ADVANCES IN OIL MIST LUBRICATION TECHNOLOGIES AND APPLICATIONS

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ABSTRACT

Oil mist lubrication is a proven, environmentally clean and cost effective method for the lubrication of rotating equipment in process industries. The use of oil mist lubrication has grown dramatically in many parts of the world because of the benefits delivered by its use. Since the late 1980's many advances have been made in both the technology of oil mist system design and methods for applying oil mist to rotating equipment. Technology for closed-loop, environmentally clean oil mist systems in addition to the latest in central mist generator design is reviewed. Advanced oil mist system components are described and new applications for use of oil mist on process equipment such as lobe blowers and filter presses are discussed. Two soon to be introduced oil mist equipment advances are also described.

INTRODUCTION

The use of oil mist lubrication in the refining and petrochemical industry dates back to the 1960's when companies such as Exxon and Chevron began to apply oil mist to pump bearings.[1] By the early 1970's oil mist lubrication was being applied to rolling element bearings of electric motors in the refining industry.[2] Today, as indicated in a bi-annual survey conducted by Lubrication Systems Company, 77% of the major, multi-location US refining companies have at least one large-scale oil mist system in at least one of their refineries.[3] The use of oil mist in the hydrocarbon processing and other industries, such as pulp/paper, world-wide is growing because of oil mist lubrication's proven performance in delivering improved machinery reliability, reducing maintenance costs and providing a fast pay back on the investment in the oil mist lubrication system.

Oil mist technology has kept pace with advances made by process industries and the mist systems being designed and installed today are far superior and more efficient than those installed in the 1980's. Some of the advances and new applications which are utilized in today's systems are:

- Microprocessor controlled central oil mist generators compatible with central distributive control systems.
- More efficient and effective distribution system design practices.
- Improved oil mist manifolds.
- Environmentally clean mist collection containers.
- Drain leg designs and components which eliminate waste and venting.
- Efficient, environmentally clean, closed-loop oil mist systems.
- Demisting system for the textile industry.
- Miniaturized, closed-loop lubricator.
- Portable mist density monitors.
- New applications for oil mist:
  - Rotary lobe blowers
  - Defibrator press

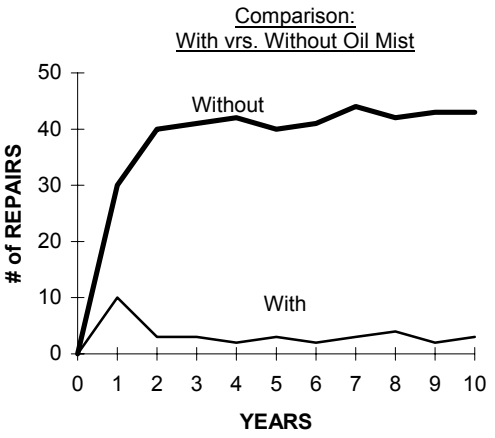
Each of these advances will be described in this paper.

BENEFITS AND DESCRIPTION OF AN OIL MIST LUBRICATION SYSTEM

An oil mist lubrication system is a centralized lubrication system that continuously produces, conveys and delivers mist lubrication to bearings and metal surfaces. Oil mist lubrication has been shown to significantly reduce the number of lubrication related bearing failures when compared to oil splash and grease lubrication. The successful application of oil mist has been documented in technical papers, trade journal articles, maintenance magazines and bearing maintenance catalogues. Specific examples follow:

"In one large petrochemical plant, bearing failures in two similar units with a

population of about 200 pumps each were compared. One had mist, the other had conventional [oil splash] lubrication. The unit on oil mist had about 85 percent fewer bearing failures."[4] (Paper by C. A. Towne, consultant formerly with Shell Oil Company USA)



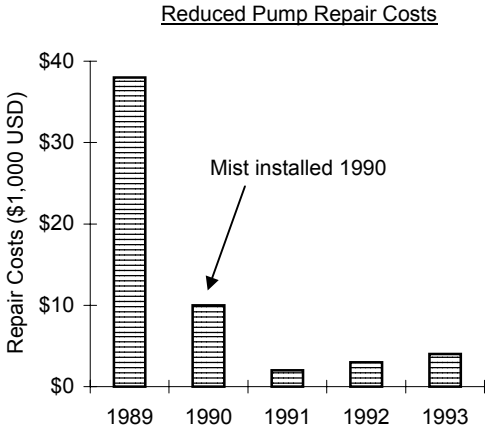
"In this research work the tribological performance of oil mist lubrication (pure mist) as applied to rolling element bearings, was investigated." ". . . oil mist lubricated bearings run cooler by about 10°C compared to oil sump lubricated bearings. The oil mist lubricated bearings also run with about 25% less friction than oil sump lubricated bearings."[5] (Research paper by Texas A & M University)

