Section 11
CONTAMINATION CONTROL

Fluid conditioning covers the methods of maintaining oil in service.

Wear mechanisms

Abrasive particles enter the space between two moving surfaces, bury themselves in one of the surfaces, and cut material from the opposing surface. The particles that cause the most damage are those with dimensions equal to and slightly larger than the clearance space. If the particles are too large, they can't fit into the space, if they are too small, they float right through.

Chain reaction of abrasive wear occurs when particles generated as a result of abrasive wear become work hardened; they become harder than the parent surface and, if not removed by proper filtration, will re-circulate to cause additional wear. This will continue and result in premature system component failure unless adequate filtration is applied to break the chain.

Erosive wear is caused by particles that strike a surface or edge and remove material as they flow over it. It is similar to the erosive wear of water flowing over rocks. This type of wear is found in metering valves where there is high velocity flow. The impact of particles also causes denting and eventual fatigue of the surface.

Adhesive wear occurs when excessive load, low speed and/or reductions in fluid viscosity can reduce the lubricant film thickness to a point where metal-to-metal contact occurs. Surface asperities are "cold welded" together and get sheared off.

Fatigue is a result of repeated stressing caused by particles trapped by the two moving surfaces. In the beginning, the surfaces are dented and cracks start to form. The cracks spread, and eventually the surface fails, producing a spall.

Water

The effects of water are insidious. Failure due to water contamination may be catastrophic, but it may not be immediate. Many failures blamed on lubricants are truly caused by excess water. The following are some of the effects of water on equipment:

- Shorter component life due to rust and corrosion
- Water etching/erosion, hydrogen embrittlement
- Oxidation of bearing babbitt
- Wear caused by loss of oil film or hard water deposits
- Lack of lubrication due to filter blocking or freezing

The effects of water on lubricating oil can be equally harmful:

- Water accelerates oxidation of the oil
- Depletes oxidation inhibitors and demulsifiers
- May cause some additives to precipitate
- Causes ZDDP anti-wear additive to destabilize over 180°F
- Competes with polar additives for metal surfaces

Water etching can be found on bearing surfaces and raceways. It is primarily caused by generation of hydrogen sulfide and sulfuric acid from water-induced lubricant degradation. Erosion occurs when free water flashes onto hot metal surfaces and causes pitting.

Hydrogen embrittlement occurs when water invades microscopic cracks in metals surfaces. Under extreme pressure water decomposes into its components and releases hydrogen. This explosive force forces the cracks to become wider and deeper, leading to spalling.

A small amount of water may not be too bad under boundary lubrication conditions. Some dissolved water helps maintain an oxide film, which may enhance the effectiveness of load-carrying additives. This benefit is offset by increased oil oxidation, and other detrimental effects discussed above.

Water can be found in three phases. Most ISO 32 to 100 industrial oils will have about 200 ppm **dissolved water**, and are still bright and clear at room temperature. An exception to this is a phosphate ester, which may contain 1000 ppm dissolved water before it starts to get cloudy.

Emulsified water can be more harmful. Since oil and water do not mix, in order to form an emulsion; there must be an emulsifying agent, such as a detergent, and energy. Since it has intimate contact with the oil, it can cause rusting, oxidation and wear. High viscosity fluids form emulsion more readily and permanently than do less viscous fluids. Logic would say that an oil mixed with water would get thinner, but surprisingly enough, most rich oil/water emulsions have a higher viscosity than either of their components.

Free water sinks to the bottom of the sump. It should be removed to prevent it from circulating and causing rust. Free water also promotes growth of bacteria and fungus.

Sources of water

The first plan of attack on controlling water contamination is to reduce the amount of water entering the system. Here are some suggested actions to take to minimize water contamination.

