Simple, Low-cost Vibration Monitoring of Cooling Towers at Bristol-Myers Squibb

By John McConville, Bristol-Myers Squibb and Tom LaRocque, CTC

Accessing cooling tower gearboxes and fan bearings for vibration analysis has been a challenge for many predictive maintenance programs. While the motor is often accessible, the gearbox and fans are usually located inside the cooling tower cell, making these components inaccessible while the fan is in operation.
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Bristol-Myers Squibb currently has thirteen cooling towers - five are jackshaft-driven fans and eight are belt-driven. The jackshaft-driven fans are used to remove heat from the critical process fluids. The cooling tower water flows through a chamber in the chiller unit and removes heat from the freon used to chill the process flow (the process fluids are lowered from approximately 75°F to 30°F by the chiller units). The heated water is pumped from the chiller to the cooling tower, dispersed in the tower cell and drops to a sump pool. As the water falls to the sump pool, a large fan, driven by a motor, drive shaft and gearbox, creates a counter air flow. This counter flow removes the hot, rising air and water vapors from the water and forces it out into the atmosphere. The cooled water is then collected in the sump pools under the cooling tower, ready to be cycled back to the chiller units. The belt-driven cooling tower fans are generally smaller in size and are used in less critical applications.

The jackshaft-driven cooling towers are more critical to the process, and were therefore the initial focus of Bristol-Myers Squibb's search for a safe, reliable and low cost alternative to vibration measurements using portable data collectors. The three jackshaft-driven fans in the northeast quadrant of the plant each have a 50-hp motor driving a 92" drive shaft at 1800 rpm. The fan speed is controlled by an 8:1 reduction gearbox, resulting in a fan speed of approximately 210 rpm. The motor is mounted outside of the cooling tower cell (Figure 3), and the gearbox and fan are located inside, making them inaccessible to the vibration analyst while the tower is in operation. The cooling tower pool is 15 feet below the water distribution point (Figure 4).

Vibration Considerations

The most common cooling tower component failures were:

- Motor - 60%
- Gearbox - 30%
- Fan - 2%
- Other - 8%

Gearbox failures

The gearbox can be a source of excessive maintenance for several reasons. Located inside the cell, it is subjected to aerodynamic loading from the fan, misalignment of the gear to the motor and/or excessive loading on the gear teeth. Environmental factors can also contribute to gearbox degradation. Chemicals added to the water to control the pH of the cooling tower water are typically caustic.

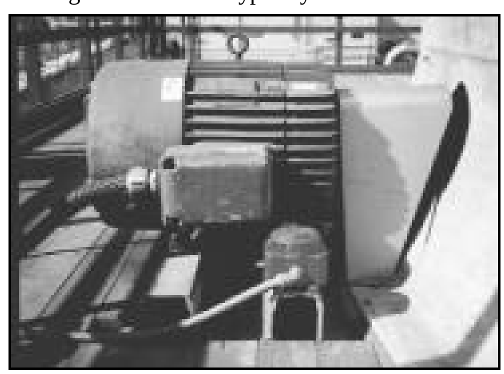

***Figure 3** - Cooling tower motor.*

***Figure 4** - Cooling tower pool (located under the tower structure).*

***Figures 1 & 2** - Cooling towers at Bristol-Myers Squibb.*

Figure 5 - *Portable collection of vibration data from cooling tower motor.*

Figure 6 - *Lock-out of cooling tower fan during accelerometer placement.*

Motor failures

Since the cooling tower motors are more readily accessible to the vibration analyst, portable measurements (magnet-mounted accelerometers) are used to monitor their condition. Motor unbalance, rotor bar defects, output shaft alignment and bearing defects are typical faults detected.

Fan failures

Fan failures, although infrequent, can be catastrophic. If undetected, the fan blades can detach and damage the cell and surrounding components.

