Spreading the Word on Oil Mist Lubrication

An Italian oil refinery learns new advantages of an important lubrication method

Part 1 of 2

By Cristian Schmid, Grupo Sicelub Europe, and Davide Nevoso, Milazzo Refinery

Figure 1: Pure oil mist in centrifugal pump. Note the collecting bottle at bottom of pump bearing housing.

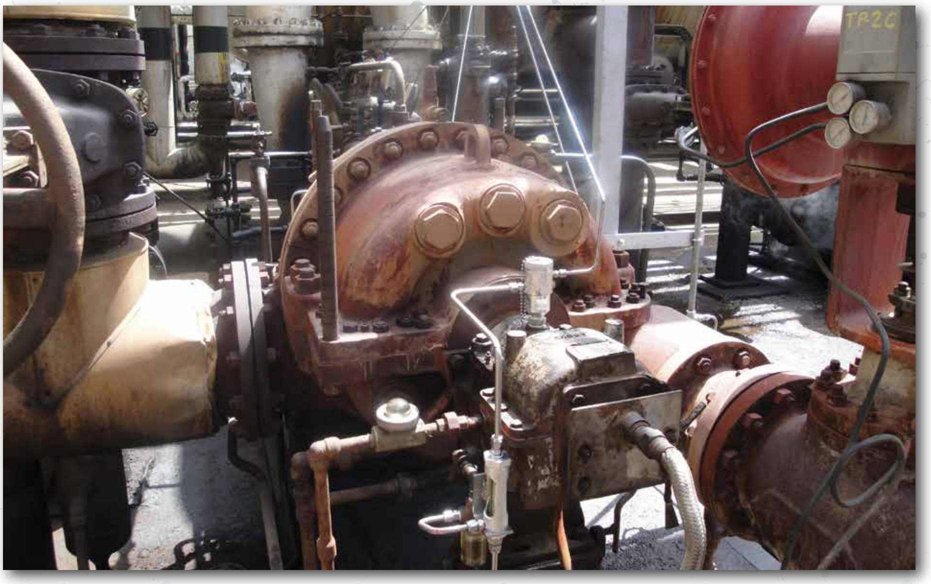


Figure 2: Purge mist applied on steam turbine bearing housing

Since its introduction as a plant-wide lubrication method in the United States, oil mist lubrication has been extended to over 100,000 process pumps and electric motor drivers. Many articles, books, and conference papers describe application details and the overwhelmingly favorable experience with oil mist (see Bibliography). The overall advantages of oil mist in bearing failure avoidance and maintenance cost reduction are well documented. Oil mist is particularly well known in the hydrocarbon processing industry (HPI) where the American Petroleum Institute (API) and International Standards Organization (ISO) took the lead in recognizing the importance of oil mist. Both API 610 and ISO 13709 Standards for pump design indicate how centrifugal pumps must be designed and manufactured for optimized lubrication by oil mist, should potential users specify or require this type of lubrication.

There are other API recommended practices, such as RP 686 and RP751, which establish the benefits obtained from oil mist technology. These recommended practices (RPs) include equipment maintenance procedures and improvements in mechanical seal reliability. While most applications are focused on process-centrifugal pumps and their drivers, oil mist is also used on small steam turbines, cooling tower gears, forced draft blowers and virtually any machine incorporating rolling element bearings. Most of this equipment operates in North and South America, the Middle East, Australia, and the Pacific Rim countries.

Until recently, however, plant-wide oil mist had not been used in Italy. This prompted an end-user and a major supplier of oil mist technology to discuss their findings. Our collaboration resulted in previously unpublished measurements and investigations conducted jointly by both parties. The article documents the first successful application of oil mist lubrication in an Italian Refinery, where the MTBF (Mean Time Between Failures) of rotating equipment has improved 25 percent during the first thirteen months of system operation.

Using ISO 281/2000 methodology, the co-authors calculated and proved

About The Author

Cristian Schmid is a professional engineer with over thirteen years of experience in lubrication engineering in the oil and gas industry. He joined Grupo Sicelub Lubritech in 2000 and has been working in different technical and commercial areas in Argentina, México, and Spain. Davide Nevoso holds a degree in mechanical engineering and has worked as a maintenance engineer at Milazzo Refinery. He is a specialist in rotating machinery, lubrication, and mechanical seals.

Figure 3: *Oil mist lubrication demonstration with a small portable oil mist generator . The centrifugal pump is driven by a steam turbine. Free steam explains oil contamination risks.*

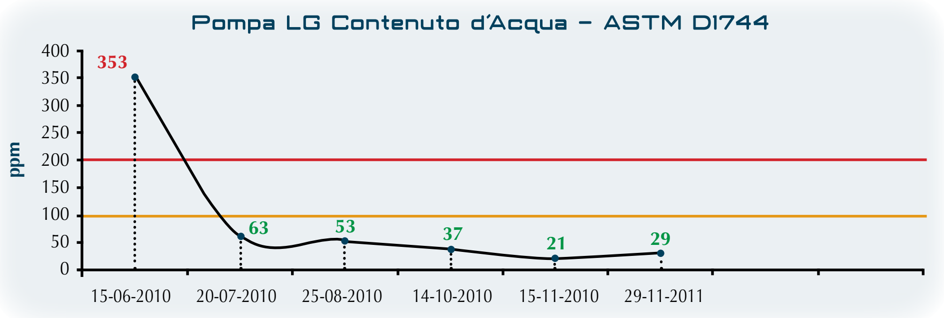


Figure 4: *Water present in oil. Centrifugal pump before/after pure ("dry sump") oil mist lubrication (with pure oil mist, the analysis was done on coalesced oil collected near the bearing housing drain).*