- Prevent wash down water from entering vents and reservoir covers

- Properly install and seal covers and hatches

- Watch for condensation caused by cold water lines located close to a hot reservoir
- Gutter water to divert flow away from reservoir hatches
- Install secondary seals or v-rings on critical systems
- Prevent contamination from condensation by using a bladder type breather on vents
- Install desiccant air breathers or vapor extractors
- Prevent water from entering new oil by storing drums indoors. If they must be stored outdoors, keep them under a shed or tarp, or store them on their sides with the bungs horizontal at the 3 and 9 o'clock positions.
- Periodically drain water from low points in system. Environmental condensation will always occur in the tank because of system breathing
- Tanks should be stainless steel or coated with an oil resistant paint.

Water Separation Techniques

Once sources of water contamination have been controlled to the extent possible, there are several methods to remove water from oil. Methods that can be used successfully for different applications include settling, heat, chemical demulsifiers, filter/coalescers, centrifuges, vacuum dehydrators and electrostatic treatment.

The principle means of water separation is by **settling** water out of the oil. There are many reservoir designs that can promote settling, but they all work on the same principle. The fluid must have enough residence time to allow the water to settle. This requires a reservoir of sufficient capacity as well as baffling to control fluid flow. Many reservoirs, such as traditional Bowser systems, are designed with separate precipitation, filtration and storage compartments.

Heating the oil increases molecular motion. The collision frequency of the water bubbles promotes coalescence. Heating also reduces the viscosity of the lubricant, and increases the difference between the density of the oil and water. Both of these allow bubbles to settle faster. Water inside the bubbles expands as it is heated which causes the bubble sheath to rupture. The disadvantage of using heat as the primary means of water separation is that it is expensive and promotes oxidation of the oil.

Demulsifier additives should be added sparingly, if at all. It is better to correct the root cause of contamination. If it is necessary to use them, consult with your oil or additive supplier on the proper type. As a general rule of thumb, use a water soluble demulsifier if the emulsion is primarily water, or if the bubbles are large. If there are a large amount of solids, choose a demulsifier that wets solids. Use an oil soluble demulsifier if the product is predominantly oil with a small amount of water contamination.

Filter/coalescers work by allowing oil to pass through wetted membranes while keeping water out. The media is commonly Fiberglass type material that has a very high surface area and fairly dense pores. Coalescers will remove free water, but cannot touch dissolved water.

Centrifuges are one of the most traditional methods of separating oil and water. They use the same principle of density differences that allow water to sink to the bottom of a reservoir, but they speed up the process by using centrifugal force. Water is thrown to the outside of a spinning element. Stacked conical plates capture the water and direct it downward to the outside of the unit. Clean oil flows through holes in the cones and upward to the top center of the cone stack, where it is collected. Centrifuges are 6,000 to 10,000 times faster than settling.

Vacuum dehydration can remove dissolved water below its solubility point and can break stabilized emulsions. Oil should be filtered before it enters the dehydrator to minimize contamination of the elements. Each pass removes 1 to 1 ½% of free, emulsified and dissolved water, so it is important to monitor the oil out of the dehydrator to make sure that it is bright and clear. If the oil is still cloudy, it should be recycled through the unit.

Particulates

Particulate contamination is primarily removed by filtration, although the methods used for water separation can also remove particles. Particulates can be detected by several different methods, including white light particle counter, pure block particle counter, ferrograph or by spectrometry.

As with water, it is important first to determine the source of particle contamination and treat it, if possible. Particles can be:

1. Internally generated – oxidation products, wear particles, rust
2. Introduced with initial fill
3. Introduced with makeup oil
4. Introduced through breathers, hatches
5. Left inside new equipment, i.e. machining swarf

If the equipment is critical to the operation, it is important to measure particles accurately. The following is a summary of different particle analysis techniques and their strengths and weaknesses.

Measuring Contaminant Levels

Method	Benefits
Optical Particle Count	Provides accurate size and quantity distribution.
Automatic Particle Count	Fast, Repeatable.
Patch Test	Raid qualitative assessment of contaminant level in field. Allows microscopic view of contaminants.
Ferrography	Provides basic information which will indicate the need for more sophisticated testing upon abnormal results.
Spectrometry	Identifies and quantifies contaminant material.
Gravimetric	Indicates total amount of solid contaminant.

