AIR TECH NOTE
#2005-001

Date 12-15-05
By: James Gable

Subject: Maintenance Strategies for Industrial Refrigeration Equipment

At some point in time, all rotating equipment must have the bearings and other key parts replaced because of wear. The number of hours a piece of rotating equipment can operate depends on a number of factors, i.e. the L10 life of the bearings, the condition of the lubricating oil and operating conditions. The L10 life of a bearing is the statistical number of operating hours 90 percent of a particular piece of equipment is designed to operate before the bearings must be replaced. For example, a manufacturer of an industrial refrigeration screw compressor expects their compressor to operate for 100,000 hours before the bearing must be replaced, thus the designed L10 life of the bearings are 100,000 hours. But as I stated earlier, the L10 life can be affected by the condition of the oil and operating conditions. Viscosity and cleanliness affect the condition of the oil. If the oil is too thick or thin, the oil will not properly lubricate the bearings, and if the oil is dirty, it contains abrasive particles that will cause pitting on the finely polished bearing surfaces. Operating conditions can alter the expected L10 life by changing the designed load placed on the bearings. With so many factors affecting the bearing L10 life, the million-dollar question is how many hours can this piece of equipment operate until it must be rebuilt? To answer this question, we must look at the different maintenance strategies that are available in today's lean plant maintenance environment.

There are three types of maintenance that are employed in today's plant maintenance. They are Reactive, Interval and Condition Based Maintenance (Predictive).

Reactive- This maintenance strategy is basically run it till it crashes or makes a lot of funny noises. It also produces a lot of heroes in the plant. If you want to be known as person who can fix anything on a moments notice and does not mind getting calls in the middle of the night or at a personal function, this is the maintenance strategy for you. You will be sure to gain the respect of your maintenance supervisor and plant manager.

The "Fix it When Broken" approach was used primarily before 1980 and is still practiced in quite a few plants today. The strategy requires a storeroom full of spare parts and manpower to repair the rotating equipment when unplanned breakdowns or shutdowns occur. Unplanned shutdowns are associated with production downtime, which is a bad word in today's lean manufacturing environment. Downtime can be best described as time when an asset is not producing because of maintenance, whether scheduled or unscheduled, repair or set-up. Performing the actual repair accounts for only half of the equipment downtime. Adding to the downtime is trouble shooting the problem, obtaining the needed spare parts, acquiring the tools (including making special tools if needed) and restarting the system. Most facilities do not have the technical expertise to repair the more complicated equipment such as industrial refrigeration screw compressors or motors. In these cases, the equipment must be rigged out of their locations and shipped to a facility that has the expertise to make the repair. After the repair, the equipment must be shipped back to the facility, reinstalled and restarted. Because of the "Fix it When Broken" approach, the repairs will most likely be extensive, such as added machine shop work or additional costly parts. For instance, the cost of repairing a compressor may exceed the cost of a new compressor. Depending on the age of the component or its availability, the needed component may not be readily available. This means the equipment is out of service for a week or more instead of a few hours, adding even more downtime to production. Another very important aspect to consider is safety; a catastrophic failure could increase the chance of fires, chemical releases or injury from ejected parts.

I have personally seen the results of a compressor starter fire from loose terminal connections and a compressor/motor coupling melt from a catastrophic bearing failure on a motor in two refrigerated warehouses. In both cases, it set off the smoke detectors and the fire department responded. Both occurred at night when the warehouses were closed. Had both facilities employed condition based monitoring, as they do now, the failures would have been avoided.

The total cost from the Reactive Maintenance Strategy approach to breakdowns includes lost production, lost sales, late deliveries, shortened equipment life and poor safety records. Lost production is most likely the largest cost and can exceed thousands of dollars per hour. Reactive Maintenance is the most expensive of the three maintenance strategies. In today's lean manufacturing environment, where just enough equipment and manpower is available to meet production needs, this is not a good maintenance strategy to follow.

Interval- Interval Based Maintenance, also known as Preventive Maintenance, is best described as time-based maintenance and is a maintenance strategy used to avoid the bad word "downtime". Time-based can be measured in hours, days, weeks, months and cycles. Most equipment instruction manuals will give an interval when maintenance must be performed. For example, a screw compressor manufacturer may state in their manual the bearings should be replaced every 30,000 hours of operation or replaced oil filters every 8000 hours. The maintenance intervals set by the equipment manufacturers are set to minimize or eliminate downtime and are conservative in nature, in other words the majority of the maintenance is performed too soon or too frequently. This results in spending unnecessary capital for parts, manpower and downtime of the equipment and is simply a waste of maintenance time. Maintenance time will be better utilized for maintenance that must be performed from the results of condition based maintenance.