Monitoring Challenges

Prior to the implementation of the low-cost, time-efficient alternative to portable vibration monitoring of the jackshaft driven cooling towers, the Bristol-Myers Squibb Reliability Department faced the following challenges:

• Safety considerations that must be taken into account every time collecting data on the cooling tower components

• Scheduling and coordination considerations

• Data collection time considerations

Safety considerations

Safety is paramount at Bristol-Myers Squibb. All activities are conducted with safety in mind. The Safety Department requires certain Protective Personnel Equipment (PPE) for all employees, contractors, or visitors working or visiting in pre-designated hazardous areas. For the jackshaft driven cooling towers, a Confined Entry Permit was required prior to accessing the cells for collection of data on the gearbox and fans. Special cleats were needed to ensure secure footing on the wet catwalks. Harnesses were required to be worn by the vibration analyst while in the cooling tower cell to reduce the risk of injury if footing was lost. Hard hats and protective eye-glasses were also required to ensure the safety of the analyst. In addition, a second person was required to be present while the analyst was inside the cell to ensure the analyst's safety. Finally, the analyst, to prevent a premature startup of the cooling tower fan, locked out the cooling tower cell prior to the entry into the cell (Figure 6). Lock-out of cooling tower fan during accelerometer placement For the belt-driven cooling towers, both the motor and the fan are located inside of the cooling tower cell. The fan and motor bearings are accessed while the unit was still in operation - since the cell for belt-driven cooling towers are much smaller (approximately 12 feet to the fan and motor bearings), no harness or cleats are required. Hip waders (to walk through the sump pool) and a small ladder is required to access the bearing housings. Extreme care must be taken while collecting the vibration data due to the environment and the close proximity of the analyst to the moving belts.

Coordination considerations

For jackshaft driven cooling towers, the Department Supervisor was contacted to coordinate a scheduled shut down window to access the cell and set up the measurement points. Coordination with a second person (usually a member of the predictive maintenance section) to fulfill the safety requirement of having a second person present while in the cooling tower cell also took place in advance. A third person must be present to communicate with the cooling tower operating engineer, who is responsible for starting and stopping the cooling tower fan. Finally, the maintenance planner may also coordinate any other work (electrical or mechanical) that may need to be done on the cooling tower cell, which can lengthen the time for collection. For the belt-driven cooling tower fans, the analyst coordinates with the cooling tower operating engineer to schedule a time to collect vibration data on the fan and motor bearings.

Time considerations

For the jackshaft driven cooling towers, vibration collection procedures relied on the support of the analyst, a safety assistant, the cooling tower operating engineer, and the radio operator. Upon the shutdown of the cooling tower cell to be checked, the analyst, with their safety assistant present, climbed into the cell (while wearing a harness) with a magnet-mounted accelerometer and the accelerometer cable, and magnetically mounted the accelerometer to the desired collection point. The analyst would then carefully climb out of the cell, and the radio operator would communicate to the cooling tower operating

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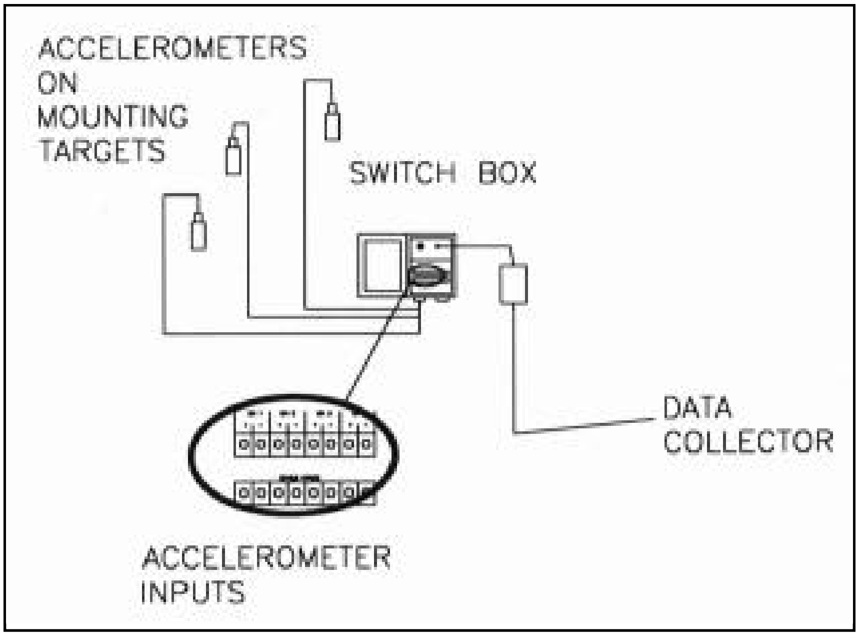