Filtration

Some materials that may be used to filter oil are paper, wood pulp, waste, felt and special clays. In most types of filters, the dirty oil is pumped in under pressure and emerges as cleaned oil, leaving the dirt in the filter. There are several types of filters that are used to filter out particulates and water. Among these are cartridge filters, cloth, paper and metal, and coalescers. Some types of adsorbent filters include activated carbon, Zeolite, Fuller's Earth and activated alumina.

Parts of a Filter Element

Filter medium filters the fluid.
Medium pack provides upstream and downstream support for the medium; provides collapse strength for the pleats; provides drainage path for fluid flow.
Side seal form the medium packs into a cylinder.
End caps hold the potting compound that seals the filter medium to the end cap.
Core provides collapse strength.
Pleat support band insures proper spacing of pleats.
"O" Ring Seal seals element to housing.
Label provides element identification.

Use the absolute rating to determine the effectiveness of a filter. All the oil holes are the rated size and all the oil must pass through the sized opening. In a nominal filter, there is no guarantee that all the pores are the rated size.

Nominal – an arbitrary micrometer value indicated by the filter manufacturer.

Absolute – the diameter of the largest hard spherical particle that will pass through a filter under specified conditions. This is an indication of the largest opening in the filter element.

Filtration Ratio (ßx) – The ratio of the number of particles greater than a given size (X) in the influent fluid to the number of particles greater than the same size (x) in the effluent fluid.

Terminal Pressure Drop- The highest pressure drop across the filter before the filter needs to be changed.

Apparent Dirt Capacity is the amount of dirt that can be added to the filter test system before the terminal pressure drop is reached.

Retained Dirt Capacity is the amount of dirt that is captured by the filter in a test system before it reaches the terminal pressure drop.

Service Life is the length of time that a filter will survive in an actual system before the filter is plugged. About 800 hours is normally expected for filters on hydraulic systems.

Beta ratio is the ratio of particles greater than a given size going into a filter to the number coming out. For example, if 200 is the rating given a filter whose absolute rating is 3 microns, this means that for every 200 particles of this size entering the filter, only one will exit.

Absorb – fluid is drawn into the pores.

Adsorb – fluid remains on the surface of the pores.

Mesh – the numbers of squares per inch.

Other than dirt capacity, service life and beta ratio, there are a number of other factors to consider when choosing a filter. A graded pore filter is one whose pores become smaller near the fluid exit. It is more effective than a filter whose pores are all the same size. At the same time, a fixed pore filter is more effective than a non-fixed pore filter because its fibers are bonded. Non-fixed pore filters are more subject to breakage. The benefit of thinner fibers in a filter is that there are more pores per square inch, which allows higher dirt capacity and lower pressure drop. Also, used filters should be examined for consistent pore sizes, pinholes and good fiber bonding.

Full flow filtration allows all of the oil from the main pump to flow through the filter. Offline filtration draws off part of the oil from the main stream and circulates it through a filter. This allows finer filtration without worrying about filter plugging. This is usually done by using a filter cart or attaching the filter to the reservoir.

The following are rules of thumb for the kind of damage that can be caused by different sized particles. Remember that the naked eye can only see particles of 40 microns or higher, so these particles are invisible.

- Particles > 40 micron may cause malfunctions jamming valves or blocking of orifices/oil channels.

- Solids > 25 micron will typically cause periodic failures because they form lumps that will cause blockage, but might flush through with pressure and flow peaks.

- Particles < than 25 micron are the real abrasive and harmful contaminants. Especially silt (2 – 7 micron) small enough to enter the clearances in servo valves or piston pumps.

Servo and proportional valves are extremely sensitive to particulate contamination. Contamination can cause slow response and instability, spool jamming/stiction, surface erosion and solenoid burnout. Systems containing servo valves need filters placed directly upstream of the valve. Generally, filters of 3 to 5 microns are used to filter out clearance sized particles. Here are a few typical clearances. Choose filters with micron sizes designed to filter out the following sized particles.

