydraulic systems, air compressors, and gear boxes. The cost of these oils is competitive with other synthetic oils.

Polyglycol Lubricants

Examples of polyglycol lubricants are the glycols, polyethers, and polyalkylene glycols. These are the least expensive of the synthetics.

They have excellent viscosity-temperature characteristics, have a low volatility comparable with silicones, and have a good lubricating quality. They are also compatible with other synthetic lubricants, and they readily accept additives for further improvement of their properties.

Polyglycols are not compatible with petroleum oils and are not acceptable for governor use in that they attack paint and other non-metallic materials, although they have little effect on rubber.

Synthesized Hydrocarbons

Synthesized hydrocarbons are high performance oils that are made from a petroleum-derived raw material and not from the refining of petroleum.

Several types of synthesized hydrocarbons (SHC) are now available. SHC oils are compatible with petroleum oils and the systems for which petroleum oils are designed. These oils do not deteriorate rapidly at high temperatures and do not congeal readily at low temperatures. SHC base fluids are free of aromatics, sulfur, and wax normally present in conventional mineral oils.

Organic Esters

Organic esters are formed by reacting of alcohol and certain types of acids. The two categories of esters used mostly for synthetic oils are dibasic acid ester and polyol esters. Characteristics of organic esters are much the same as the synthesized hydrocarbons.

Remarks

In applications where the Woodward governor or actuator shares the oil supply with the engine, use the oil recommended by the engine manufacturer. Protect governors or actuators using engine oil with a suitable filter. Refer to the appropriate governor manual for filter size requirements.

Governors with a self-contained oil supply, or using a self-contained oil sump, do not require an oil containing detergents or dispersants since they do not have the "hot spots" found in internal combustion engines, and do not have the contaminants resulting from the internal combustion. As a result, oil that has been carefully selected to match the operating conditions, and is compatible with governor seals, is suitable for governor operation.

Providing all other necessary characteristics are met, most detergent oils are satisfactory for use in governors and actuators. The oil that meets the requirements and is locally available should be selected.

In addition to oils listed in the Oil Chart, oils which meet the API (American Petroleum Institute) engine service classification in either the "S" group or the "C" group (starting with "SA" and "CA" through the current API standard) are suitable for governor service. Oils meeting performance requirements of the following US military specifications are also suitable:

- MIL-L-2104A
- MIL-L-2104B
- MIL-L-2104C
- MIL-L-46152
- MIL-L-46152A
- MIL-L46152B
- MIL-L-45199B

Chapter 3.
Oil Maintenance

General Information

Oil maintenance is essential to long and reliable governor operation. Regular oil changes must be maintained, but there are also other important factors to consider.

Once a class of oil is selected, continue using that oil. Adding or changing oil of one class to another class without thoroughly cleaning a hydraulic system may cause operational problems such as foaming, filter plugging, and sludge formation. Some classes of oil may not be compatible with diaphragms, gaskets, or seals.

Any water, regardless of the quantity, in a governor should immediately be removed and the oil changed. Water, even in trace amounts, contributes significantly to early bearing failure as well as forming oxides that also contribute to failures.

Clean oil is a necessity, whether filling the governor for the first time or whether adding make-up oil. Clean oil cannot remain clean if the container or pouring spout is not clean. Partially used cans of oil should not be used unless kept covered in a clean area. Cleanliness of oil and container cannot be overstressed.

Most governors with self-contained sumps do not have filters or screens, and this makes it essential that contaminants are not introduced into the governor through the oil. Make sure to protect governors using engine oil with a suitable filter. Refer to the appropriate governor manual for filter size requirements.

The effects of oil on governors using engine oil are determined by filter changes and engine oil condition. If engine manufacturer's oil recommendations are closely followed, satisfactory service should result.

Oil Change Intervals

Self-Contained Oil Sump

The “best time” to change oil is difficult to determine. The best time, of course, to change the oil is just before the oil is worn out, but before any damage to the machine has occurred.

This condition is best determined by oil analysis, but because the cost of doing this exceeds the cost of a quart or two of governor oil, it is not a practical solution on a continual basis. Analysis can be used to set up a maintenance schedule which should remain in effect as long as the original conditions do not change. Experience with other hydraulic equipment similar to governors can also be used as a guideline. Conditions such as operating temperature, atmospheric conditions which include dirt, moisture, etc., or anything that may change the composition of the oil, or shorten its useful life, should be taken into account when determining the frequency of oil changes.

Anytime a known contaminant gets into the governor, the governor should be drained, flushed, and refilled with clean oil as soon as possible.

Particles of dirt and water in the oil are the greatest causes of governor or actuator failures. Particular care should be taken to keep dirt and moisture out of opened or stored governors and opened control lines.