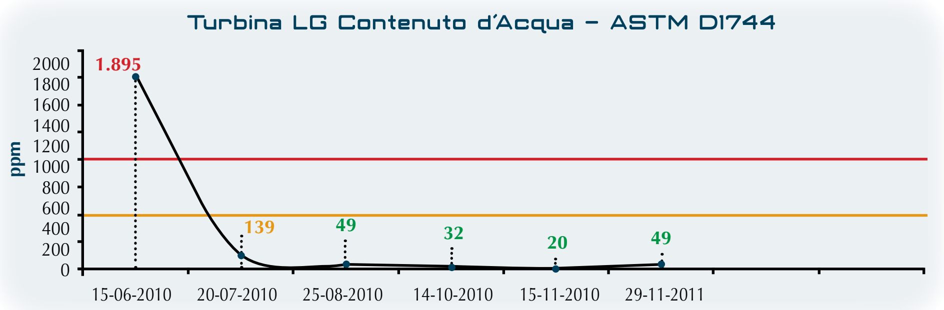


Figure 5: *Water present in conventional oil sump. Steam Turbine before/after applying oil mist purge. Purge oil mist is often called "wet sump."*

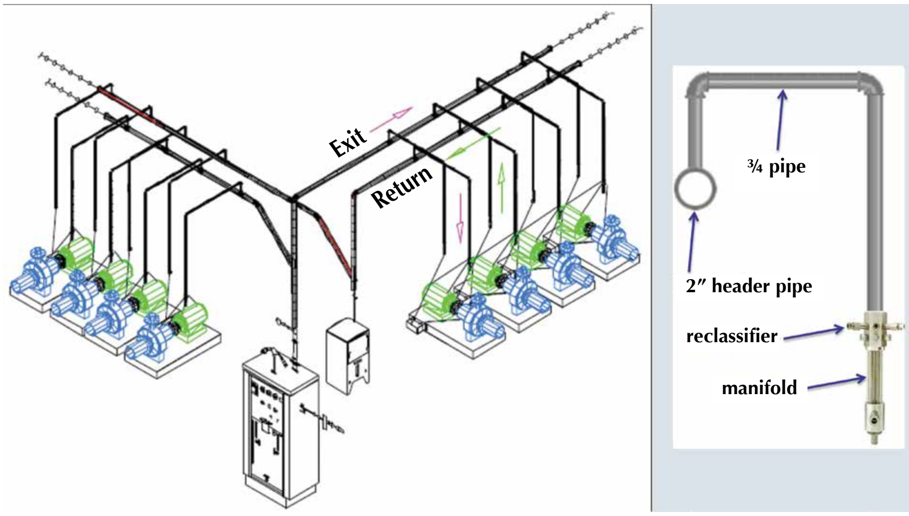


Figure 6: *Oil mist system layout. Sloped return headers lead back to the oil recovery units. Coalesced oil mist is collected in small containers at the edges of pump baseplates and manually pumped to the nearest return header*

bearing life extentions. These ISO-based bearing life calculations relate the cleanliness level of the lubricant to the bearing life (L10). In addition to the increase in reliability which was thus determined, the co-authors point out enhanced operating safety and energy savings achieved by upgrading the lubrication at this oil refinery.

BACKGROUND

The Raffineria di Milazzo is a joint venture between ENI and Q8; the refinery processes 240 killobarrels per day (kb/d) of crude oil. Located in Sicily's northwest, it has been designed to accommodate a wide slate of crudes. In recent years, the maintenance department had looked into technology improvements to increase equipment reliability. Rotating equipment reliability is related to optimized lube application and oil cleanliness—two key attributes of oil mist.

However, because this technology is virtually unknown in Italy, Raffineria di Milazzo decided to first study oil mist on critical equipment using a small portable oil mist generator (POMG). A centrifugal pump driven by a steam turbine in the refinery's No. 3 Topping Unit was selected as the initial pump set for a number of interesting reasons:

- The MTBF of rotating equipment in this unit was one of the lowest in the refinery.
- It was possible to simultaneously observe pure mist ("dry sump") as a means of bearing lubrication in the centrifugal pump (figure 1.), and purge mist ("wet sump") as a means of excluding air from the steam turbine's bearing housing (figure 2). The same oil mist unit (POMG) would be used for pump and driver (figure 3).
- Earlier observations and oil analyses had shown the presence of substancial quantities of particles and water in the lubricant. Many distress events and reduced equipment reliability had been traced to lubricant contamination.

STARTING THE TEST

The oil mist lubrication testing phase was initiated in June 2010. The portable oil mist generator (POMG) shown in figure 1 was commissioned at that time.

The tests showed very favorable results. Within a few weeks it was possible to measure and observe a significant reduction in oil contamination caused by water and solid particles (figures 4 and 5). Demonstrably improved reliability and equipment life could be expected.