Figure 7 *- Hardware layout for cooling tower vibration monitoring.*

engineer via radio to re-start the fan. Upon the cooling tower fan's return to running speed, the analyst then collected the vibration data at that particular point. For each cell, Bristol-Myers Squibb uses six different measurement locations to monitor the gearbox and fan. The cell then had to be stopped and started six different times to collect all of the desired measurement points for one cooling tower. It was common for three cooling towers to take up to five hours for a single scheduled collection. If a key person was not available at a specified time or had to be pulled from the job for another priority, the time could extend even further. Scheduled jobs have been aborted and rescheduled for a different day due to coordination conflicts. The frequency of start up and stopping the cooling tower cells also cause unwanted wear and tear on the cooling tower components, as vibration in the fans can be high during this procedure. For belt-driven cooling tower fans, only the vibration analyst and the cooling tower operating engineer were required to be present, since all of the components were accessed while the cooling tower was in operation. Although somewhat less time-consuming, the collection time for the belt-driven cooling tower fans was still 1 hour for each cooling tower.

A cost-efficient, time saving alternative

For the initial three jackshaft-driven cooling towers, a system of low cost accelerometers connected to a remotely mounted switch box was designed using the following criteria:

• Accelerometer Selection - The following vibration frequency criteria was taken into consideration:

- Motor operation speed
- Bearing defect frequencies
- Gear mesh frequencies
- Fan and blade speed

Frequencies for detecting vibration faults should be within the frequency response of the accelerometer. Bristol-Myers Squibb uses the gear mesh and bearing frequencies (3 x gear mesh = approximately 43,200 CPM) as the upper limit, while fan running speed (210 rpm) was used to set the lower limit. An accelerometer with a frequency response of 42 - 900,000 CPM was selected.

• *Mounting Hardware Selection*

To provide the optimum vibration transfer between the machine surface and the accelerometer, they needed a mounting system that used the full frequency range of the accelerometer. A mounting target attached with an adhesive to the prepared machine surface using a customized endmill with an adjustable depth pilot drill was selected. The adhesive mounted target improves vibration transfer, and the full frequency range of the accelerometer can be utilized. Another advantage of the adhesive mounted target is the machine surface does not have to be drilled and tapped. A flat mounting target with a 1/4-28 threaded hole was selected.

• *Cable Selection*

Due to the environment of the cooling tower cell, the cable connecting the accelerometer to the switch box needed to be robust, chemically resistant, water resistant and reliable in a caustic environment. In the past, integral cables were primarily used for this interface. If either the cable or the accelerometer failed, however, the complete cable-accelerometer system had to be replaced. A low-cost, composite connector with a silicone o-ring and threaded locking ring (type "A" connector) provides the seal needed to keep out the environment. A chemically resistant Teflon jacketed twisted shielded cable was chosen to carry the signal from the accelerometer to the switch box.

• *Junction (Switch) Box Selection -*

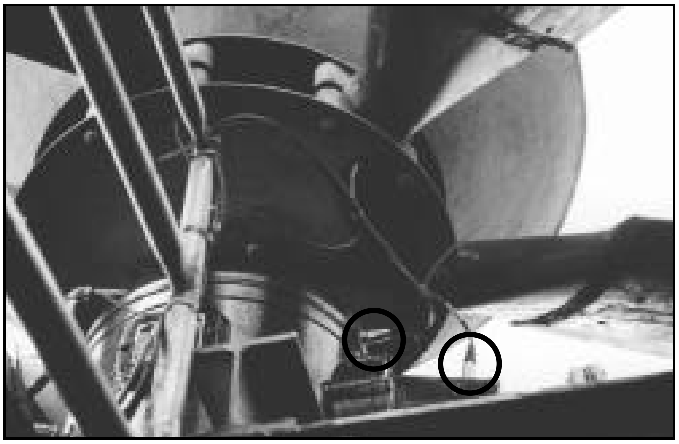
A switch box provides direct access to the vibration signals for the analyst, and its location is often outside, exposed to the environment. A NEMA 4X enclosure with a water-tight cable entry into the enclosure is recommended to ensure that water will not collect inside the switch box. In the past, powered switch boxes were used for cooling tower applications to power the accelerometers. New accelerometers can use the power supply of the data collector due to the fast settling time of the accelerometers. The elimination of the duplicate power supply results in cost savings. The enclosure selected is fiberglass and features factory installed cord grips that provide the water tight entry of the cable into the junction box. Figure 7 shows the layout that was installed by the Predictive Maintenance Department.

