

# Practical Experience with Oil Mist Lubrication

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*Although oil mist lubrication has been available for about 30 years, it has not gained widespread acceptance in the petrochemical industry. Recent experience has demonstrated reduced bearing replacements and downtime when pure oil most lubrication is used. A key to a successful oil mist system is careful attention to design and construction. While oil mist systems are essentially "trouble free," periodic inspection helps keep the system "in tune" and helps maintain the highest degree of performance and reliability. Field results show that bearing failures can be reduced 80 percent to 90 percent by converting from conventional lubrication to pure oil mist.*

## INTRODUCTION

Although it has been over 30 years since oil mist was introduced in the United States, it has not gained widespread acceptance throughout the petrochemical industry. For many skilled machinists and operators, the idea of draining a bearing housing and lubricating a pump with "a puff of smoke" is extremely hard to visualize and accept.

Rolling element and sliding contact bearings can be lubricated with oil mist. When sliding contact bearings are used, oil mist alone does not provide complete lubrication. In this case, an oil level is maintained in the bearing housing. Oil mist is used to purge the bearing housing and to provide partial fresh oil makeup. Ball and roller bearings can use either purge mist, as described above, or pure mist, also called dry sump lubrication. When pure mist is used, the bearing housing is drained and all lubrication is provided by the oil mist. Discussions in this paper relate to API- and ANSI-type process pumps which have single-row-ball radial bearings and double-row-ball thrust bearings.

As energy conservation and cost reductions become increasingly critical, oil mist lubrication appears even more attractive. The usual slow progression toward accepting oil mist has been followed at this manufacturing complex. Dur

ing the past two and a half years, much valuable experience has been gained and some of the earlier questions have been answered. Information available in open literature (1) - (5), can help develop an effective program sooner. This paper will discuss how a system operates, practical problems encountered, solutions taken, and general experience with oil mist systems.

## SYSTEM DESIGN

An oil mist system is a means of generating and transporting a finely dispersed oil mist from a central location to a bearing housing. The finely dispersed mist is coalesced into larger droplets just prior to reaching the bearing housing so the larger particles can lubricate the bearing.

Oil mist systems are installed to provide longer bearing life and reduced maintenance compared to conventional lubrication methods. They do this in two ways. First, they reduce internal bearing friction and temperature caused when a bearing pumps oil. Second, they provide a positive pressure, oil-containing atmosphere inside the bearing housing to eliminate external sources of contaminants such as moisture, dust, and chemical atmospheres. Other advantages include lower lubricant consumption, reduced handling and spillage, constant oil supply and centralized control and operating locations.

An oil mist system consists of a mist-generating console where the mist is produced, a distribution system in which the mist is transferred to the lubrication point, reclassifiers which cause the oil to combine into larger droplets, vents which help control pressure and establish flow paths in bearing housings, and drains to remove condensed oil. A typical system is shown in Fig. 1.

## GENERATOR

The heart of an oil mist system is the generator head. It operates similarly to a carburetor in a car. Various types of mist-generating heads (Fig. 2) are available which use different approaches for producing oil mist. All function by atomizing oil into very small particles (in the range of 1 to 5 microns). The most important factor when selecting a

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generator head is not the type but the size. A mist generator head must be sized to match its application. Often, generator heads are sized to match its application. Often, generator heads are sized too large for the existing system. This usually occurs because engineers are anticipating future expansion.

Mist generators do not operate well at the low end of their capacity. When inlet air pressure is low, velocity through the atomizing orifice is also low causing insufficient vacuum to lift the oil from the reservoir and atomize it (Fig. 3). Unnecessarily large reclassifiers are then used to increase air flow and allow the generator to operate in a more efficient range. This results in overoiling, housekeeping problems increased losses to the atmosphere, and wastes energy.