Typical Dynamic Clearances

Component	Clearance (μm)	Recommended Beta Ratio
Pump, Gear	0.5 – 5	
Pump, Vane	0.5 – 13	
Pump, Piston	0.5 – 40	
Valves (Radial clearance spool to sleeve)		
Servo	1 – 4	
Proportional	1 – 6	
Directional	2 – 8	
Pressure Control	2 – 8	
Roller Element Bearings	0.1 – 1	$ß_{(1\ to\ 6)} = 200$
Ball Bearings		$ß_{(1\ to\ 6)} = 200$
Journal Bearings	0.5 – 100	
Hydrostatic Bearings	1 – 25	
Gears	0.1 – 1	$ß_{(3\ to\ 12)} = 200$
Dynamic Seal	0.05 – 0.5	

The ISO cleanliness code, ISO 4406, recently changed from a two number designation to a three number designation. Formerly it was a code that indicated that the range of particles greater than 5 microns, and a second number for particles greater than 15 microns. Now the code is three numbers that indicate numbers of particles greater than 4, 6 and 14 microns. It will be reported in numbers like 18/16/12. New, unfiltered oil would typically range from 20/18/15 to 14/13/11.

Air

Almost all lubricating oil systems contain some air. Air is found in four phases: free air, dissolved air, entrained air and foam.

Free Air is trapped in a system, such as an air pocket in a hydraulic line, and may have minimal contact with the fluid. It can contribute to other air problems when lines are not bled properly during equipment start-up and free air is drawn into circulating oils.

Dissolved air is not readily drawn out of solution. It becomes a problem when temperatures rise rapidly or pressures drop. Petroleum oils contain as much as 12% dissolved air. When a system starts up or when it overheats, this air changes from a dissolved phase into small bubbles. If the bubbles are less than 1 mm in diameter, they remain suspended in the liquid phase of the oil, causing air entrainment.

Air entrainment is a small amount of air in the form of extremely small bubbles dispersed throughout the bulk of the oil. Air entrainment is treated differently than foam, and is most often a completely separate problem. Some of the potential effects of air entrainment include:

- Pump cavitation
- Spongy, erratic operation of hydraulics
- Loss of precision control; vibrations
- Oil oxidation
- Component wear due to reduced lubricant viscosity
- Equipment shut down when low oil pressure switches trip
- "Micro-dieseling" due to ignition of the bubble sheath at the high temperatures generated by compressed air bubbles
- Safety problems in turbines if overspeed devices do not react quickly enough
- Loss of head in centrifugal pumps.

Foam is a collection of closely packed bubbles surrounded by thin film of oil that collect on the surface of the oil. It is generally cosmetic, but it must be treated if it makes oil level control impossible, if it spills onto the floor to create a safety or housekeeping hazard, causes air locks at high points, or is so extreme that equipment is lubricated with foam. Do not treat small amounts of stable foam unless the system suffers from the above conditions.

Particulates act as seeds on which bubbles grow. Anti-foam additives may also be attracted to their surface, reducing their effectiveness in the bulk oil. In particular, cement dust can cause copious foam.

If the system is new, make sure that lines are bled properly. If that does not eliminate air pockets, evacuate the system and refill slowly under vacuum. Preheat the oil, or delay full speed operation until the oil temperature is high enough to release air that comes out of solution. Make sure the lines are flushed free of machining swarf and scale.

Some oils that contain detergents may dislodge deposits left behind by a non-detergent product. Foam that is produced while the system is being cleaned of old deposits usually goes away with time.

In an established system, check the oil level at working elements or in the reservoir when the equipment is at rest. Ensure that make-up oil is added slowly, or place the outlet of the hose under the surface of the fluid to prevent splashing. Check vents to see that they are not plugged, and clean them as required.