Various studies have shown that less than 20 percent of all failures are time-based, but are the result of other factors, one being abuse. Abuse can be intentional or unintentional, such as operating the equipment out of their designed parameters, performing the wrong work, not assembling parts correctly "if isn't broke, don't fix it" and not knowing the operating characteristics. Interval Based Maintenance may miss problems if equipment is subject to abuse. With pressure from production to get the equipment on line as soon as possible, abuse could be common in any facility.

I recently had a food manufacturing facility where we conducted Condition Based Maintenance surveys exchange a booster compressor for a rebuilt compressor on a weekend. The booster compressor was swapped on a weekend because it was the main compressor for their blast freezer. If this compressor went down their production would have been severely disrupted. The booster compressor had accumulated the number of hours where the manufacturer stated the bearings should be replaced. This compressor had very good historical trending through vibration analysis and no problems were found in the bearings. They exchanged a perfectly good compressor with no bearing problems, while at the same time, a problem was found with the bearings in a high stage compressor. I asked why they replaced a perfectly good compressor with no bearing problems and not the compressor with the bad bearings. The maintenance supervisor stated "The compressor manual indicated the bearing are supposed to be replaced every 30,000 hours and this is a critical compressor while the high stage is not". When I explained to him the purpose of Condition Based Monitoring versus Interval Based Monitoring and the amount of capital he wasted by replacing a perfectly good compressor, he understood the concept.

The facility needlessly spent the following:

Rebuilt Compressor- $15,000.00
Compressors shipping to and from the facility- $1,200.00
Two Mechanics to remove and reinstall compressor
at overtime rate for Saturday and Sunday work- $2,240.00
Total- $18,440.00

The total cost does not include the lost production on Saturday from the planned down time and other miscellaneous costs associated with the compressor swap. The $18,000 would have been better spent repairing the compressor with the known bad bearings.

Preventive maintenance has proven it can eliminate or minimize downtime, but when lean manufacturing principles are applied, we find preventive maintenance is a waste of maintenance time and capital. For example, one principle in lean manufacturing is to have just enough inventory in stock to supply a certain task. Any excess inventory is considered a waste of capital and space. Likewise, any unnecessary maintenance is a waste of time and capital.

Condition Based Maintenance- Condition Based Maintenance is also known as Predictive Based Maintenance (PdM) or Reliability Driven Maintenance. I prefer the term Condition Based Maintenance because the condition of the apparatus is being monitored, where as Predictive sounds like you are trying to predict when an apparatus will fail.

Condition Based Maintenance focuses on the equipment and components health by determining when corrective action should be taken. It provides advanced warning before a failure can occur thereby allowing ample time to schedule maintenance, only the maintenance that is needed and reduces the severity of the repair. It also eliminates or reduces production downtime.

An effective condition monitoring program must employ more than one technology to be successful and must include some necessary mechanical integrity inspections. By unitizing more than one technology and some necessary mechanical integrity inspections, nearly all problems should be caught before a failure occurs. Some of the technologies in the PdM tool box are vibration analysis, infrared scanning, lubrication analysis, sonic analysis and motor circuit analysis. The program must be an on going and ever-evolving process to be effective. It is not a one shot deal and you're done for the year. If your are planning to do condition monitoring once a year, you are doomed for failure and will not be pleased with the results. A lot of problems can occur within a year's time. The interval of condition monitoring should depend on how critical an asset is to your operation, goals and how often it runs. For example, a food production facility has a large capacity booster screw compressor and it is operating a blast freezer. Without this critical compressor, production would be slowed down. In this case I would perform a vibration survey on this compressor 3 or 4 times a year instead of 2 times a year like I would do on a non-critical compressor. There will be times where you want to increase the vibration survey intervals if an anomaly is detected in an asset, but not at the point where maintenance must be performed.