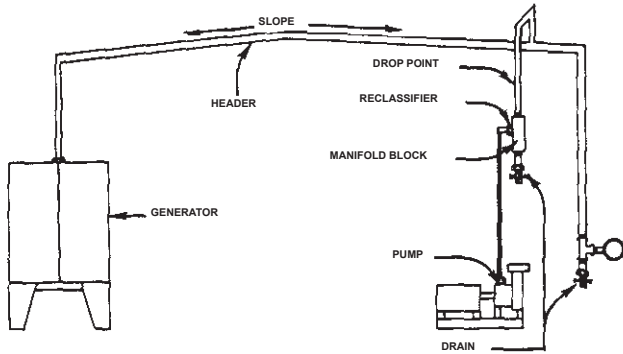


Fig. 1—Simplified oil mist system

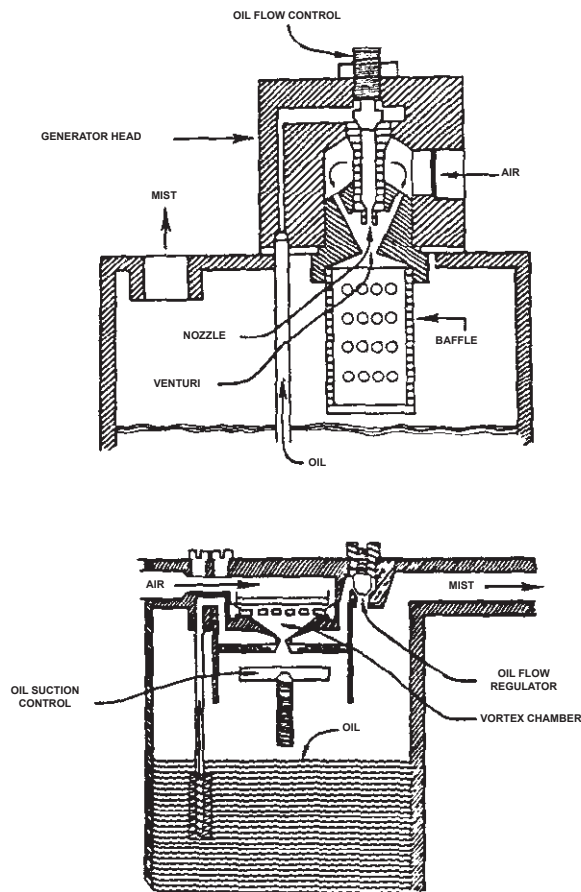


Fig. 2—Typical oil mist generator heads

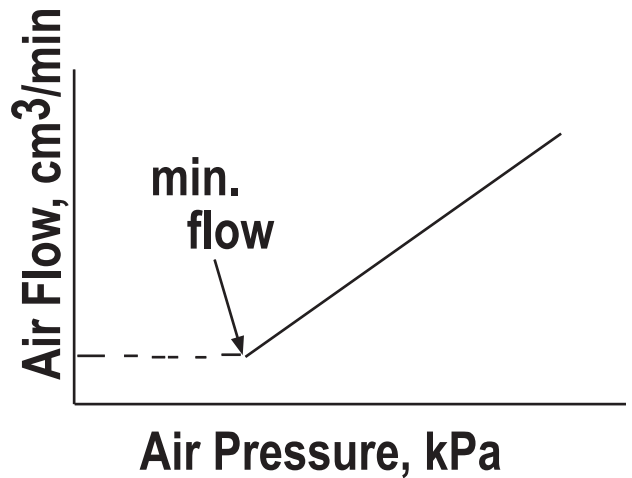


Fig. 3—Generator characteristics

### HEADER SYSTEM

After the mist has been generated, it must be transported to the user equipment. This occurs in the main header system. The header system should be sloped back toward the generator but the distance the line is sloped will vary according to the length of the header. For instance, if very long headers, say 90 meters (300 ft) are used, at least the first fifteen (15) meters (50 ft) should be sloped toward the generator. If the lines are shorter, say 30-45 meters (100-150 ft), the entire line could be sloped back toward the generator. Vertical clearance in a pipe alley will often influence the amount and direction the header is sloped.

Sloping is required because some mist particles collide with one another or impact the walls forming larger particles which are too heavy to remain airborne. These heavier particles collect in the bottom of the pipe and drain back to the reservoir or a drain leg. Most of this “condensation” occurs in the first 15 meters (50 ft). To reduce impact and collisions, velocity in the header is kept low (below 7.3 m·s<sup>-1</sup>) to provide laminar flow.

Properly commissioning the header system is important. Scale, trash, and moisture can all be present in a newly installed system. Our procedure has been to flush the header system with high-velocity steam, 1.4 MPa (200 psi), followed by air, 0.7 MPa (100 psi), drying. When the lines are completely dry, the generator is immediately started, the air/oil ratio is set rich and the header pressure is set high. After a day’s operation, the air/oil ratio and header pressure are adjusted to normal, the equipment (pumps, motor, turbine, etc.) is connected and the system is operational.