"This method of lubrication [oil mist] has proven very effective in reducing the [bearing] operating temperature . . . Since the air under pressure in the housing escapes through the housing enclosures or vents, the entrance of moisture and grit is retarded. In addition, oil mist lubrication continuously supplies only clean, fresh oil to the bearings. The two factors combine toward full life expectancy. Because the bearings require very little lubricant, the oil consumption is comparatively small."[6] (SKF Bearing Installation and Maintenance Guide, February 1992)

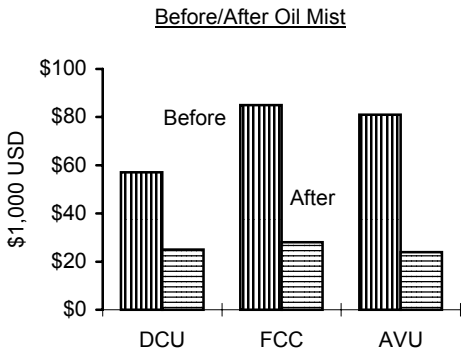
"In fact, sufficient experience has accrued to single out dry sump oil mist methods as best suited for plant-wide petrochemical complexes."[7] (Paper by H. P. Bloch, Machinery Reliability Consultant formerly with Exxon)

In addition to technical and failure statistics, plant owners also turn to cost reduction and return on investment to justify use of oil mist systems. One of the largest cost savings attributed to the use of oil mist lubrication is reduced equipment repair and lower maintenance costs. On an anonymous basis, two users have shared this information.

The following graph shows what happened to pump repair costs attributable to bearing failures after oil mist was installed on a US refinery crude unit in early 1990. After the mist system was fully commissioned and brought on-line, these repair costs dropped by over 90%.



The next chart shows annual pump bearing repair costs for three process units in a US refinery. The data represents the average annual repair costs for the two-year periods immediately before and after oil mist was installed on these units. An overall 65% reduction in costs was measured.



There are other factors which add to the justification for use of oil mist. Some are:

- Reduced lubricant consumption.
- Greater manpower flexibility.
- Reduced spare parts inventory.
- Low mist system maintenance requirements.
- Higher equipment availability.

Oil mist systems are extremely reliable and have fifteen to twenty year useful life without major overhaul. Oil mist systems can be installed with new projects or retrofit to existing facilities. When savings are compared to total installation costs the payback period normally calculates to be between one and two years.[8] Given the twenty year life of the systems, the discounted rate of return (DCF) on the investment in oil mist is typically 50% to 100% meaning it represents a very attractive investment project.

CONVENTIONAL OIL MIST SYSTEM

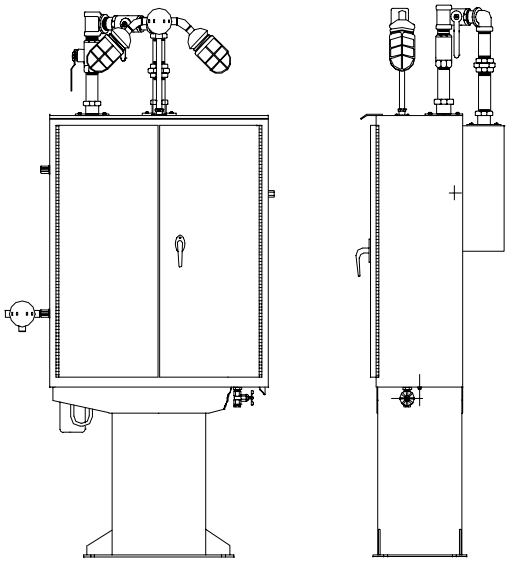
The key components of a conventional, "one-way" oil mist system are:

- Central *oil mist generator* and *oil supply tank*.
- *Distribution piping* to convey the mist.
- Piping *drops* at the equipment receiving the oil mist.
- *Mist manifolds* to divide and direct the mist.
- *Stainless steel tubing* to direct mist to each application point.
- *Reclassifiers* to measure and apply the mist.
- *Drain lines* to an oily water sewer or some type of collection container.

Each of these types of components remain but significant design improvements to each have made today's systems more effective, efficient, reliable and environmentally friendly.

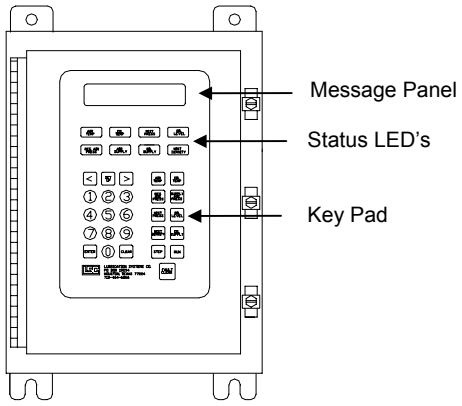
NEW CENTRAL MIST GENERATOR DESIGN

The heart of the system is the generator which utilizes the energy of compressed air, typically from the instrument air system, to atomize oil into micron-size particles. For modern, large-scale systems the mist generator is fully monitored and micro-processor controlled.