No bearing failures were experienced during 6 months of intense observation. After operating the demonstration POMG and carrying out exhaustive follow-up on all variables involved, it was decided to move to the next stage. An investment proposal to retrofit oil mist lubrication in the thirty-nine centrifugal pumps and four steam turbines of No. 3 Topping was presented to Refinery Management.

PROJECT EXECUTION DESCRIBED

A survey of the unit was made and shown as a closed oil mist system schematic (figure 6). The feasibility of installing all elements without interfering with normal operation of the unit was confirmed. An IVT oil mist generator (OMG) console (figure 7) and six residual oil mist recovery systems with 656 feet (200 meters) of piping were included in the proposal. Refinery project personnel and the potential vendor ascertained that adequate lubrication would reach every point.

Figure 7: *IVT oil mist lubrication console in No. 3 Topping Unit at Raffineria di Milazzo*

The unit-wide system was commissioned in late November 2011. During the first weeks of equipment operation a notable decrease in bearing operating temperatures was recorded (table 1). Two reasons were given: With conventional liquid oil lubrication, bearing rolling elements plough through the oil and frictional heat is generated. With pure oil mist there is no longer a liquid oil level. The continuous flow of oil mist lubricant at approximately 68 degrees Fahrenheit (20 degrees Celsius) contributes to efficiently dissipate whatever frictional heat still exists. Overall, less frictional heat means higher mechanical efficiency of the equipment—energy savings of typically 1 to 2 percent.

Table 1 represents a summary of temperature decreases recorded in the first month of operation. On average, a decrease of 19 percent was recorded on these seventeen process pumps.

Extensive data collection started from the time the unit-wide oil mist system was commissioned. Throughout the first year of operation every conceivable oil mist system operating variable was logged-in. The primary reliability indicators on pumps and drivers in No. 3 Topping were compiled. Accurate data would allow determining cost and savings and comparing these with anticipated or claimed payback for this investment. Data collection would also help define if extending this technology upgrade to other Refinery Units at Milazzo was justified.

AVAILABILITY AND RELIABILITY

It is worth noting that all operating variables of the unit-wide oil mist system have remained within the recommended range. These include moisture content (dew point) of the instrument air supply at the oil mist console, oil mist header pressure, oil-air mixing temperatures, mist density, etc. Also, the system has been continuously monitored from the DCS control room. Throughout its now thirteen months of operation the oil mist lubrication system at No. 3 Topping has proved to be 100 percent reliable.

When the technology study was initiated and even before its implementation at Raffineria di Milazzo, questions were raised regarding the use of an oil mist lubrication system without a full spare. Therefore, answers were sought in extensively reviewing prior experience with the now over 2500 large-scale systems in successful operation world-wide. The important findings were listed as follows:

- An oil mist system does not have any moving parts or components prone to wear.
- For flawless operation the system requires only clean instrument air and an oil supply.
- The system does not require electric power to operate. (Note: Electric power is used by instruments that monitor variables).
- Each console at Milazzo contains two mist generators, one a main and the second an auxiliary. Switching over from the main to the auxiliary--if it should ever be needed—would be very easy and could be done in 30 seconds.
- All critical system variables are monitored in real time in both the console and in the DCS control room.
- There are more than 2,500 oil mist lubrication systems operating around the world. Considerable data have been compiled on the effective reliability and availability of these systems. Most modern systems have been in operation for decades with zero downtime.
- Electric motor drivers can easily be added to the oil mist lube system in the future

ITEM	LATO GIUNTO				LATO OPPOSTO GIUNTO			
	OLIO	NEBBIA	ΔT	Δ%	OLIO	NEBBIA	ΔT	Δ%
P16	60,70	36,41	-24,29	-40%	63,43	41,49	-21,94	-35%
P18 B	57,13	41,20	-15,93	-28%	53,77	46,00	-7,77	-14%
P18 A	42,30	37,60	-4,70	-11%	38,00	37,49	-0,51	-1%
P15 B	40,30	29,47	-10,83	-27%	49,05	38,67	-10,38	-21%
P14B	50,12	33,04	-17,08	-34%	47,48	34,81	-12,67	-27%
P13 A	51,40	42,29	-9,11	-18%	45,84	34,45	-11,38	-25%
P5 B	40,87	31,43	-9,43	-23%	51,53	46,05	-5,48	-11%
P5 A	43,97	33,34	-10,62	-24%	46,53	39,58	-6,95	-15%
P12 A	41,67	35,97	-5,69	-14%	38,83	33,13	-5,70	-15%
P32 A	53,07	34,54	-18,52	-35%	44,73	32,48	-12,26	-27%
P32 B	48,27	37,68	-10,59	-22%	48,47	31,15	-17,32	-36%
P6 A	43,00	34,38	-8,62	-20%	68,45	53,00	-15,45	-23%
P7	39,53	33,18	-6,36	-16%	54,60	44,07	-10,53	-19%
P2 B	62,10	55,43	-6,67	-11%	69,60	61,00	-8,60	-12%
P2 A	57,71	52,47	-5,24	-9%	71,32	59,44	-11,87	-17%
P1 B	49,85	43,76	-6,09	-12%	64,88	63,00	-11,88	-18%
P1 A	46,86	49,70	2,84	6%	59,76	61,10	1,34	2%

Table 1: *Oil temperatures*

- Oil mist is the "ultimate filter" because dirt resists being atomized in an oil-air mixing unit