Breakdown of oil or depletion of additives is another frequent cause of governor failure. The presence of sludge, varnish, sediment, or a dirty filter is a good indication that an oil change is required. It is also an indication that perhaps a different oil should be used, especially if it has only been a short time since the last oil change.

A varnish buildup is an indication that governor operating temperatures are exceeding the capability of the oil. This problem can usually be solved by going to an oil with good high temperature characteristics or by installing a heat exchanger. Low operating temperatures may lead to the formation of sludge. Sludge is a complex mixture of products from sources such as fuel combustion, water, carbon, and oxidized oil that has agglomerated and is no longer soluble in oil.

Sludging may be controlled by raising the governor operating temperature, increasing the frequency of oil changes, or by changing to a different type of oil. Fluids, such as automatic transmission fluids, may prove to be more resistant to sludge than some engine oils.

Oil that has been carefully selected to match the operating conditions and is compatible with governor seals should give long service between oil changes. For governors operating under ideal conditions (minimum exposure to dust and water, within the temperature limits of the oil), oil changes can be extended to two or more years. If available, a regularly scheduled oil analysis is helpful in determining the frequency of oil changes.

Engine Oil Governors

Oil change intervals are dependent upon the various operating conditions of the engines and the sulfur content of the diesel fuel used.

Oil change intervals are normally recommended by the engine manufacturer for the engine. However, if governor problems develop due to oil breakdown or contaminated oil, the frequency of oil changes should be increased for a specific lubricant.

A conservative recommendation of high temperature degradation threshold for a variety of lubricant types is listed below.

	Degradation Begins	
Fluid Family	**°C**	**°F**
Natural petroleum	93	200
Polyglycols	107	225
Diesters	121	250
Synthetic hydrocarbons	121	250
Polyol esters	135	275
Methyl silicons	149	300
Phenyl silicons	204	400
Halogenated silicons	218	425
Polyphenyl ethers	246	475
Fluoroethers	288	550

When to Change Governor Oil

Oil should be changed if:

- Appearance is different than when new.
- Oil feels gritty when rubbed between fingers.
- Oil smells different than when new. (NOTE: some oil may smell burned and still be acceptable. Check with oil company representatives.) If in doubt, change oil.
- Any water, antifreeze, or other incompatible material contaminates the oil.
- Viscosity has changed; increased or decreased.
- Excessive wear of parts occurs.
- If governor has been run at temperatures exceeding the recommended limit for the type of oil use.
- If governor operating temperatures have changed, bringing fluid viscosity outside of ideal operating condition.

Contaminated Governor Oil

Replace the governor oil if it is contaminated. Also change it if it is suspected of contributing to governor instability. Drain the oil while it is still hot and agitated. Flush the governor with a lighter weight of the same oil or with a solvent having some lubricating quality before refilling with new oil.

CAUTION

Be sure the solvent is compatible with seals. Serious damage to diaphragms, gaskets, and seals can result, requiring replacement of parts. If in doubt, contact Woodward for specific recommendations.

If the drain time is insufficient for the solvent to completely drain or evaporate, flush the governor with a lighter weight of the same oil it is being refilled with to avoid dilution and possible contamination of the new oil. To avoid recontamination, the replacement oil should be free of dirt, water, and other foreign material. Use clean containers to store and transfer oil.

WARNING

Observe manufacturer's instructions or restrictions regarding the use of solvents. If no instructions are available, handle with care. Use the cleaning solvent in a well ventilated area away from fires or sparks.

Failure to follow above safety instructions can result in dangerous fires, extensive damage to equipment, personal injury and/or loss of life.

Oil Filters

Industrial surveys show that 80% of all governor problems are caused by dirty or contaminated oil. Although particles of dirt are always present, good properly-maintained filtration controls dirt particles effectively.

Proper use of filtration not only pays for itself, but it also reduces the overall cost of operation and maintenance. Compared to the cost of downtime, proper filtration is a good investment.

Selection Of Filter Element

It is relatively easy to under-filter or to over-filter because of the wide range of contaminants and the wide range of filter materials available to control them.

Filter material which is too coarse allows dangerous contamination. Filter material which is too fine requires replacement too often, or if not changed, filters operate in the bypass mode and all protection is gone.

Filter Element Specifications

Beta Ratio

The Beta Ratio is a numerical representation of the efficiency of a filter. It is the number of particles of a given size found upstream of a filter divided by the number of same-size particles found downstream, as described by the multi-pass test method recognized by ANSI, NFPA, and ISO (ANSI/B93.31-1973).

$\beta_x = \frac{N(up)}{N(down)}$, where x = particle size (in µm)

Thus $\beta_{10} = 2$ means that the filter will remove 1 particle greater than 10 µm for every 2 particles greater than 10 µm entering the filter.