If air is dispersed throughout the fluid and clears very slowly, and the system is relatively stagnant, the air entrainment is probably caused by silicone contamination. Check seals, gaskets and other possible sources of silicone. IF the system is turbulent, watch for an air leak on the suction side of a high-pressure oil pump or for working elements that may churn the air into tiny bubbles. If the root cause cannot be corrected, it may make sense to add an after-market anti-foamant in this case.

Section 13
STORAGE, HANDLING AND APPLICATION OF LUBRICANTS

Storage

Drums of lubricants should be stored inside, if possible, but they may be stored outside if they are under a shed or tarpaulin or placed on their sides and chocked so both bungs are horizontal at the 3 and 9 o'clock positions and out of the water. Make sure solvent drums and tanks are grounded and vented to avoid explosions from static discharge.

In a manufacturing plant, drums should be opened and lubricants dispensed indoors. Ideally, the lids of grease drums should be removed and special drum covers put in place to prevent the entrance of dirt. Appropriate transfer pumps fit into the covers. The bungs of oil drums are removed, proper-dispensing pumps inserted and made secure, and drip pans placed to catch spillage.

Faucets can be fitted into oil drums and they may rest on their side n a rocker-type rack, allowing oilcans to be filled from the faucet by gravity.

Hand trucks are used to move drums of lubricant over reasonably flat, smooth surfaces. Drums may also be moved by an overhead crane or by forklift.

When a grease drum is emptied, it should be inspected and properly cleaned before it is returned to the storehouse. Any grease remaining should be scraped from the drum with a clean paddle and added to the top of a new drum if it is uncontaminated. Replace drum lids and oil bungs.

Proper inventory records should be maintained with quantity of each lubricant in stock, its location, and minimum order quantities.

Room should be made to handle the following:

1. Unopened containers and bulk tanks
2. Opened containers from which lubricants are being drawn
3. Lubrication accessories including rags, swabs, paddles, cleaning supplies, sample cans, and spare parts

4. Oil filtering equipment and supplies
5. Cleaning and storing of dispensing equipment
6. Record keeping
7. Empty returnable containers
8. Dispensing equipment, drum covers
9. Area for drum handling and movement
10. Expansion (if expected)

To prevent an oil spill from bulk tanks from harming the environment, the EPA requires the dike volume to be 110% of the largest tank

Handling

Where possible, machinery should be stopped before attempting to oil, clean, or repair it. Notify the operator to make certain that the machinery can not accidentally be started up again. If machinery cannot be shut down, be careful not to reach over moving parts such as shafts and pulleys, and do not wear lose-fitting clothing that might be caught in machinery.

Lubricants will burn; greasy and oily clothes are especially flammable. Know the location and proper use of fire extinguishers. Keep lubricants away from oxygen tanks. Oil or grease may explode if it comes in contact with oxygen under pressure. There should be no smoking around petroleum products.

Ladders, steps and platforms may be greasy and slippery. Spilled oil or grease or leaks from machinery should be cleaned up immediately in order to eliminate the possibility of someone slipping on it.

It is important to handle drums safely. Drums are not made to be dropped or bounced. Full drums weigh approximately 450 pounds, and empty drums weigh about 36 to 38 pounds. Even a pail of oil weighs about 40 pounds, so all should be treated with respect.

Two people are required to stand up a drum. They should grasp the near rim close to the high point and lift together, leg muscles doing the lifting. Roll drums by pushing on the sides with the hands, only. To overturn a standing drum, grip the near side of the top rim and push so as to tilt the drum away before letting it fall to the pad on the floor. If the drum is near a wall or another drum, position the overturn tool on the top rim of the near side and pull. Withdraw the tool, allowing the drum to fall to a pad on the floor, being careful to step quickly out of the way.

For inventory control, use the oldest product first, also called FIFO for First In, First Out, Avoid drum mix-ups. Segregate drum inventory by type and brand, and make sure identification labels are clear and adequate. Date drums to assure first in, first out turnover.

Contamination-free products received from the supplier must stay clean until they are applied to the machinery. Open original containers only when ready to use. Use dedicated dispensing equipment, if possible, to prevent contamination between different brands or types of products. Never use wooden paddles to fill grease guns from open containers.