If auxiliary headers are required, they should come off the top of the main header. The auxiliary header can be sloped either way (toward or away from main header) provided a drain leg is installed at the end of the auxiliary header if it is sloped away from the main header. In all cases, both main and auxiliary headers, there should be no low spots where oil can be trapped and interfere with mist flow to equipment. All piping should be checked before starting the mist system and periodically checked afterwards to make certain that lines have not been bent or moved during installation and construction.

## DRAIN LEGS

When long headers are used, making it necessary to slope the header away from the generator, they should terminate with drain leg. A drain leg is merely a vertical section of pipe which is the same diameter as the main header and terminates with a valve. "Condensed" oil can then be drained. Oil accumulated in a header could prevent adequate mist from reaching the equipment.

Drain legs should be emptied routinely especially when they are located where the header changes elevation and direction (see Fig. 4). Here the drain leg can fill and excess oil can accumulate in the main header. If the header is long enough, oil could seal off mist flow to the auxiliary header. Preferred design if possible would be to eliminate the drain leg and slope the header back toward the console.

## DROP POINTS

Drop points are small lines which come off either the top or the bottom of the main header and supply mist to the lubrication point. If taken from the top of the header, chances for getting "condensed" oil or other material into the reclassifiers are minimized. Two methods for terminating drop points are given in Fig. 5.

As shown, reclassifiers are located at the drop point rather than on the equipment. Our experience has shown that if the reclassifiers are screwed into the bearing housing, they are often taken to the shop when pump repair is required. Depending upon reclassifier make, some are mistaken for tubing fittings so they are thrown away and replaced by tubing fittings. (Note that spray or condensing fittings must be handled differently. If attached as in Fig. 5, flow through the fitting would be backwards.)

It is always good practice to observe and record operating parameters routinely. Then if marked change occurs in any one, the systems can be inspected. Without routine monitoring and recording, many indications of potential problems will be missed.

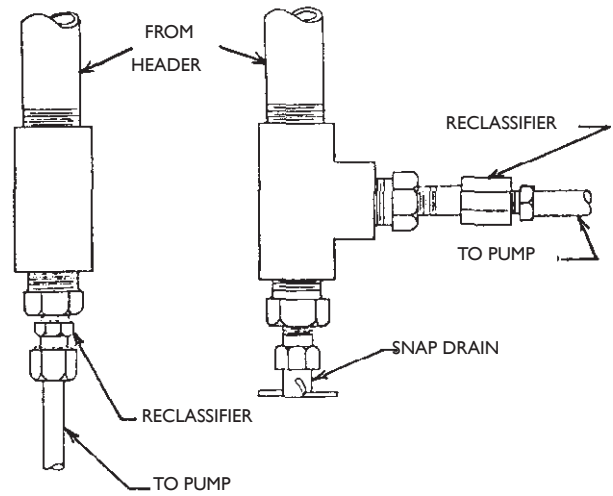


Fig. 5—Drop point designs

When an open piece of tubing discharges into the atmosphere, mist header pressure is obviously reduced. In most cases, header pressure will be low enough to cause an alarm. If pressure is low but an alarm is not sounded, the system might not be providing adequate lubrication to all other points. When a pump has a tubing fitting instead of a reclassifier, it is being overlubricated and free fog emissions to the atmosphere are increased. If an operator observes the low pressure and readjusts air supply without determining the cause, both air flow and oil flow will be excessive.

Line size for drop points is often 1.9-cm (3/4-in) pipe. In most cases, user equipment is close to the main header so drop points are short. A few instances require relatively long horizontal piping runs to equipment. Because of the small diameter piping, mist velocity is increased and chances for collision and condensation are increased. Hence, these runs should be sloped toward the main header to prevent excess oil from reaching the reclassifiers.

## RECLASSIFIERS

Reclassifiers or mist fittings are devices which convert small particle-size dry mist to larger particle sizes which can lubricate bearings. A reclassifier is basically an orifice (Fig. 6). As mist accelerates to get through the small opening, turbulence and collision rates increase, thus forming larger particles. Spray, mist, and condensing reclassifiers are available. The major difference is how long mist particles are maintained at high velocity so agglomeration can occur. Our practice has been to use only mist reclassifiers. Experience has been very satisfactory. In general, the smallest reclassifier that will provide adequate bearing lubrication should be used. Calculation techniques for air flow by volume,  $m^3 \cdot \text{min}^{-1}$  (cfm), or bearing-meters (in) are provided by all oil mist equipment suppliers. Bearing-meters are the shaft diameter in meters multiplied by the number of bearing row. Volume flow is determined by multiplying bearing-meters by a constant severity factor (either light, moderate or light heavy duty). Our experience has shown that in all but the very most severe applications (high speed, load and temperature), the moderate-duty service factor is completely satisfactory. This will help prevent grossly oversizing the generator head; will help reduce oil consumption and will help keep atmospheric emissions low.