In our second installment, we will examine the technical and economic justifications for converting to oil mist lubrication using mean time between failures. ■

Spreading the Word on Oil Mist Lubrication

Technical and Economic Justification Using MTBF

Part 2 of 2

By Cristian Schmid, Grupo Sicelub Europe, and Davide Nevoso, Milazzo Refinery

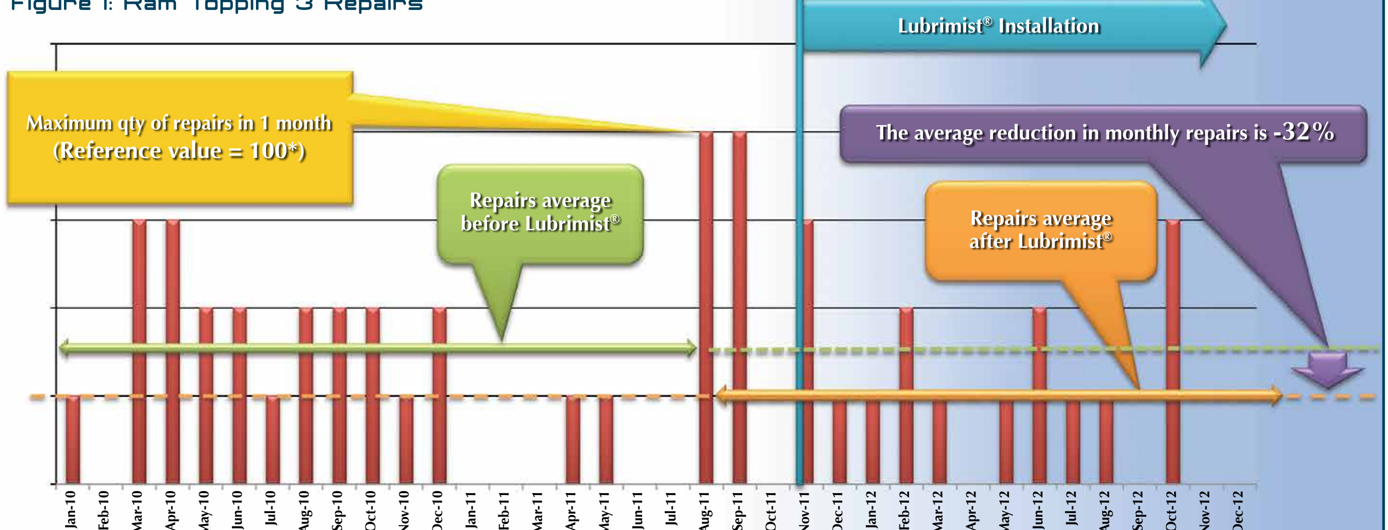
In the first installment of this article, we documented the first successful application of oil mist lubrication in an Italian refinery, the Raffineria di Milazzo, and reported the results of the refinery's test using a small portable oil mist generator (POMG). In part 2, we will show the how the MTBF (mean time between failures) of rotating equipment has improved 25 percent during the first thirteen months of system operation, as well as the technical and economic justification for converting to oil mist lubrication.

OIL MIST LUBRICATION'S EFFECT ON MTBF

An analysis was performed on Milazzo's No. 3 Topping Unit considering the following parameters:

- MTBF increases for pumps and turbines: An increase of 30 to 50 percent in the MTBF was considered, which consequently causes a reduction in maintenance costs of 40 to 50 percent.
- Reduction in oil consumption and cooling water through automation and reduced bearing operating temperatures: Oils with optimized viscosity have allowed deletion of cooling water from pumps with rolling element bearings since about 1970. At best-of-class refineries, cooling water is not being used on such process pumps--irrespective of lube application method and with pumping temperatures as high as 730 degrees Fahrenheit (394 degress Celsius).
- Reduced energy consumption attributable to lower friction coefficients.
- Automation of lubrication tasks: This is an increasingly important factor in countries with limited access to a trained work force.
- Additional unit uptime: Increased equipment reliability reduces outage frequency and duration; both could affect plant throughput.
- Safety: Once the MTBF increases, fire risks are reduced. Failure statistics show one fire event for every 1,000 pump outage events.