Never pressurize a drum to remove oil, and do not weld on them to make barbeque pits

Investigate feasibility of bulk storage for those products such as hydraulic oil, where usage is high. In addition to price advantages, bulk dispensing avoids most storage and contamination problems found with individual containers.

Application

The following is a list of lubricating devices and systems. Even this list is not comprehensive.

1. Oil Squirt cans
2. Screw-type Grease Cup
3. Grease Gun
   Oiler
4. Drop-feed Oiler
   Oiler
5. Auto Drop-Feed Oiler, Pressure Actuated
   Positive-Feed Lubricator
6. Vibrating-pin Bottle Oiler
   Lubricators
7. Thermal Oiler
8. Wick-feed Oiler
   Circulating Systems
9. Splash-lubrication System
   Systems
10. Ring Oiler
11. Chain Oiler
12. Collar Oiler
13. Waste Feed Oiler
14. Underfeed Pad
15. Saturated-Pad
16. Mechanical
17. Oiled-Air
18. Spray Vales
19. Pressure
20. Centralized
21. Direct Systems
22. Indirect Systems

Once-through oiling is so named because the oil passes through the bearing only once and is lost for further use.
It is also called “All Loss” oiling because the oil is used only once. Methods of this type include hand oiling; drop feed oiling, wick-feed oiling, and bottle oiling.

Hand oiling is the direct application of oil to a moving machine part from a hand oil can. An excess of oil is applied, which soon runs off, leaving the bearing to operate with insufficient oil until the next oiling. For this reason, bearings lubricated by hand oiling are not as well protected against wear as those on which more reliable oiling methods are used.

Grease is also applied by hand onto bearings and gears to protect them from rust and to ensure lubrication when the machine is started for the first time. Grease can be applied manually through grease fittings. Grease fittings must be wiped clean with a lint free cloth to prevent dirt from being forced into the fitting when grease is applied.

Drop feed oilers usually consist of a glass or plastic reservoir, a needle valve feed rate adjustment, a snap level shut-off, and a sight glass for observing the feed rate. They are generally used on lightly loaded, horizontal bearings that require a low rate of oil supply.

An electrically controlled form of drop feed oiler is fitted with a large capacity reservoir and a manifold providing individually adjustable drop feeds for several bearings. Lines of tubing convey the lubricant to various bearings. A solenoid is a valve that opens and closes when the machine motor is started or stopped and it controls the flow of oil from the reservoir to the feed control manifold.

The **grease cup** is grease's equivalent to a drop feed oiler. The ordinary screw-down type consists of a small reservoir for holding the grease and a plate that screws down into the reservoir.

Wick Oilers have a wick of loose textured, long fiber wool that supplies oil to the bearing through capillary action. Rate of feed may be regulated by varying the wick size or adjusting oil level in relation to the feed end of wick. Raising the wick will stop oil flow. The underfeed oiler consists of a metal reservoir with a shank that threads into a hole in the bearing housing. Oil feeds up the wick to the shaft through the hole in the underside of the bearing sleeve.

Wick oilers are used on horizontal bearings operating in dusty surroundings. The wick serves as a filter to prevent contaminants from reaching the bearing. When the wick becomes choked with dust it must be cleaned or replaced. When the wick end becomes glazed from the rotating shaft, it should be trimmed off to provide a fresh surface. These are often used in traction motor bearings in railroad applications.

The bottle oiler consists of an inverted glass bottle mounted above the bearing and fitted with a sliding pin, which rests on the journal. When the journal rotates, it vibrates the pin. The vibration encourages a flow of oil from the bottle to the bearing through the space between the pin and its sleeve.

In the **ring oiling** method, a metallic ring, larger in diameter than the journal, rides on the journal and turns as the journal rotates. The ring, dipping into the oil, carries it to the top of the journal where it flows along and around the journal, providing lubrication before returning to the reservoir.