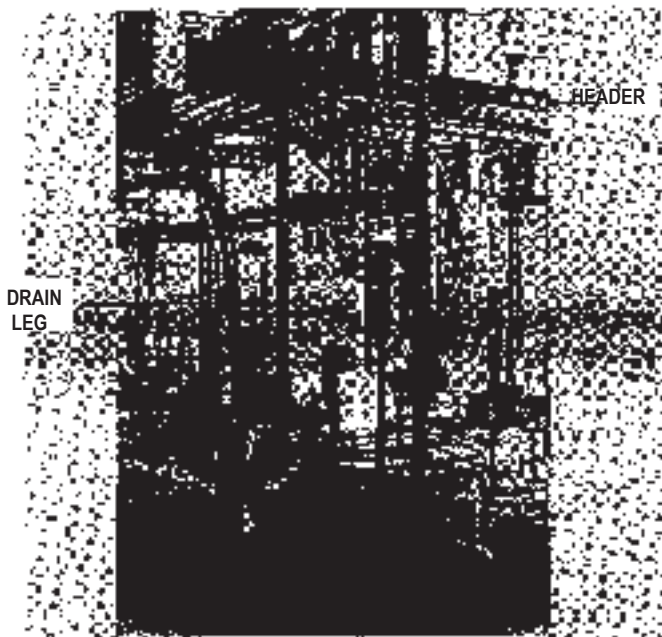


Fig. 4—Unacceptable drain leg design

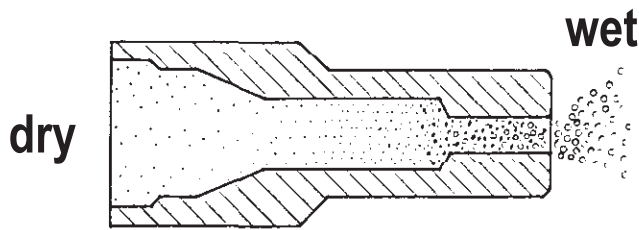


Fig. 6--Reclassifier operation

## PUMP CONNECTIONS

Two lubrication methods are used, as shown in Fig. 7. One is dry sump or pure mist while the other is wet sump or purge mist. In a pure mist system, the bearing housing is drained of oil and all lubrication is accomplished by mist. A sight glass is installed on the bottom of the bearing housing to catch mist which condenses. Any water or other contaminants which might reach the bearing housing can be seen in the sight glass. Currently, practice is to vent the bearing housing to be certain that oil mist passes over the bearings.

Venting single-row bearings (pumps radial bearings) on dry mist is relatively simple. Leakage through a labyrinth or a small hole drilled in lip seal is adequate. In most cases, no external vents are used and windage from the rotating bearing provides adequate circulation through the bearing. All methods have been successful but it is important to know pump design characteristics so the correct method can be applied.

When dual-row thrust bearings are used, more care is taken to vent the bearing housing to ensure equal flow through both rows of bearings. Vent size is usually at least twice the cross-sectional area of the mist fitting (reclassifier) or larger. If a pump has labyrinth seals, additional vents are not required.

A pump using purge mist has its bearing housing filled to normal level with oil and is equipped with a constant level oiling device. In this system, oil mist provides a positive pressure in the bearing housings to prevent the ingress of contaminants. A 5-mm (3/16-in) hole is drilled in the oiler 6 mm (1/4 in) above the desired oil level. This permits excess oil which condenses in the bearing housing to be drained. Hence, the oil mist provides a continuous source of makeup oil. However, oil should still be periodically drained since any heavy materials or contaminants will sink to the bottom.

Adequate venting is mandatory with purge mist. If venting is inadequate, oil can be pressurized out of the bearing housing leaving the pump operating on pure mist. The equipment will probably be unharmed if it has ball bearings but it could be damaged if it has sleeve bearings.

As discussed above, excess oil is drained from the bearing housings of pumps with purge mist by drilling a hole in the oiler just above the oil level. A different type of system is used to drain pumps with pure mist, as shown in Fig. 8.