Figure 1: Ram Topping 3 Repairs

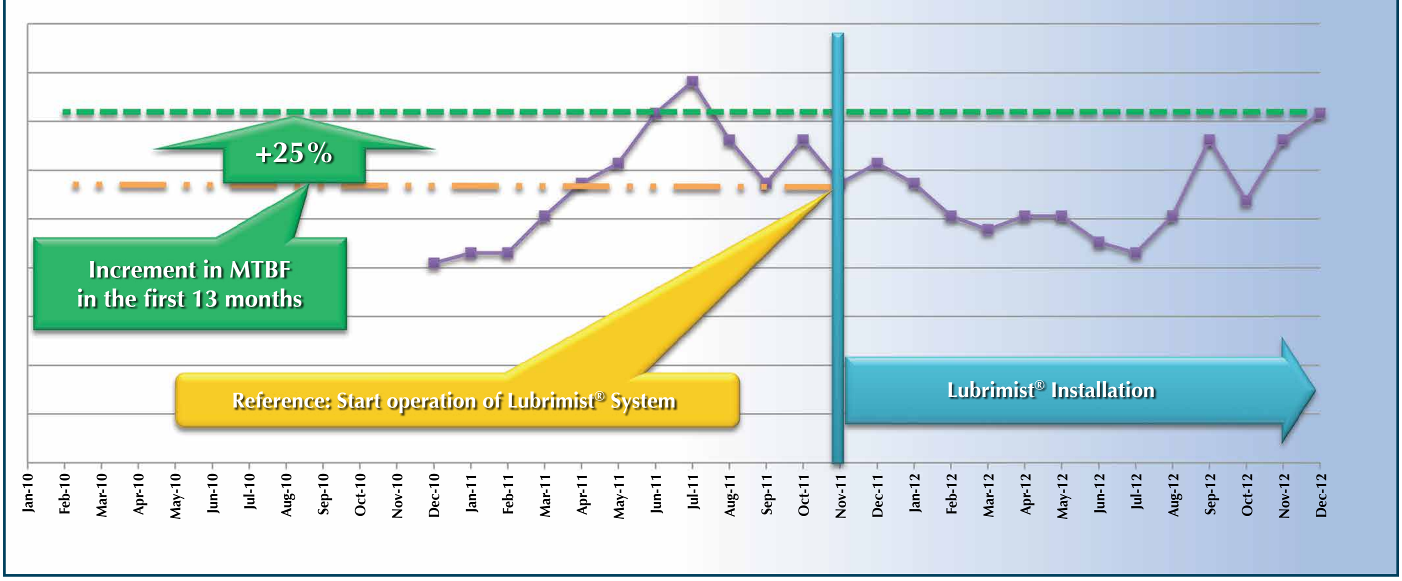


*This is not real value; only a reference.

About The Author

Cristian Schmid is a professional engineer with over thirteen years of experience in lubrication engineering in the oil and gas industry. He joined Grupo Sicelub Lubritech in 2000 and has been working in different technical and commercial areas in Argentina, México, and Spain. Davide Nevoso holds a degree in mechanical engineering and has worked as a maintenance engineer at Milazzo Refinery. He is a specialist in rotating machinery, lubrication, and mechanical seals.

Figure 2: Ram Topping 3 MTBF

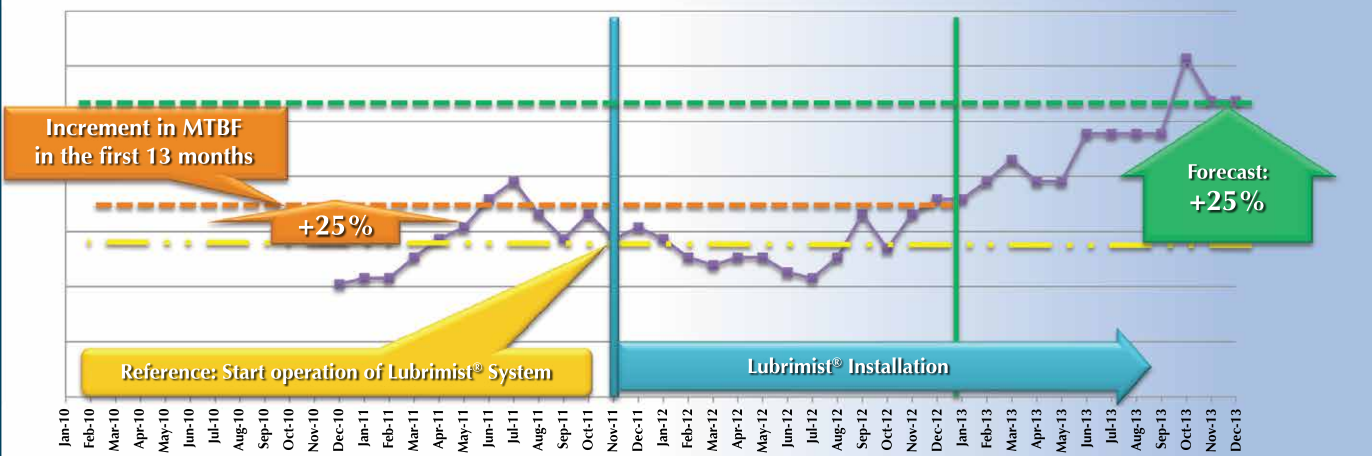


RESULTS AFTER INITIAL OPERATION

The composite influences of the above are generally reflected in MTBF, the mean-time-between failures. An increasing MTBF translates into sizeable economic savings. Therefore, MTBF data starting with January 2012 were examined; only failure incidents related to bearings, lubrication and mechanical seals were recorded (figure 1). The recorded failures represent a very high percentage of the total failure population and have generated the highest costs.

Figure 1 shows first an average of twenty-three months of conventional lubrication which is the compared with thirteen months of oil mist lubrication at No. 3 Topping. A 31 percent repair decrease can be observed after 13 months of oil mist lubrication. As is also seen on this illustration. As

Figure 3: Ram Topping 3 MTBF

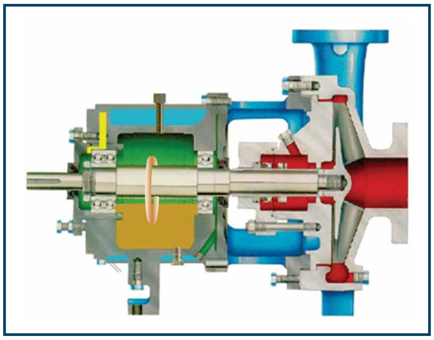


can be seen from this illustration, a number of failures occurred in the time frame from February to October 2012, which is after oil mist lubrication was implemented. Similar observations were made decades ago at Shell Oil refineries in the United States; all were traceable to the fact that failures-in-progress cannot be reversed by oil mist lubrication. However, once bearings with incipient defects are replaced, things change. Oil mist will prevent future failures of rolling element bearings operating within their as-designed load ranges.The progress chart, figure 2, indicates MTBF results for twenty-five months. It starts out with a twelve month period on conventional liquid oil lubrication and then transitions to thirteen months on oil mist.