One company that started a condition monitoring program and has paid large dividends is Brakebush Bros. in Westfield, Wisconsin. They perform infrared scanning on their electrical apparatus once a year and perform vibration surveys on the major rotating equipment 3 times a year. They have a Sullair B32 booster compressor, along with 2 other Sullair boosters that are part of a blast freezer system. The Sullair B32 is the largest booster

compressor on the system and without it, production was severely reduced. During one of their vibration surveys they discovered the Sullair B32 had worn bearings and they were at the point where replacement was necessary (Fig.1). The Maintenance Manager had a replacement compressor shipped to their facility while still operating the problem compressor and maintaining their production levels. They scheduled the compressor swap for a Saturday when production was down for the weekend. When Monday arrived they were back in full production without having any production downtime. If the compressor bearing problem had not been found, the compressor would have had a failure and the facility would have lost production for at least a week until a replacement compressor arrived. This would have resulted in a substantial loss of profits and delayed deliveries.

Another example of a world class Condition Based Maintenance program is Atlas Cold Storage in York, PA. During an infrared thermography scan, a loose wire was detected on the overload block of the starter contactor for a condenser water pump (Fig 2). During a closer examination of the wire, it was discovered the insulation was discolored from the heat that was generated from the loose connection. The water pump was taken out of service, the overheated damaged end was cutoff and reinstalled. The total down time was about 10 minuets. Had the wire and connection not been repaired, a fire, burned wire and the possibility of pump motor destroyed from single phasing could have been the result. Even though they had a back up pump, one has to take into consideration the cost of a new motor, wire replacement, overload block replacement and the wasted maintenance time to perform the work.

Condition Based Maintenance follows today's lean manufacturing principals by eliminating wasteful capital expenditures, thus allowing a company to meet its business objectives by having its assets operating at their expected capacity and being ready when it is needed for production.

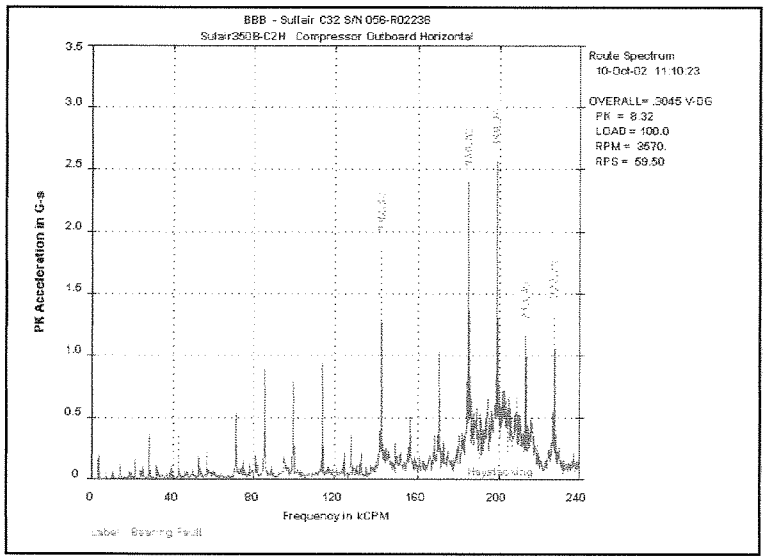

Fig.1

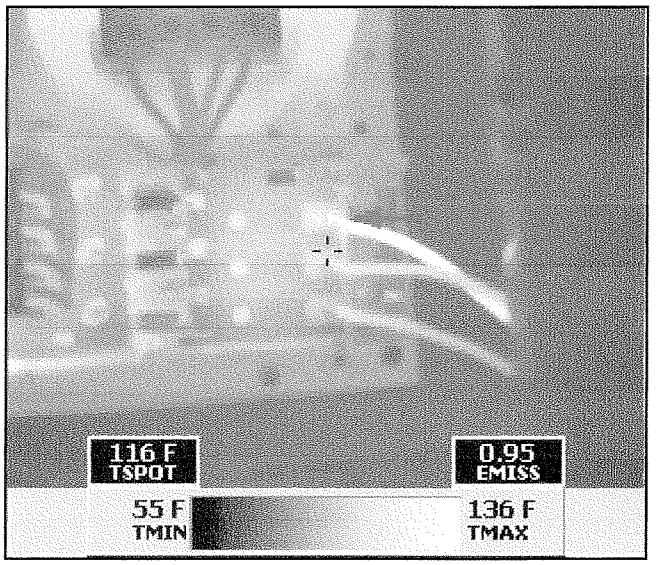

Fig. 2

By James Gable
Jim is a Reliability Engineer for FES Systems Inc.
He is a Certified Level 3 Vibration Analyst and
Certified Level 1 Infrared Thermography Analyst