Condensed oil drains from the pump and is collected in a clear plastic sight glass. As oil accumulates, the excess is drained through a suitable line to a rich oil drain. This arrangement helps reduce housekeeping problems because oil does not drip on the baseplate or around the pump. It also retains the advantages of the sight glass in which the condition of the oil can be observed. The small line to drain can also be bent into a u-tube shape. This will help hold

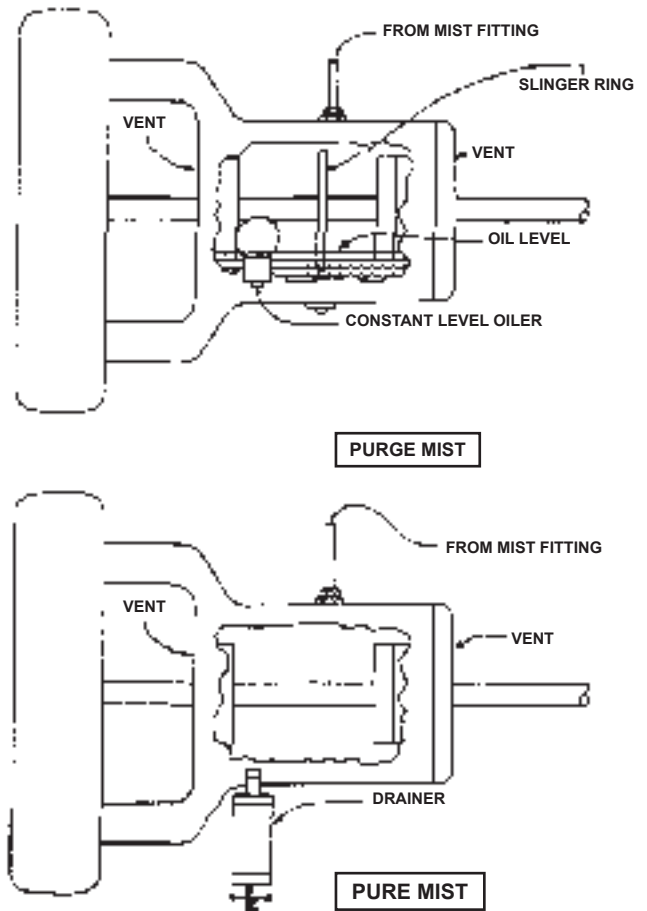


Fig. 7—Oil mist types

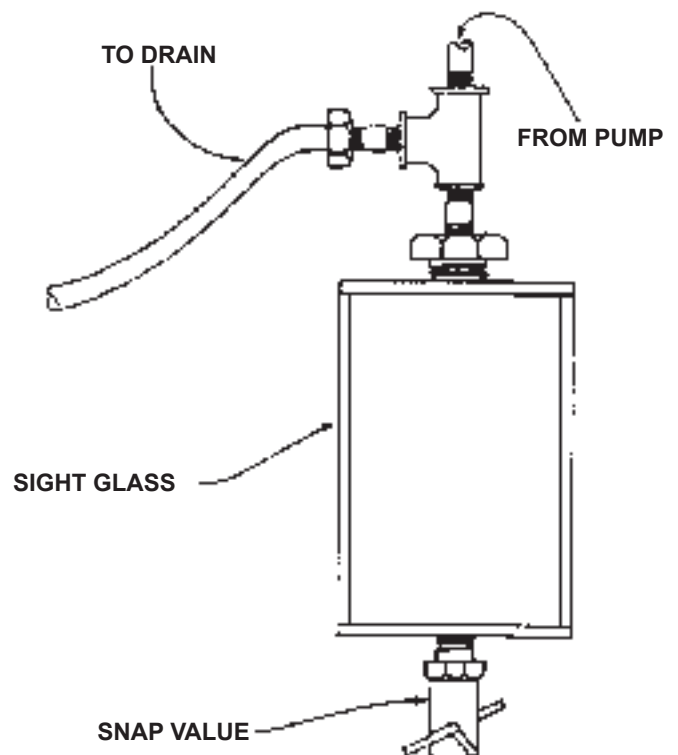


Fig. 8--Pump drain system

pressure on the bearing housing plus reduce stray mist liberated to the atmosphere. If water or contaminants become present, they fall into the sight glass. When oil stands for a long time in the presence of heat and air, it oxidizes and changes color. The sight glass should be drained periodically when this occurs. If restrictions do not permit running the oil to a drain, a larger container can be used. However, periodic draining and collection will be required.