Chain oiling is similar to ring oiling except that a small-linked chain is substituted for the ring. The chain will carry a larger volume of oil than the ring.

An **oil collar** may be used to carry oil from the reservoir to journals turning at speeds so high that rings and chains would slip. The collar, fastened to the journal, dips into the oil reservoir as the journal rotates, carrying the oil to an overhead scraper which removes and distributes it along the journal.

Splash lubrication is used by most internal combustion engines and many gears. The moving elements dip into a bath of oil and splash lubricant onto other components.

Mechanical lubricators consist of an oil reservoir; one or more pumps (usually plunger type), operated by rotary or ratchet mechanical drive or by electric motor; feed rate adjustment for oil delivery; usually a sight feed for checking delivery of lubricant; and an oil strainer at the intake of each pump.

The **constant level oiler** consists of an inverted glass or plastic bottle with a neck extending into the oil in an overflow cup of the bearing reservoir. When oil level in the bearing reservoir falls below the end of the bottleneck, air is admitted into the bottle through a vent. Lubricant flows from the bottle to overflow cup and thence into bearing reservoir. When correct oil level is reestablished, oil covers the bottleneck and prevents any more air from entering the bottle. A constant level is thereby maintained in the bearing reservoir. This offers the advantage of an auxiliary reservoir.

Airline lubrication supplies lubricant by the use of compressed air. Air is injected near the compressor and is carried through the lines. Airline lubricants often have an emulsifier to absorb water and prevent it from condensing in the lines and freezing or causing rust. Most airline systems will have a filter, regulator, lubricator (FRL).

The difference between air mist and airline oiler systems is that mist systems generate a mist that is reclassified at application point. Airline oilers transfer a thin film of oil to the application point, and the oil is not recirculated.

Oil Mist lubrication uses a stream of compressed air to break up the oil into a fine mist. A fine dry fog of oil is conveyed from the generator through tubing lines to the bearings. From there, the oil particles are reclassified on impact and are converted to a wet fog at point of application. Turbulence will cause the droplets to recombine. Distribution lines are tied to the top of the main line to prevent any contaminants from being transferred to the equipment being lubricated. Very small quantities of oil are consumed.

The flow of air helps keep dirt out of the bearings and also has a cooling effect. Oil mist is especially effective at cooling high-speed bearings.

Oil mist has the following advantages over other lubrication systems:

- Constant supply of fresh lubricant
- Slight pressurization helps to reduce contamination
- No moving parts, or cyclic mechanism in the system
- Alarm systems monitor flow rate and oil level
- Low lubricant consumption reduces lubricant cost
- Reduces temperature in bearing housings by up to 30%

However, the advantages may be offset by disadvantages:

- High initial cost
- Difficult to set and maintain flow rates
- Some environmental and/or health concerns if stray mist is not contained
- Very sensitive to temperature changes
- Return lines must capture mist that is not reclassified to liquid
- Potential varnish and sludge if oil overheats excessively

Spray lubrication for oil is used to lubricate plain roll neck bearings on mills. A spray gun, similar to those used for paint, uses compressed air to spray gear teeth with a film of grease sufficient for lubrication.

A centralized grease system is the best method for supplying grease to a large number of bearings on a machine, if it is properly serviced and maintained. Such a system consists of a centrally located grease reservoir with a pump and permanently installed piping having grease distribution valves through which grease is conveyed from the reservoir to the various bearings.

1. It is safer than greasing by hand, since a worker does not have to climb over the machinery to reach the bearings.

2. It reduces housekeeping.

3. It assures that all bearings will be lubricated and that each will receive its proper proportion of lubricant.

4. It permits more frequent application of lubricant and, thereby, gives better lubrication and longer equipment life.

5. It reduces down-time of operating equipment since the machine may be lubricated while it is operating.

6. It takes less time than hand-lubrication methods.

Centralized systems can be single line, dual line or progressive. Single line and dual line systems consist of a reservoir, a pump, valves, and main line piping to which the measuring valves are connected.