Front and side view of large-scale, oil mist generator with back-up unit

Solid-state pressure and temperature transducers and level sensing devices have replace the old-style electro-mechanical switches. Rather than gauges all monitored variables are displayed on demand by an alpha numeric panel which not only shows typical gauge values but also provides messages describing the operating condition.



Control Panel

The control panel is password protected meaning only those operators trained and authorized have the capability to set and adjust operating and alarm conditions. Therefore, the possibility for making well intended but incorrect adjustments is minimized.

This state-of-the-art central mist generator has the following properties:

- Meets Class 1, Division 2, Groups B/C/D, standards.
- Continuously monitors eight (8) operating variables including mist density.
- Factory plus user set control ranges allow for establishing sequential and system specific alarm limits.
- Alarm save and recall function allows for efficient and effective troubleshooting.
- Independently set and monitored mist and regulated air pressure control ranges to safeguard against improper trouble-shooting and alarm elimination.
- Independent 4 to 20 milli-amp current signal which allow for external monitoring of each operating variable.
- Large capacity, nine (9) gallon, internal reservoir constructed of stainless steel or painted carbon steel.

Controls and Alarms

In addition to improved reliability, the microprocessor control of the new mist generator units provides for customizing operating set points and alarm limits to exact user requirements. High temperature cutout controls are factory set. The user sets operating conditions and alarm limits for all monitored variables meaning the system can be optimized for that particular application. For example, clients can tailor the unit to mist very heavy viscosity lubricants.

Fault conditions are enunciated locally in three (3) ways:

1. External status lights switch from green to red.
2. Individual panel indicators located on the control pad change from green to red.
3. Alpha/numeric message appears on the display panel.

In addition to the local enunciation, remote alarm contacts are available for communication to control centers:

1. Common remote alarm contact (dry FORM-C).
2. Individual 4-20 mA current conditioning circuits for each of the eight (8) operating functions.
3. RS-232 communication port.

Trouble shooting Assistance and Alarm Interlock

Another superior design feature of new central mist generators is the trouble shooting capability. They identify and distinguish the first alarm condition from all secondary alarms. The first alarm continues to be identified and enunciated on the alpha numeric panel even when secondary alarms occur. This is extremely helpful when trouble shooting and searching for the root cause of a problem.

Alarms are also interlocked. For example, the low mist pressure alarm is linked, using control logic, with the air heater. If mist pressure falls to the low alarm setting, this being the first fault, the air heater control is then disabled and the air heater is de-energized. This results in a secondary fault, low air temperature, but because of the capture of the first fault the operator inspecting the unit will know how to best search for the root cause of the failure.

The interlocking control logic also insures that an alarm condition cannot be avoided or ignored by improper adjustment of another related variable. For example, if header pressure increases because of plugging reclassifiers, a condition that can occur if parafinic based lube oil is used in colder climates, on old style mist generators the high mist pressure alarm can be corrected by simply lowering the supply air pressure. The alarm is eliminated but the problem, plugged reclassifiers, remains. This false correction is not possible with the newer oil mist generators. Manually lowering the regulated air supply pressure will send this channel into fault condition and thus trigger another alarm. The operator or maintenance person must find the root cause of the problem and not simply be satisfied by changing the red status light to green.

Internal Reservoir Design

The internal reservoir of the new oil mist generators are compartmentalized and equipped with baffles. This design allows for efficient heating of the oil and elimination for the

possibility of coking. The design also allows for settling of any contaminants that may be present in the lube oil. These reservoirs have a bottom that slopes to a low point where a bulls-eye allows for inspection of the oil. There is also a low point, valved drain port to draw off contaminants. The internal reservoir of the new oil mist generators are much more than a simple rectangular shaped container as used on older units.

Because of the advances incorporated into the mist generator described herein, the unit was issued on June 30, 1992 US Patent 5,125,480.[9]

DISTRIBUTION HEADER SYSTEM DESIGN

Sloping and Distances

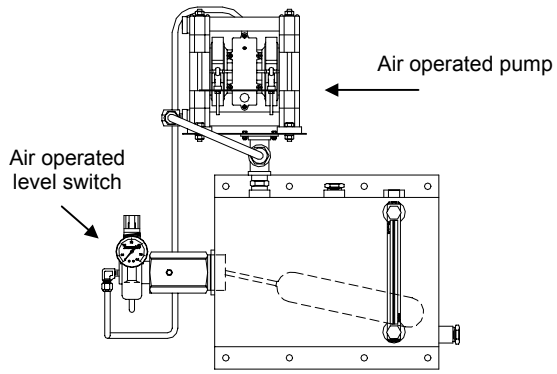
The oil mist produced in the central oil mist generator is transported throughout the process unit through header pipe. Typically this is 2 inch schedule 40 galvanized, threaded and coupled. In the hydrocarbon processing industry the header pipe is normally installed in overhead pipe racks. The header pipe must be installed without traps or sags as pressure in the header is only .050 bar (20 inches water column).