Sight glasses are also used for the bearing housings of small general purpose turbines. Turbine bearing housings use purge mist because they have sleeve bearings. Sight glasses are screwed directly into the bottom of the bearing housing and no drain line is used. One problem with turbines is that steam leaks through the labyrinths and condenses in the bearing housing. By using the sight glasses, condensed water can be immediately observed and can be drained before damage occurs. Line size between the bearing housing and sight glass must be large enough so that surface tension does not prevent water from dropping into the sight glass.

## CONTROLS AND ALARMS

Controls are provided to maintain oil and air temperatures at proper levels and, in some cases, to maintain correct oil level (Fig. 9). An oil mist system can operate well without oil and air heaters, but the heaters are used to provide more uniform atomization and to help prevent low-temperature problems. If not heated, oil in the reservoir gets thick at low temperatures and becomes more difficult to lift and atomize. Lubrication problems could result. Heating the air helps transport the mist more uniformly to the lubricating point. Oil formulation is also important. The oil should have a low pour point and a low wax concentration to help prevent plugging of reclassifiers. More viscous oils require more extensive oil and air heating to maintain viscosity in the proper range. Guidelines are provided by oil mist equipment suppliers, but each location will have to select the oil for its application. Air and oil heaters are then adjusted to provide proper lubrication using the oil selected. Additives are available which can help control particle size, and thus, stray mist but they should be used cautiously.

When a mist unit is equipped with an automatic fill system, oil level controls consisting of a solenoid valve and a level control switch are used. Oil level is controlled over a narrow range, say 0.6

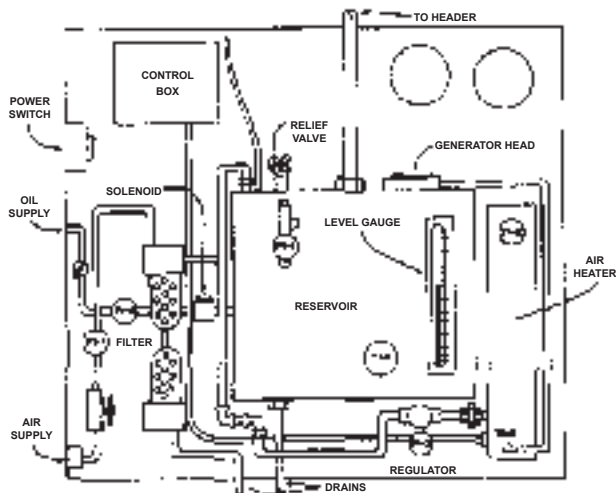


Fig. 9--Oil Mist Consols--schematic

cm (1/4 in) or less so that bulk oil temperature in the reservoir is essentially constant.

Other controls include an air pressure regulator for setting mist header pressure and an air/oil ratio screw which is mounted on the generator head. Incoming air is adjusted until the desired header pressure, usually 4.98 kPa (20 in H<sub>2</sub>O), is reached. Air/oil ratio is then adjusted. Some units are equipped with air bypasses which bypass a slip stream of air around the generator head to permit better control of the oil/air ratio.

Generally, as air flow increases through the generator head, oil flow is also increased. At high air flows, oil flow can become excessive, so the oil/air ratio adjustment is leaned. In some units, it is possible at high air flow to run out of adjustment and still be providing excess oil. This is where the bypass can be used. Regulated air pressure is reduced until the desired oil flow is produced at the generator head. The bypass is then opened to maintain header pressure at the desired level. Hence, header pressure is increased while maintaining constant oil flow.

Alarms are provided for low- and high-mist pressure, temperature, oil level and, sometimes, oil temperature. Each alarm point can be adjusted separately according to user needs. Some units employ self-cancelling alarms that clear automatically when rectified while others must be manually reset.

Mist density monitors are available which can indicate when mist density changes markedly from initial setting. These monitors use photo cells to measure relative mist capacity. They are most beneficial for indicating extremely lean air/oil ratios.

## CONVERSIONS

When installing a conversion unit, all pumps which can use pure mist are converted to pure mist. If a pump has rolling bearings, it is candidate for pure mist regardless of pumping temperature. Pumps with sleeve bearings get purge mist. Oil slinger rings and oil flingers are left intact until a pump is removed for service. To make a conversion, a fitting is screwed into the top of the bearing housing to accept the reclassifier line, and a sight glass drainer is installed. Provisions are made for venting through doublerow thrust bearings where required. Cooling water to the bearing housing is eliminated on all pumps with pure mist. We have been operating without cooling water for over a year through one of the hottest summers on record and have not observed any problems. Many pumps have internal passages which connect the outboard of the bearings to the sump. With conventional lubrication, this passage provides a path to drain oil which has passed through the bearings back into the sump. It has been suggested that oil mist would preferentially pass through this passage rather than through the bearings. None of these passages has been plugged to prevent bypassing in any pump that has been converted. Bearing lubrication has not been affected.