After replacing defective parts in the November 2011 to August 2012 time frame, the MTBF starts to steadily increase and there is noteable improvement from July 2012 to the present.

A number of failures occured in August and September of 2011, but only one repair is registered for the same two months in 2012. Also, the MTBF last calculated in December 2012 compares quite favorably with that seen in November 2011. There is a meaningful increase of 25 percent.

Figure 4: Conventional Lubrication



By December 2013 Raffineria di Milazzo hopes to have achieved a 30 percent failure decline. The expected MTBF increase for 2013 is then plotted in figure 3.

TECHNICAL BASIS OF MTBF INCREASES

Oil mist is an atomized mixture of one part of oil (by volume) with 200,000 parts of clean, dry air. Plant-wide oil mist lubrication presents many important advantages over conventional lubrication. Oil mist will constantly lubricate, clean, cool, and protect all bearing housing-internal parts from corrosion, both in normal pump operation and in stand-by mode. Decades of experience can be summarized in table 1.

FOCUS ON BEARING LIFE EXTENSION

With oil mist being the "ultimate filter," the researchers paid attention to bearing life extension. The various considerations and examples follow:

Oil Level or Conventional Liquid Oil Lubrication

On moderate speed bearings the oil level could be set to reach the rolling elements, as shown in figure 4. On higher speed pumps, a slinger-ring is added; it

Table 1: Characteristics of Different Lubrication Methods

Lubricating Oil Function	Oil Level Lubrication	Oil Mist Lubrication	Observations
Lubricate	Baseline "Normal"	Excellent	Atomized mist can reach all contact points; provides superior cleanliness compared to conventional liquid oil lubrication.
Clean	Baseline "Normal"	Excellent	Oil mist provides positive internal pressure, preventing dirt or water vapors from getting into the housing. Wear debris tends to get flushed away from the bearing's internal regions.
Cooling	Baseline "Normal"	Excellent	Oil mist provides a reduced friction coefficient, generating less heat and at the same time a cooling effect. Mist enters the system at a temperature of approximately 20°C and prevents heat build-up as it passes through the housing.
Protection against internal corrosion	Baseline "Normal"	Excellent	Oil mist maintains a positive internal pressure in the bearing housing, even when the equipment is in stand-by mode. Contaminant intrusion and bearing component metal-to-metal contact are prevented.

would dip into the somewhat lowered level of oil and splash the oil into the bearings. With either "liquid oil" lubrication method there is a finite and relatively small oil volume. Dirt, water, and contaminants tend to accumulate and increase over time, until an oil change is made. When the pump is not operating, most of its internal parts are exposed to the vent or breather; the air volume floating over the oil expands and contracts with temperature changes. Accordingly, air alternates as inflow to or outflow from, the bearing housing. These movements are responsible for the presence of condensed water vapor and other contaminants in the liquid lubricant.

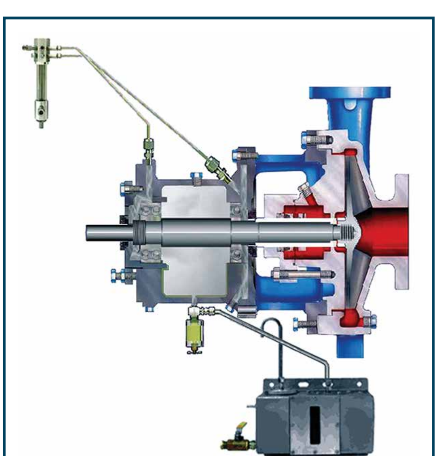
Oil Mist Lubrication

With oil mist applications, atomized oil at slightly higher than ambient pressure fills the bearing housing. Irrespective of whether the pumps are in operation or in stand-by mode, oil mist fills the bearing housings. A constant quantity of new, clean oil mist, free of dirt and water, enters and pressurizes the pump bearing housing. Wear debris is excceedingly rare in pure oil mist because there is no atmospheric vent and there are neither constant level lubricators (oiler bottles) nor abrasion-prone slinger rings. In the highly unlikely event of wear products being liberated from bearing surfaces, oil mist flow tends to flush these towards the waste collector (see bottom of bearing housing, figure 1 in part one of this article: "Spreading the Word on Oil Mist Lubrication: Part 1," Modern Pumping Today, April 2013: 40).

Both the small observation bottle and the larger rectangular collector tank serve to accumulate coalesced (erroneously called "recondensed") oil. Piping the on-off valve to the return header allows coalesced oil to be pumped back to the residual oil mist recovery system (small console) in figure 5.