The latest design specifications state that the oil mist can be transported using standard installation practices up to 180 meters (600 feet) horizontally from the central generator. Older design standards limited this run length to 60 meters (200 feet).

Today's designs call for the header to be sloped back to the central generator; none of the header should be sloped away from the generator.[10] This design promotes oil usage efficiency as the oil mist that coalesces in the header is returned to the mist generator for reuse. Older technology allowed slopping header away from the mist generator towards drain legs[11].

Automated Drain Legs

Where elevation changes do not allow for sloping back to the generator, drain legs are installed. The drain leg prevents accumulation of oil in the main header because such accumulation of oil would block the flow of mist downstream of the trap. In drain legs utilizing the prior art, the collected coalesced oil flowed either to a sewer or a container which needed to be manually emptied, while the drain leg continuously vented oil mist to atmosphere. Today's distribution systems utilize automated drain leg assemblies which do not require manual operation and can be fully integrated into closed-loop systems.



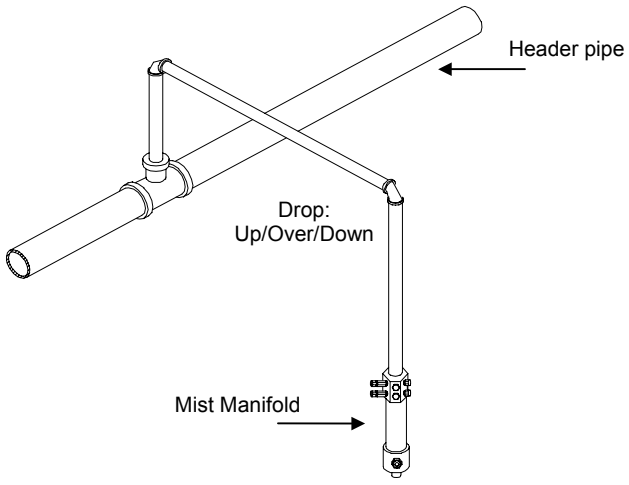
Drain Leg Reservoir Assembly

These assemblies are equipped with an air activated level switch and pump. They collect the coalesced oil and automatically pump that oil overhead to a point in the distribution header that does slope back to the central generator.[12]

These automated drain leg assemblies can also be retrofit to older, once through mist systems thus enhancing oil recovery and minimizing oil flow to sewers.

MIST MANIFOLD

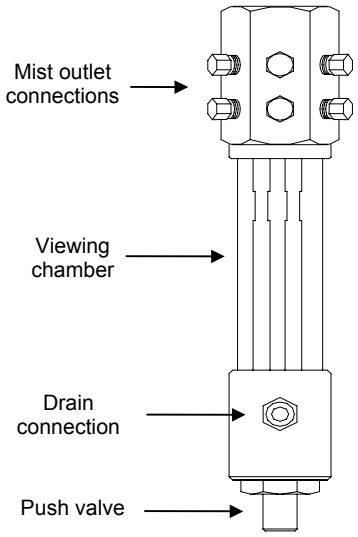
Above the equipment that is to receive oil mist, a "drop" is installed. Drop piping is normally 3/4 inch galvanized. The drop rises from the top of the 2 inch header so that liquid oil and any particulate contamination are not carried to the lubricated equipment .



Header and Drop Piping

The drop terminates in a manifold assembly which divides the mist flow to the individual lube points that receive oil mist. Often the reclassifier or application fitting, an orifice metering device, is mounted in the manifold block. From the manifold block, stainless steel tubing is used to direct the mist to the application point.

In older mist systems the manifold was typically a rectangular metal block with ports drilled for mist flow. Most of these blocks were equipped with a snap acting valve for draining of the collected coalesced oil but the level of the collected oil was not visible. New mist manifolds contain a high temperature glass viewing chamber which allows for visual monitoring of the level of collected, coalesced oil.[13]



Mist Manifold Assembly

Operators can see when oil needs to be drained. Draining is accomplished through an internally ported push valve that is channeled to a vent port on the side of the manifold. This port is tubed via a return manifold and into a collection container. When the manifold is drained, the flow of mist can be seen in the viewing chamber. Thus, mist flow is inspected without venting to atmosphere.

CLOSED-LOOP OIL MIST SYSTEMS

The performance and reliability of a properly designed, installed and maintained once-through oil mist system should not be subject to debate. They have proven their worth and delivered the intended benefits. Their only shortcoming has been related to housekeeping and venting of excess mist in a world highly focused on and energized about environmental matters. On June 7, 1994 closed-loop oil mist system design and technology received US Patent 5,318,152.[14]

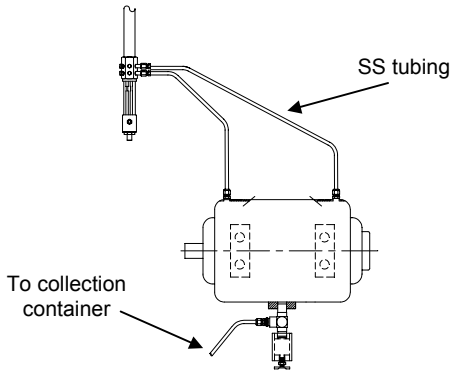
Return Header System

Parallel to the mist distribution header a return header pipe/system is installed. Sloping direction is the same as for the supply header but the return header drains into an oil supply tank/demisting vessel. The return header is constructed of 2 inch galvanized schedule 40 pipe threaded and coupled; the same as the main header.