Spare, or piggyback units are usually installed to provide emergency backup when pure mist is used on large scale. Obviously, if an entire system is on purge mist, a spare unit is not needed since lubrication reverts to conventional if the generator fails. In fact, the need for a spare unit with pure mist system is questionable *provided* adequate spare parts and knowledgeable personnel are available at all times. If both these conditions are not met, a backup unit is highly desirable. We have documented evidence that pumps can run more than eight hours after oil mist flow has ceased.

## OPERATION AND PERFORMANCE

Correct mist header pressure is required to operate a mist system properly. Normally, header pressure is set at 4.98 kPa (20 in H<sub>2</sub>O). However, we have found that the gauges used to measure header pressure have been very erratic and inaccurate. In some instances, we have found gauges that were in error as much as 1.49 kPa (6 in H<sub>2</sub>O). Such errors can seriously affect the amount of oil delivered to bearings. Hence, all mist pressure gauges should be calibrated and mist header pressure should be checked using a water manometer when the system is first started, and periodically afterwards.

Some mist equipment use pad-type heaters under the reservoir for heating the oil. Our experience has been that, in even the relatively mild winters of Houston, these heater pads have been inadequate. Immersion heaters are much more effective.

It is important to know the oil/air ratio that the generator is providing. This will help ensure each pump is getting proper lubrication. Air flow is determined by knowing mist header pressure and the number and size of reclassifiers. Oil flow is more difficult to define. The closest approximation to oil consumption without using extremely elaborate systems is to measure the decrease in oil reservoir level over a given time period. Obviously, in automatic refill systems, a block valve must be installed in the oil supply line. The amount measured is a stabilized value representing the net difference between generator output and liquid drainback to the reservoir. Accuracy can be improved by collecting the oil which flows to each drain leg (where used) and subtracting from the apparent amount consumed. This provides a fairly good picture of the oil/air ratio delivered to each reclassifier. With out system, the amount of oil which condenses between the main header and the reclassifier can also be measured.

A series of tests were run in one system which included 25 pumps and 13 turbines to determine how much oil condensed in bearing housings. Condensed oil was determined by daily measuring the amount collected in the sight glass drainers.

Two fairly obvious results were obtained. Pumps that were running condensed about twice as much oil as pumps which were not running. This occurs because of high turbulence inside a bearing housing when a pump is running. Secondly, as reclassifier size is

increased, a higher percentage of oil is condensed. This also relates to turbulence within the bearing housing.

It was observed that with larger reclassifiers, even though a higher proportion was condensed in the bearing housing, the absolute amount lost to the atmosphere was increased. As shown in Table 1, oil lost to the atmosphere was increased 17 percent with larger reclassifiers in running pumps and by over 50 percent in standby pumps. Reclassifier size should be the smallest consistent with adequate lubrication to reduce excess stray mist. Vents should also be the smallest practicable to provide adequate flow through the bearing.

Test results also showed that as air/oil ratio was richened, the percent condensed remained about the same. Here again, while the total amount of oil collected increased, the absolute amount lost to the atmosphere also increased. Hence, air/oil ratio needs to be controlled to the leanest consistent with adequate lubrication.

An oil mist system is almost trouble free but it cannot be installed and forgotten. Systems should be checked daily for correct air and oil temperature, oil level and mist header pressure. Once a week, drain legs and drop points (if so equipped) should be drained. We have instituted a program where oil and air filters are changed every six months and the oil reservoir and generator screen are cleaned once a year. When a red light does occur, the cause must be determined. Most newer generators are equipped with firstout indicator lights which help pinpoint the problem quickly.

Bearing performance data have been maintained more carefully during the past three years since oil mist lubrication has been used. Results are shown in Table 2 for units which started new and for units which were converted. Percent bearing failures per year is a relative value and is defined as the average number of bearings failed per year operation divided by the total number of pumps. Bearing failure results for wet sump applications in new units are inconclusive because of the limited number of pumps which use wet sump. However, when results from the conversion units are compared with results from the new units, it can be seen that considerably more bearing failures occur with wet sump than with dry sump. These limited results also show that a 90 percent reduction in bearing failures is not unusual when converting from conventional lubrication to dry sump oil mist lubrication.