No such flushing action takes place with static oil sumps. The result is shown in figure 6, which shows ISO contamination numbers and how progressive contamination of a static oil sump must be counteracted by periodic oil changes. In contrast, with pure oil mist lubrication, the level of contamination is expected to remain constant and no greater than that of new oil. Moreover and because in an

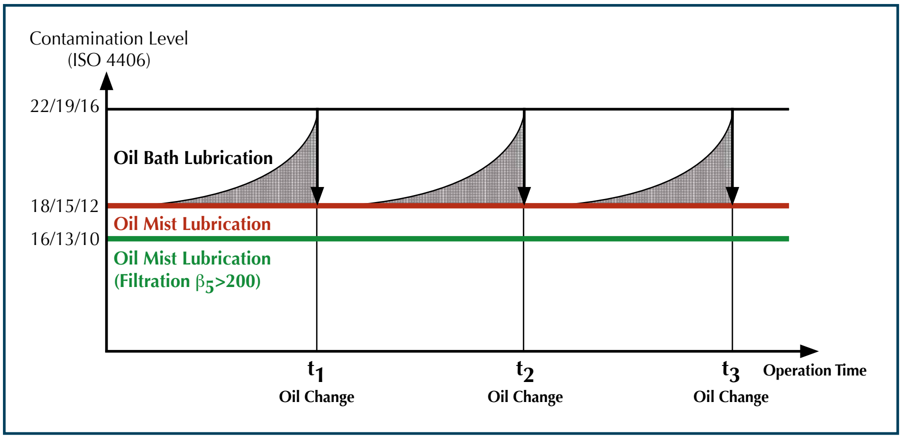
Figure 5: Process Pump with Pure Oil Mist Lubrication



oil mist console the oil is filtered with β_5>200 filters, an actual contamination level may be even better than that of the new oil; contamination may also remain consistently low over time.

To quantify the benefits of oil mist lubrication we considered the ISO 281/2000 Standard for bearing life calculation. The standard employs lubricant cleanness and contamination as important factors in bearing life assessments. Decades ago, bearing manufacturers also demonstrated that equally dimensioned bearings with identical loads will survive very different life cycles. At issue are the fundamental oil application method and oil properties that include contaminant content.

Figure 6: Common Lube Conditions for Different Types of Lubrication



Calculations harmonizing with the applicable code, ISO 281/2000, give very different L10 values with optimized lubrication methods and using lubricants with very low contamination.

LIFE CYCLE CALCULATIONS

The results of L10 life cycle calculations for 7312 BECBY bearings are tabulated in table 2. We considered the two prominent lube application methods and typical levels of contamination.

It can be clearly seen how the particle content of a lubricant affects calculations of theoretical L10 life of bearings. Putting these results into practice will make it possible to understand why 91 percent of all bearings fail prematurely and why low MTBF values are experienced by an inordinate number of Industrial Plants. These are plants that allow oil contamination.

Oil mist lubrication is proven as a a mature and excellent technology for improving MTBF/MTBR values in Industrial Plants. It will greatly streamline, reduce and facilitate the need for maintenance interventions of all kinds.

CONCLUSIONS

The Raffineria di Milazzo achieved "Technology Leader" status in Italy as regards oil mist lubrication. Other national refineries are now interested in implementing this type of technology. After the first thirteen months of operating on oil mist lubrication in the No. 3 Topping Unit, we proved the benefits by verifying earlier economic justifications. An MTBF increase of 25 percent is evidence of favorable change. Furthermore, as we compare the pump failure rate with conventional lubrication (2010–2011) versus oil mist lubricated pumps (January¬–December 2012) a decrease of 32 percent was demonstrated.

With time, the process unit's MTBF will improve and stabilize as already weak components are being replaced.

Table 2: Bearing Life for Two Different Lube Application Methods and Contamination Severities

Contamination Level	Bearing Life in Operating Hours
Oil Level Lubrication (Conventional Sump Lube) Average Level of Contamination ISO 20/17/14	29.000
Oil Mist Lubrication Average Level of Contamination ISO 18/15/12	193.100

The target for MTBF increases during 2013 has been set at 60 percent higher than existed at original project commissioning in November 2011. We are now poised to advocate investment in oil mist technology at other refinery units. Raffineria di Milezzo confirmed oil mist as an attractive investment opportunity. Oil mist technology represents a high potential for improvements in other European Refineries, as regards increased MTBF, progressive automation, increased safety, and less stress on the environment (reduced oil losses). ■

General Bibliography for Oil Mist Lubrication Technology

Cristian Schmid's areas of expertise are lubrication contracts, high speed oil flushing services, and oil mist lubrication, and Davide Nevoso's recent work has concentrated on improved rotating machinery lubrication and sealing technology. In addition to their two-part article concluding in this month's issue, authors Schmid and Nevos have provided *Modern Pumping Today* with the following reference list concentrated on oil mist lubrication technology.