The pressure in the return header is at atmospheric pressure. It is not under vacuum. The design of the demisting vessel insures that only the flow of air from the central mist generator supplies the motive force allowing excess oil mist to flow through the return header. Liquid oil travels, by gravity, back to the demisting vessel.

Pure Mist Application per API-610

Placement of reclassifiers can remain in the manifold when closed-loop technology is adapted to existing systems and equipment. Pumps purchased to API-610 Standards, August 1995, Eighth Edition, Section 2.9.2.7, will have bearing housings equipped with ¼ inch NPS connections on the housing end covers.



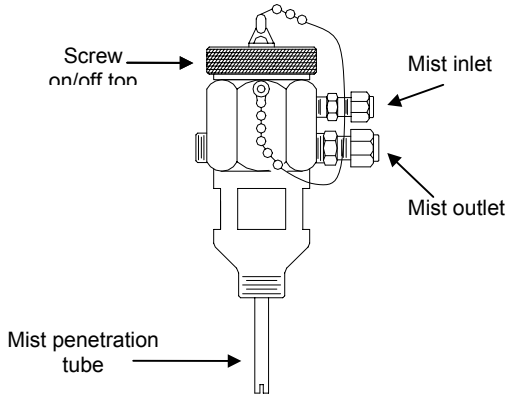
Mist Application Per API-610, Section 2.9.2.7

This design is compatible with closed-loop design as mist is directed through the bearing

and the tendency for mist to flow out through the seals is minimized. The flow of mist is continuous and vents through the bottom drain port of the bearing housing as does coalesced oil.

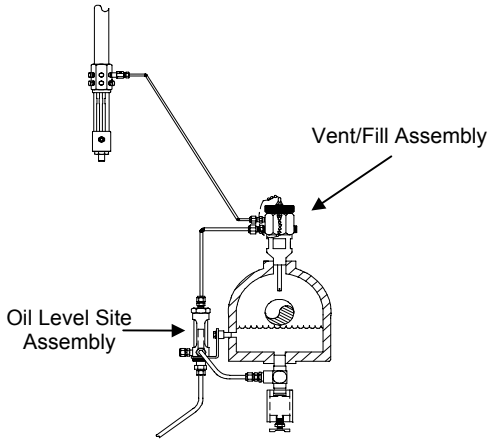
Purge Mist Application

To eliminate mist system venting with purge mist/wet sump applications, a unique purge mist vent/fill assembly has been developed. It is easily affixed to bearing housings. It eliminates uncontrolled venting, oil accumulation on and around the equipment receiving purge oil mist and problems associated with re-filling reservoirs with oil.[15]



Purge Mist Vent/Fill Assembly

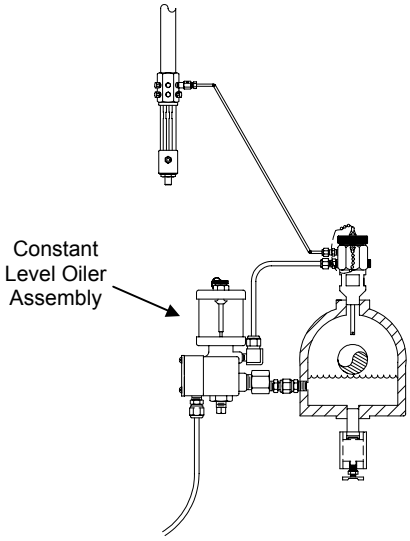
The device provides clog-free mist flow into and from the cavity receiving purge mist. It incorporates a screw on/off cap with internal porting into the mist penetration tube. This porting is designed so that when the cap is removed mist is not flowing into the housing and creating back pressure which causes problems when adding oil. The 38 mm (1 1/2 inch) wide funnel mouth makes for easy, spill-free addition of oil.



Purge Mist Application

The internal porting allows for the controlled venting of escaping purge mist through tubing into the companion oil level sight and constant level oiler assemblies. The oil level sight assemble protects against overfilling from both coalesced oil mist and liquid oil addition and it provides for visual inspection of the oil level in the bearing housing.