The progressive system, reversible flow (loop system), consists of a reservoir; a pump; a four-way valve; a supply line; and a series of progressive, non-adjustable measuring valves inserted in the supply line. The progressive system, non-reversing, divides the delivery from the pump into several bearing outlets. The measuring valve is progressive and non-adjustable. System includes a reservoir, a pump, a supply line, and a measuring valve manifold consisting of three or more measuring valve sections.

Circulating oil systems provide a continuous supply of oil to bearings. Since oil is continuously re-used, oil can be strained, filtered, and cooled. Oil pressure is controlled by a relief valve or orifice sizing. In a direct circulating system, a pump is used to meter the lubricant. In an indirect system, the pump builds pressure, and metering valves in supply lines meter the amount of lubricant.

Two reservoirs feed gravity systems: one above the highest bearing to be lubricated and the other below the lowest bearing. Oil leaves the upper reservoir, lubricates the bearings by gravity, drains to the lower reservoir, and is returned to upper reservoir by means of a pump.

Pressure feed systems use a pump to force oil to bearings from where the oil drains to a reservoir by gravity. Cooling may be used on the return lines. Systems of this type are useful where large volumes of oil are handled.

Reservoirs should allow oil to dwell long enough to separate air, water and solid impurities. Fluid residence time can vary from 3 minutes to 60 minutes depending on the system. The reservoir capacity can be calculated as follows:

Capacity = dwell time (min) x oil requirement for all components (in gpm)

Capacity = minutes x gallons /minute

Low oil depth permits faster escape of entrained air and quicker settling of water and solids. A long tank places the pump suction farther from the oil inlet to give the longest possible oil path. These factors lead to the following typical reservoir proportions:

Width = Height
Length = 2 x Width

The reservoir bottom should slope about 1 in. /ft. from the oil entrance toward the drain at the other end. Effective baffling allows use of shorter dwell periods and smaller reservoirs. Baffles should be placed between the inlet and suction lines.

Oil usually returns to the reservoir through horizontal lines at or just above the oil level to minimize splashing and foaming. When gear units are served, oil is returned slightly below the surface to keep air pressure caused by gear windage from backing up into the bearing housings. Spill from relief valves and pressure regulators and return flow from separate oil-purification systems are free of air and contaminants; they discharge 6 inches or more below the oil level to avoid splashing.

In large tanks, oil-pump suction openings should be placed about 6 to 12 inches above the tank bottom to prevent dirt or water pickup, or at least 4 to 6 inches above bottom in smaller tanks. The suction opening must be kept well below the lowest oil level to avoid sucking air and losing pumps prime. Where oil level varies widely, use a floating suction with attached strainer.

In all methods of reservoir lubrication, it is important that the reservoir be checked periodically to be certain that proper oil level is maintained. A level gauge is provided in the lower part of the reservoir for this purpose.

Vents allow moisture and vapor to escape. Filters prevent dust from contaminating the oil. Large oil systems are frequently vented to a vapor extractor pump. In addition to the vent, a manhold (or handhold in small reservoirs) above the maximum oil level should be provided for tank inspection and cleaning. Headspace is needed in the design of oil reservoirs to allow for thermal expansion, turbulence, foaming and air release, and system fluctuations.

Pipe should be large enough to prevent cavitation in pump-suction lines, to avoid undue pressure drop in feed lines, and to avoid backup in drain lines. Piping selection is based on flow velocity, which is measured in FPS. Orifices in oil piping control oil feed rate to individual components and they prevent starvation of all bearings if a single component fails.

Schedule 40 piping is commonly used except in cases of extreme vibration, high stress, or shock. Large systems sometimes use Schedule 80 for its physical strength. In systems combining both lubrication and hydraulic operation, high pressures occasionally require use of Schedule 160.

When designing a circulating system, it is important to consider reservoir capacity, dimensions, location, materials, baffles, oil flow; temperature; hydraulic fluid; size and positioning of vents; pump type and rating; filter types, ratings and location; actuator type and size; design of fluid conductors; valve types and orientations.