1. Miannay, C.R., "Improve Bearing Life," ***Hydrocarbon Processing*** (May 1974).
2. Bloch, Heinz P., *Pump Wisdom*, John Wiley & Sons. Hoboken, NJ (2011).
3. Bloch, Heinz P., "Large Scale Application of Pure Oil Mist Lubrication in Petrochemical Plants," *ASME/ASLE International Lubrication Conference*, San Francisco, CA (1980).
4. Shamim, A. and Kettleborough, C.F., "Tribological Performance Evaluation of Oil Mist Lubrication," *ASME Journal of Energy Resources Technology*, Vol. 116, No. 3 (1994): 224-31.
5. Shamim, A. and Kettleborough, C.F., "Aerosol Aspects of Oil Mist Lubrication Generation and Penetration in Supply Lines," presented at the Energy Resources Technology Conference and Exhibition, Houston, Tribology Symposium ASME, PD - Vol. 72 (January 1995): 133–40.
6. Bloch, H.P. and Ehlert, Don, "Get The Facts on Oil Mist Lubrication," *Hydrocarbon Processing* (August 2008).
7. Ehlert, Don, "Getting the Facts on Oil Mist Lubrication," Texas A&M Middle East Turbomachinery Symposium (2011).
8. Bloch, Heinz P., "Update Your Oil Mist Lubrication Knowledge," *Hydrocarbon Processing*, February 2003.
9. Bloch, Heinz P., *Oil Mist Lubrication Handbook*, Gulf Publishing Company. Houston, TX (1987).
10. Bloch, H.P. and Shamim, A., "Oil Mist Lubrication: Practical Applications," Fairmont Publishing Company. Lilburn, GA (1998).
11. Bloch, H.P. and Geitner, F.K., "Machinery Uptime Improvement," Elsevier-Butterworth-Heinemann. Stoneham, MA (2006).
12. Rehmann, Chris, and Bloch, H.P., "Closed Oil Mist Lubrication Is Best Available Technology," *Machinery Lubrication Magazine* (November 2010).
13. Ehlert, Don C., "The Ultimate Oil Filter," *Pump Engineer* (January 2013).
14. Ehlert, Don C., "Consider Closed-Loop Oil Mist Lubrication," *Hydrocarbon Processing* (June 2011).
15. Bloch, Heinz P., "Oil Mist Lubrication: Is it justified and how should it be executed in the 90s?" *Hydrocarbon Processing* (October 1990): 25.
16. Bloch, Heinz P., "'Best-of-Class' Lubrication for Pumps and Drivers," *Pumps & Systems* (April 1997).
17. Bloch, Heinz P., "Preservation by Oil Mist Application," *Plant Services Magazine* (November 1987).
18. Smith, E.A., "Electric Motor Bearing Lubrication Faces New Challenges," *Machinery Lubrication Magazine* (June 2001).
19. Underwood, John, "Grease-lubricated Electric Motors—A New Perspective," *Machinery Lubrication Magazine* (January 2008).
20. Bloch, Heinz P., "Dry Sump Oil Mist Lubrication for Electric Motors", *Hydrocarbon Processing* (March 1977).
21. Bloch, Heinz P., "Lubrication Strategies for Electric Motors," *Machinery Lubrication Magazine* (January 2004).
22. Honeycutt, Jerry, "Reducing Motor Bearing Failures," *Machinery Lubrication Magazine* (May 2002).
23. Bloch, Heinz P., "Benefits of Oil Mist Lubrication for Electric Motor Bearings" *Plant Services Magazine* (April 1986).
24. Bloch, Heinz P., "Oil Mist Lubrication for Electric Motors," *Hydrocarbon Processing* (August 2005).
25. Bloch, Heinz P. and Budris, Alan, *Pump User's Handbook: Life Extension*, Third Edition, Fairmont Press. Lilburn, GA (2010).
26. Clapp, A.M., "Fundamentals of Lubrication Relating to Operations and Maintenance," Proceedings of Texas A&M International Turbomachinery Symposium (1972).
27. Hartman, John, "Oil Mist System Provides Rapid Payback," *Hydrocarbon Processing Magazine* (August 2004).
28. Budris, Allan, "Bearing, Lubrication Issues that Can Reduce Pump Life Cycle Costs," *Water World*, Vol. 26, Issue 8 (August 2010): 14.
29. Radu, Ciprian, "The Most Common Causes of Bearing Failure and the Importance of Bearing Lubrication," *RBK Technical Review* (February 2010).
30. McNally, Bill, "Why Pump Bearings Fail," McNally Institute (April 2012).
31. Budris, Allan, "Optimizing Bearing Lubrication can Extend Bearing Life, Reduce Costs," *Water World* (October 2011).
32. McNally, Bill, "What is Wrong with Centrifugal Pumps," McNally Institute (March 2010).
33. Bloch, Heinz P., "Oil Mist Lubrication Cuts Bearing Maintenance," *Plant Services Magazine* (November 1983).
34. Bloch, Heinz P., "Applying Oil Mist," *Lubrication & Fluid Power* (February 2005).
35. Ehlert, Don C., "Centralized Lube Systems Often Best," *Plant Services* (June 1991).
36. Ehlert, Don C., "Bearing Lubrication Trends and Tips," *Pumps & Systems* (December 1993).
37. Ehlert, Don C., "Lubrication Made Simple," *Pumps & Systems* (April 2005).
38. Ehlert, Don C., "Consider Updating Your Lubricant System," *Hydrocarbon Processing* (May 2012).
39. Ehlert, Don C., "Eliminate Risks in Bearing Lubrication," *World Pumps* (July/Aug. 2012).
40. Noria Corp., "Redefining Bearing Failure," *Reliable Plant Magazine* (November 2008).
41. Towne, C.A., "Practical Experience with Oil Mist Lubrication," *Lubrication Engineering*, Vol. 39.8 (1983): 496–502.