The constant level oiler assembly also protects against overfilling and will add oil if oil is lost, for example, through seals.**[16]**

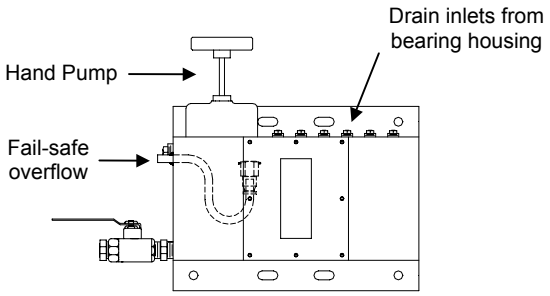


Purge Mist with Constant Level
Oiler Assembly

With these newer devices excess oil mist and overflow oil is directed to the collection container. Thus, even with purge mist, venting at the equipment and oil drainage to base plates and foundations is eliminated with today's technology.

Oil Collection Container

This recently commercialized container is mounted to the equipment foundation.



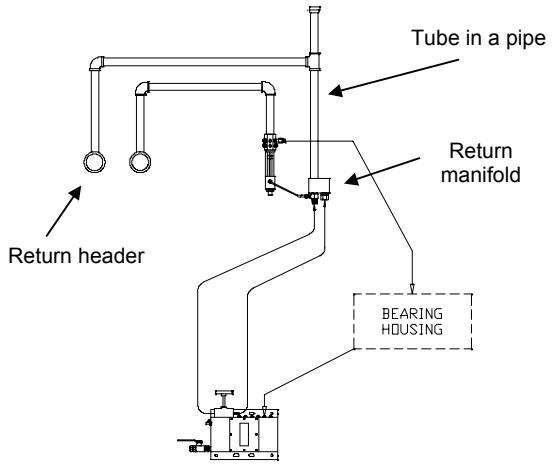
Collection Container

Oil mist plus coalesced oil flow into the container. The internal overflow tube with liquid seal prevents the container from filling with oil if it is not emptied. If the container overfilled, oil would rise into the bearing housing and block the flow of mist. The excess mist from the bearing housing that does not coalesce in the container travels through the container and tubing to the overhead return header. The container is also equipped with a manually operated pump that pushes collected liquid oil through piping into the overhead return header.[17]

The 3.8 liter (1 gallon) capacity of the container means it needs to be emptied only once per month. Because the frequency for evacuating the container is infrequent, incorporating automated, air operated level controlled pumps has not been considered cost effective. In fact, the monthly interval is significantly longer than that required for emptying the traditional sight bottle located under dry sump mist applications.

Return Drop

The oil collection container is connected via stainless steel tubing to the return manifold assembly. Internal porting with a check valve accommodates the continuous flow of mist to the return header and the intermittent pumping of liquid oil to the same return header.

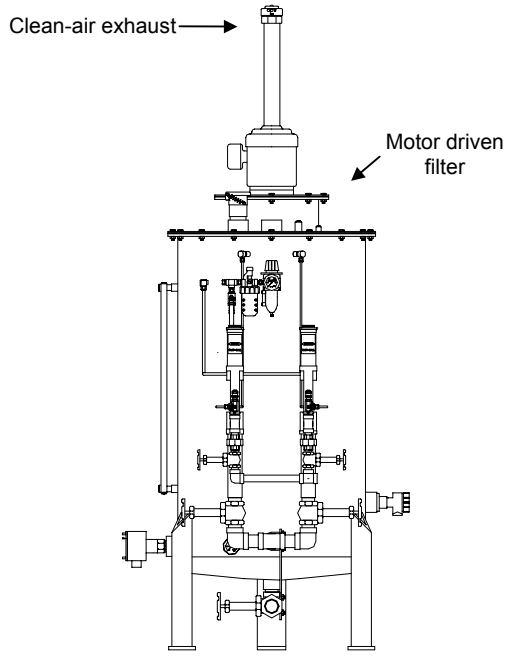


Supply and Return Drop;
Closed-Loop Oil Mist

The vertical return line is not simply a length of pipe but rather a tube within a pipe. This arrangement allows for efficient field installation and provides for a more compact, less cumbersome piping arrangement. This design also allows for the simultaneous pumping of oil and the continuous flow of mist without creating blockage of mist flow or unwanted system back pressure.[18]

Demisting Oil Supply Vessel

The 2 inch return header slopes back to and is connected into a central demisting oil supply vessel. The liquid oil drains back to this vessel. The oil mist that reaches the vessel, the very small mist particles that have traversed the entire supply piping network, gone through the bearing cavities and collection containers plus the return header system, must now be recaptured. This is accomplished by the electric motor driven, rotating filter located in the top of the demisting vessel.



Demisting & Oil Supply Vessel

The rotating internal element captures the returned mist and coalesces the small particles into large droplets that then fall into the oil below. Clean, essentially hydrocarbon-free air, vents from the raised exhaust pipe.[19]

The spinning filter has been designed so as not to "pull a vacuum" on the return header system. If it did one of the benefits of oil mist lubrication, maintaining positive pressure in bearing houses, would be negated. The filter will operate over a wide range of ambient conditions. It does not suffer the inherent problems of changing differential pressure across the filter media encountered with static filter elements. In fact, the filter media is by-passed if there is a failure of the electric motor meaning the unit will fail in the safe mode.