In the above example, assume 10 000 particles greater than 10 µm were counted upstream, and 5000 particles greater than 10 µm were counted downstream. Then,

$\beta_{10} = \frac{10\ 000}{5000} = 2$

Some filter literature may show a rating as:
$\beta_x = 2/20/75$, x = 6/11/15
which means: $\beta_6 = 2$, $\beta_{11} = 20$, $\beta_{15} = 75$.

The first three numbers (2/20/75) are the Beta ratings at the particle size of the second three numbers (6, 11, and 15 µm respectively).

Efficiency

The efficiency of a filter at a given particle size can be derived by the formula:

Efficiency = $(1–1/\beta)$ x 100%

So, if $\beta_{10} = 2$
Efficiency at 10 µm = (1–1/2) x 100% = 50%

Here is an efficiency table for "x" size particles:

β_x =	1.01 is	1%	efficient
β_x =	1.1 is	9%	efficient
β_x =	1.5 is	33%	efficient
β_x =	2.0 is	50%	efficient (nominal)*
β_x =	5.0 is	80%	efficient
β_x =	10.0 is	90%	efficient
β_x =	20.0 is	95%	efficient
β_x =	75.0 is	98.7%	efficient (absolute)*
β_x =	1000.0 is	99.9%	efficient
β_x =	3000.0 is	99.97%	efficient

*—The filtration industry is coming to accept a nominal rating as 50% efficient at removing a given particle size, and an absolute rating as at least 98.6% efficient at removing a given particle size.

Filter Capacity
Filter capacity is the amount of contaminant (measured in grams) that a filter element will hold before reaching a specified differential pressure. Everything else being equal, the capacity indicates the service life of the element. The greater the capacity, the longer the life.

Oil Compatibility
Filtering elements are compatible with petroleum base lubricating oils. When using synthetic fluids, it is advisable to check with a filter company representative regarding compatibility of specific elements.

Oil Lacquering

Hydro-mechanical governors can be affected by a condition known as oil "lacquering". If not prevented, lacquering can lead to various possible failure modes, with the potential for the governor to stick in the max fuel or min fuel position.

WARNING
Lacquering can lead to governor failure, with the potential for engine overspeed. In a marine application, a vessel could be unable to maintain headway. Preventing lacquering, and having a backup governing/safety system, are essential for safety.

Lacquering is defined as the condition in which the governor is coated internally by a residue from the oil (often referred to as varnish or sludge). The deposits form a hard layer which is difficult and time-consuming to remove (the cost of cleaning a lacquered governor can be as high as 40% of the new price of such a unit.). Lacquering is generally accompanied by a smell similar to burnt oil.

The results can range from sticking pilot valves to plugged oil passages and orifices.

Lacquering is generally caused by the oil breaking down, which can be caused by:

- too high an oil temperature;
- too long an interval between oil changes;
- water condensing inside the governor during cooldown periods (water in oil can cause hydrolysis which is a known failure mode for oils).

Oil selection is important, as some oils are less prone to lacquering than others. It is up to the plant operator/vessel owner and the oil supplier to establish the correct oils and change intervals for each application. Such a selection should consider operating temperature, oil change interval, and other operating conditions known to the plant operator/vessel owner. A proper selection can achieve suitable economies of cost and change interval while also preventing lacquering.

Any governor can be affected, depending on oil change interval, operating temperature, and oil type. Some governor types work their oils harder than others.

Since Woodward is cannot be aware of the operating conditions of each application, here are some general recommendations:

- **Oil Temperature**—Woodward recommends that the oil temperature for continuous operation be between 60 and 93 °C (140 and 200 °F).
- **Oil Change Interval**—Because oil change interval must take into consideration all operating conditions, the correct oil change interval must be established between the plant operator/vessel owner and the oil supplier.
- **Oil Selection**—Woodward specifies two essential factors that need to be considered in the selection of an oil for proper governor operation:
  - **viscosity range**—allowed is 7.5 cSt (50 SUS) to 650 cSt (3000 SUS); ideal is 20 cSt (100 SUS) to 65 cSt (300 SUS).
  - **operating temperature**—recommended is an oil temperature for continuous operation between 60 and 93 °C (140 and 200 °F).

NOTE

Failure to avoid lacquering of oil inside a governor is considered to be a misuse outside Woodward control. Such misuse is not covered by Woodward warranty.

WARNING

If a governor has become lacquered, it is imperative that this situation be diagnosed and corrected as soon as possible. A lacquered governor should not be used, since this can have serious consequences.

Carefully consider the choice of governor oil with your oil supplier. When choosing an oil interval, start with shorter than expected intervals and slowly try longer intervals. Monitor the condition of the oil, especially the build-up of deposits, to ensure that the oil remains within the operating conditions defined by the oil supplier.

We appreciate your comments about the content of our publications.

Send comments to: icinfo@woodward.com

Please include the manual number from the front cover of this publication.

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