TABLE 1—BEARING HOUSING OIL CONDENSATION RATES

Air/Oil Ratio cm <sup>3</sup> · L <sup>-1</sup> · h <sup>-1</sup>	0.29	0.29
Reclassifier Size, L · min <sup>-1</sup>	2.55	5.10
Oil Supplied*, cm <sup>3</sup> · h <sup>-1</sup>	0.61	1.22
Oil Recovered, cm <sup>3</sup> · h <sup>-1</sup>		
Pump Running	0.26	0.81
Not Running	0.08	0.41
% Recovered		
Running	43.0	66.0
Not Running	13.0	34.0

\*Measured Result

TABLE 2—PERFORMANCE OF OIL MIST SYSTEMS					
NEW UNITS		% ON DRY SUMP	YEARS EXPERIENCE	% BEARING FAILURES PER YEAR	
UNIT	PUMPS ON OIL MIST			DRY SUMP	WET SUMP
A	85	94	1 1/2	2.5	0
B	45	87	2 1/2	7.2	13.3
C	31	87	3	8.6	33.3
D	17	65	2 1/2	7.3	20.0
E	13	85	2	4.5	0
WEIGHTED AVERAGE =				5.3	16.8
CONVERSION UNITS		% ON DRY SUMP	BEARING FAILURES PER YEAR		PERCENT REDUCTION
UNIT	PUMPS ON OIL MIST		BEFORE	AFTER	
F	200	98	31	1	97
G	70	30	7	<1	>86
H	58	0	No Data	>5	—

Two very similar olefins plants are being operated in our location. The first unit was started about 10 years ago and used conventional lubrication. The second unit was started about 2 1/2 years ago and was equipped with oil mist lubrication in which about 90 percent of the pumps used dry sump. Bearing performance in these two units is compared in Fig. 10. As shown, bearing failures per year increased for the first three years until a stabilized value was reached. Since that time, about 43 or 44 bearing failures have been recorded each year. It should be noted that this figure is probably conservative because recordkeeping at night and on weekends is often incomplete.

The new unit with oil mist was started during the eighth year. Ten bearing failures were observed the first year and only four the next year. A stabilized level at 4 or 5 bearing failures per year seems to be developing. In this case, bearing failure incidents are accurate because the system is being watched closely.

These results indicate about a 90 percent reduction in bearing failures when oil mist is used instead of conventional lubrication and corroborate the results observed with conversion units.

## CONCLUSIONS

Our experience with oil mist lubrication has been extremely encouraging. Maintenance costs and downtime caused by bearing failures have been significantly reduced. Because oil mist systems are simple and almost trouble free, the tendency is to start them and "walk away." Periodic inspection and maintenance are required to keep the systems "in tune" and maintain the highest degree of performance and reliability. The key to a successful oil mist system is careful attention to design and construction. The systems must be matched to the operating equipment. A properly applied and installed oil mist system can reduce maintenance costs significantly by reducing failures as much as 90 percent.

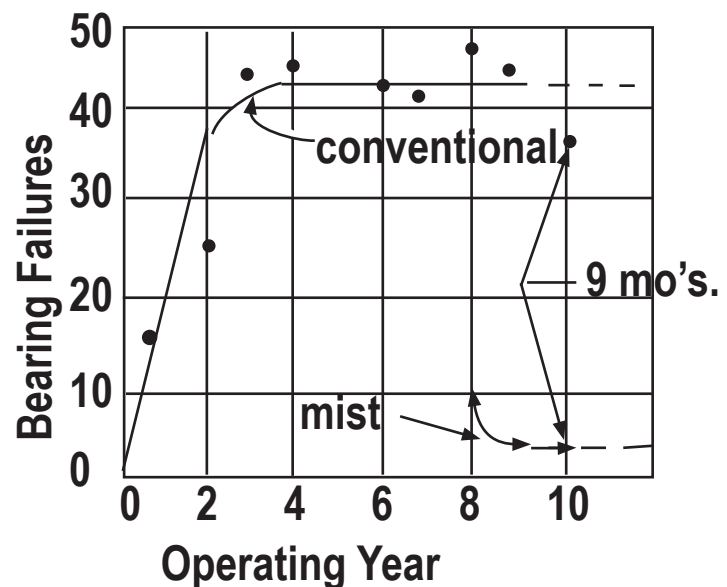


Fig. 10—Oil mist performance

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