The demisting vessel also acts as the oil supply tank for the central oil mist generator. It is common practice to locate the generator and demisting vessel adjacent to one another. This makes for efficient connection to the common utilities; compressed air source and electrical supply. Also, the oil supply line is kept short. The oil from the demisting vessel is pumped, on demand, through a filter and into the mist console reservoir for reuse.

Since it is expected that over 95% of the oil is recycled, superior performing, higher cost synthetic lubricants can now be easily justified for use in mist systems. The oil in the demisting vessel should be analyzed periodically to assess its quality. The design of the demisting vessel allows for piping to an oil purifier for on-line reconditioning of the mist oil.

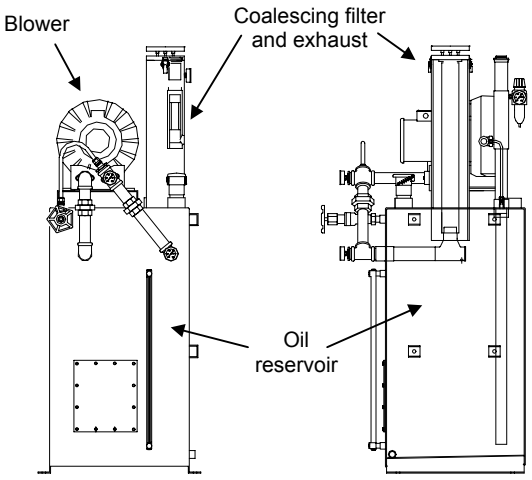
DEMISTING SYSTEM FOR THE TEXTILE INDUSTRY

The manufacture of man-made synthetic fiber from polymers such as nylon and PET involves the melting, extruding, cooling, orienting, winding and sometimes crimping and or chopping of the fibers. These processes involve high speed rotating equipment and hot, often humid, environments. There is also a strict requirement that bearing lubricants do not leak, drip or in any way come in contact with the fiber. The aggressive environment combined with the high speeds and need for reliability have lead fiber manufacturers to investigate oil mist lubrication.

The main hurdle that kept oil mist from penetrating this market was the potential for escaping stray mist while avoiding recycling systems that depended on negative pressure to promote the return of the oil mist. Negative pressure in bearing housings brings external contaminants such as water vapor into the system thus offsetting many of the benefits delivered by positive pressure mist systems. In response to the desire to use oil mist lubrication while meeting the operating requirements a unique oil mist demisting filter technology was developed and commercialized.

This unit utilizes an air blower to circulate returned oil mist through a coalescing filter. The design insures that the blower does not create a negative pressure in the return oil mist header. That header operates at atmospheric pressure. The volume of air that exhausts from the system is equal to the volume of air introduced by the mist generator.

Oil mist that has coalesced to liquid drains by gravity flow back to the reservoir of the demisting vessel. The oil mist that flows back to the unit is coalesced in the filter and the droplets created fall to the oil in the reservoir. The returned and captured oil is pumped on demand into the mist generator for reuse.



Demisting Vessel for Textile Industry

This re-circulation technology has proven to be extremely effective. The exhaust is clean and these systems are operating in closed-room environments. Systems are in place lubricating crimper bearings and bearings on heated spindle rollers. The inventor has applied for patents on this technology.[20]

NEW APPLICATIONS FOR OIL MIST

Rotary Lobe Blowers

This type of blower is often used in air systems for conveying solid materials in flake and pellet form. It is not uncommon to find these blowers in polymer plants producing such plastics such as polyethylene, polypropylene, PVC and polystyrene. The blowers are part of the pellet conveying systems moving product from one step in the manufacturing process to another and to final load out and packaging. In this service the blowers are subject to intermittent operation. It has been reported that users operate blowers at maximum speeds and temperature. A reliability study by a major end-user of this type blower reported, "Two of the biggest contributors to premature bearing failure are loss of lubrication and contaminated lubricant."[21] One of the steps taken to improve the reliability of their blowers was to convert from splash lubrication to oil mist.

Both purge and pure mist application is used; purge on the gear end of the machine, pure on the drive end. Closed-loop oil mist systems are being utilized to insure that no stray mist escapes so that product contamination is avoided. The client now states, "It is recommended that oil mist be the first choice for bearing lubrication because it provides the bearings with a continuous supply of cool, clean oil even with the equipment in stand by mode."[22]

Today at one major polyethylene plant in the United States, 56 rotary lobe blowers are being lubricated with oil mist. Failure rates have been reduced by over 95%.

Defibrator Displacement Press

This press is a device used in the Pulp and Paper industry. The equipment removes water from pulp by mechanical means. The operation requires large amounts of applied energy to separate the water from the fibers.[23] The unit contains an auger to feed pulp between rotating press roles. Under heat and pressure the pulp is squeezed and the de-watered pulp is ready for the next stage of the process.