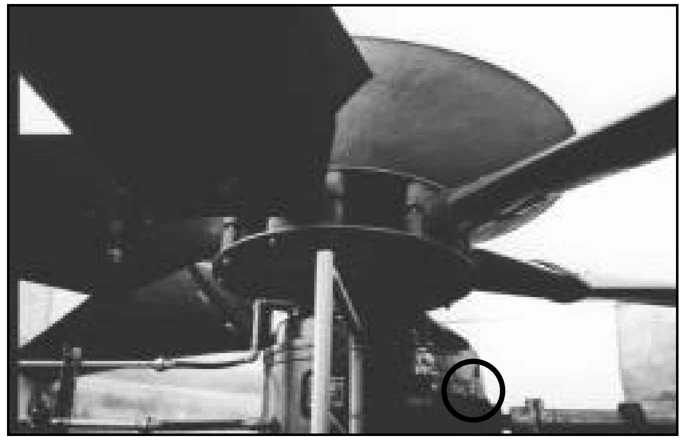
The following benefits to this system are:

• Permanently mounted accelerometers increase the accuracy of data over a wide frequency range of the vibration data collected, while ensuring the repeatability of the measurement locations

• The recommended maximum frequency of the 2-pole magnets is 150,000 CPM, while stud-mounted accelerometers with adhesive mounting targets have a frequency span up to 600,000 CPM

• Permanently mounted accelerometers connected to a remote switch box allow the analyst access to the vibration data without having to physically enter the cooling tower cell, which would require that the tower





Figures 8, 9 - *Permanently mounted accelerometers.*

be shut down. The safety concerns were reduced, and the data collection time was greatly reduced.

• Coordination with the Department Supervisor and cooling tower operating engineer was eliminated, thus removing variables that were outside the vibration analyst's control.

Financial analysis

In order to monitor the gearboxes and fans on all thirteen cooling towers, vibration data had to be collected on over 500 measurement points. Bristol-Myers Squibb compared the cost of the hardware needed to permanently monitor the three cooling northeast quadrant towers versus the cost of the Predictive Maintenance Department collecting vibration data for each cooling tower component as they had in the past. The time required to historically monitor the three cooling towers each time was estimated at 4 hours, with a total cost of $576. The cost for the permanently mounted accelerometers and vibration hardware (9 measurement points) was less than $2900, including installation, labor and less than $80 for each accelerometer. As a result, the permanently installed system would pay for itself after only six measurement periods.

Approved cooling tower monitoring setup

After the financial and benefits analysis Bristol-Myers Squibb decided to permanently mount accelerometers on the three jackshaft-driven cooling towers in the northeast quadrant (Figures 8, 9). They also plan to eventually revise all of the jackshaft driven cooling towers in the plant, as well as the fan bearings and motors for the belt-driven cooling towers.

Conclusion

The following factors were critical in convincing management that this program was beneficial to the Predictive Maintenance Program and should be expanded for all cooling towers:

• Reduced exposure to safety hazards

• Reduction in data collection time

• Ability to collect data on previously inaccessible cooling tower components

• The low cost of vibration analysis hardware

• Lifetime, unconditional warranty offered by the hardware supplier

The previously difficult task of monitoring the inaccessible components of Bristol-Myers Squibb's cooling towers has now become very efficient. What would take up to four hours and three people to monitor a single tower with three cells now takes less than thirty minutes of data collection time by one vibration analyst.

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Figures 10 - *Accessing data from switch box.*