The rolls are supported by large bearings which turn at relatively low RPM. The process exerts much force to the bearings and this along with the high temperature and aggressive environment make the achievement of extended bearing life a challenge. Typical lubrication has included special greases to withstand the temperature and humidity. Also, oil bath and circulating oil are used. Recently a progressive pulp mill in Canada converted their oil lubricated bearings to oil mist and has found remarkable success.

The oil used in the application is a heavy grade ISO VG 460. The mist generator is equipped with both air and oil heater to facilitate the production of oil mist. Also, because of the criticality of the application the systems uses a mist monitor to insure mist density stays within design limits.

On each of the large bearings five (5) spray reclassifiers provide the mist lubrication. A bottom drain in the bearing housing is used to channel the mist away from the equipment thus insuring a clean application. One of the first observable effects after the conversion to oil mist lubrication was a 20% reduction in bearing operating temperature. The application of mist to these bearings has resulted in extended bearing life while proving to be extremely reliable and trouble free.

FUTURE EQUIPMENT DEVELOPEMENTS

Portable Mist Density Monitor

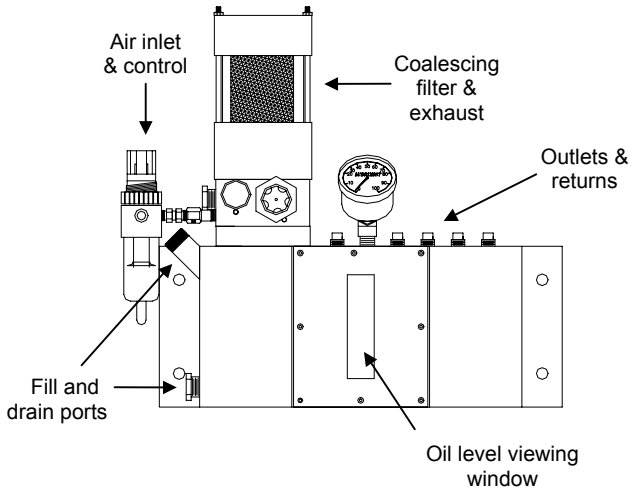
There is a desire by many users of oil mist systems to have the capability to test for the quality of the oil mist at various points throughout the mist system. They are confident that the fully monitored central oil mist generator is operating properly. However, having the ability to cost effectively and quantifiably measure mist quality downstream of the generator would add to system effectiveness and reliability.

A prototype model of a portable mist density measuring device is currently under evaluation by Lubrication Systems Company. The unit is designed to utilize the push button drain valve of the mist manifold described above as a sample point. The sample of oil mist is captured in a test chamber and the relative density of that mist is then measured on a 0 to 100% scale. Future optimization plans for the unit include computerization for storage and downloading of the sample information for trend analysis and statistical evaluation. Commercialization is anticipated in the first half of 1997.

Miniaturized, Closed-Loop Lubricator

Market place feedback indicates there is a need for a reliable, small lubricator which is environmentally clean (no emissions) and delivers improved machinery reliability. Such a machine will soon be introduced. It is based on proprietary, circulating, closed-loop mist technology.

Operating cost of the unit is low and reliability is high because the lubrication and re-circulation is achieved with the use of compressed air. No other utilities are required. The unit is safe and can be used in hazardous areas. The unit is designed for the lubrication of from one to five lubrication points. It is equipped with an air pressure regulator and filter separator. A mist pressure gauge monitors pressure in the lubrication delivery piping and tubing. An oil level viewing window allows operations to conveniently see the oil level in the reservoir. Depending on loses from the bearing housings receiving lubricant, the unit is capable of re-circulating over 95% of the oil lubrication.



Miniaturized Lubricator

This miniaturized lubricator will be introduced by Lubrication Systems Company to the market in the first quarter of 1997.

SUMMARY AND CONCLUSIONS

Centralized oil-mist systems continue, for many in process industries, to be their technically preferred approach for lubricating rotating equipment. Oil mist technology has kept pace with other developments in these industries especially in the area of microprocessor controls and process monitoring. In addition, system design specifications have expanded allowing oil mist systems to reach further and today's distribution systems are more efficient because they allow coalesced oil to return to the central mist generator for reuse.

Components such as mist manifolds have been redesigned and improved and new devices such as vent/fill assemblies and automated drain legs have been developed making today's systems more efficient and cleaner than defined and delivered by prior technology and installation practices. The invention and commercialization of closed-loop, circulating oil mist systems and related demisting equipment have positioned oil mist for greater use by process industries in an environmentally conscious world. Oil mist now meets the requirements for clean, emission-free operation while still delivering the improved reliability results expected of oil mist.

Future advances in the areas of portable mist density measurement equipment and the introduction of miniaturized, closed-loop lubricators indicate that oil mist technology will continue to adapt to the needs of industry.

FOOTNOTES

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