Simple, Low-Cost Vibration Monitoring of Cooling Towers

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The installation of low-cost vibration hardware for monitoring inaccessible cooling tower components has proved to save Bristol-Myers Squibb time and money. Here they give Machine Plant and Systems Monitor the full story.

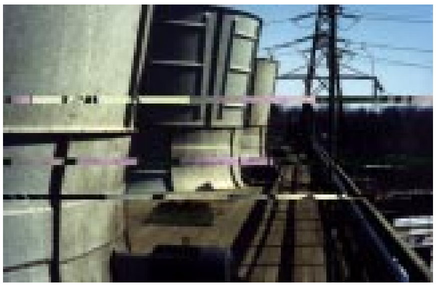

Figure 1. Cooling towers at Bristol-Myers Squibb

Introduction

Accessing cooling tower gearboxes and fan bearings for vibration analysis has been a challenge for many predictive maintenance programmes in the past. While the motor is often accessible, the gearbox and fans are usually located *inside* the cooling tower cell, making these components inaccessible while the cooing tower fan is in operation. Measurements on these components may not therefore be taken as regularly as they should be. The preferred method for monitoring cooling tower components is usually permanently mounting accelerometers to the measurement point and running the cable out to a remote switch box – but until recently, the cost of suitable equipment has been a prohibitive factor.

Now, however, Bristol-Myers Squibb has seen the implementation of a programme to monitor the inaccessible machine components of cooling towers by permanently mounting low-

Figure 2. Cooling tower motor

cost accelerometers and cables to the gearboxes and fans and connecting them to a single, centrally-located switch box which can be quickly and conveniently accessed.

Cooling towers

Cooling towers are used when the removal of heat from process fluids is required. Bristol-Myers Squibb currently has thirteen cooling towers; five have jack-shaft-driven fans and the other eight, belt-driven fans. The jack-shaft-driven cooling tower fans are utilized to remove heat from the critical process fluids that flow through large centrifugal chiller units. The cooling tower water flows through a chamber in the chiller unit, removing large amounts of heat from the freon used to chill the process flow (the process fluids are lowered from approximately 75˚ to 30˚F by these chiller units). This heat is absorbed by the cooling tower water, which is then returned back to the cooling tower. The heated water that is pumped back from the chiller to the cooling tower is dispersed in the cooling tower cell over the area of the cell and is allowed to drop to a sump pool. As the water falls to the sump pool, a large fan, driven by a motor, drive shaft and gearbox, and located above the distribution system, creates a counter airflow. This counter-flow removes the hot, rising air and water vapours from the water and forces it out into the atmosphere, cooling the returned water. 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 utilized in less critical applications. The jack-shaft-driven cooling towers were more critical to Bristol-Myers Squibb's process, and were therefore the initial focus of their search for a safe, reliable and low-cost alternative to portable cooling tower measurements.

The three jack-shaft-driven cooling tower fans in the north east quadrant of Bristol-Myers Squibb have a 50 hp motor driving a 92-inch drive shaft at 1800 rpm each. The fan speed is controlled by an 8:1 reduction gearbox for a fan speed of approximately 210 rpm. The motor is mounted outside the cooling tower cell (Figure 2), and the gearbox and fan are located inside, inaccessible to the vibration analyst while in operation (Figure 3). The cooling tower pool is located 15 feet below the water distribution point (Figure 5). Vibration measurements are now taken monthly on all these cooling tower components following the installation of permanently-mounted accelerometers to the inaccessible cooling tower components.

What are the specific maintenance problems experienced in cooling towers? Bristol Myers Squibb have analysed their maintenance history and found the most common component failures to be motor (60%), gearbox (30%), fan (2%) and others (8%). Within this general outline, the inaccessibility of the fan and gearbox are a major challenge to the monitoring of these components. Let us look at the details.

Motor failures

Since the motors are easily accessible to the vibration analyst at Bristol-Myers Squibb, portable measurements (via magnet-mounted accelerometers) are utilized effectively to monitor the condition of the cooling tower motors. Motor unbalance, rotor bar defects, output shaft alignment and bearing defects are typical faults that are monitored.

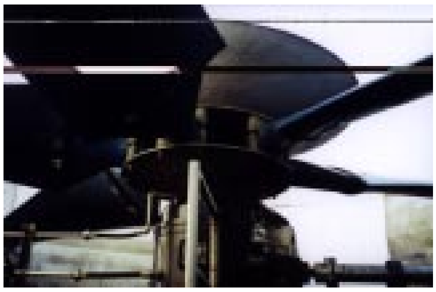

Figure 3. Cooling tower gearbox and fan

Gearbox failures

The gearbox can be highly consumptive of maintenance for several reasons. Its location inside the cell means that it is subjected to aerodynamic loading from the fan, misalignment of the gear to the motor and/or excessive loading on the gear teeth. Other environmental factors can also contribute to the degradation of the gearbox – chemicals added to the water to control the pH level of the cooling tower water for instance, are typically caustic in nature.

Motor fan failures

Failure in the fans, although rare, can be catastrophic. If a fault goes undetected, the fan blades can become

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

detached and damage the cell and the surrounding components. In search of a cost-efficient, timesaving alternative, Bristol-Myers Squibb and CTC (an accelerometer and vibration analysis hardware manufacturer) together investigated efficient alternative means to portable measurements. For the initial three jack-shaft-driven cooling towers, a system of low cost accelerometers mounted to mounting targets and connected to a remotely-mounted switch box was specified after consideration of a number of different issues.

Figure 5. Portable Collection of Vibration Data from Cooling Tower

Accelerometer selection

The choice of accelerometer for the monitoring of cooling tower components had to be made with a whole range of different vibration frequencies borne in mind:

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

The accelerometer selected would need to have a frequency response capable of detecting all the different vibration faults. For the accelerometer specification, Bristol-Myers Squibb determined the gear mesh and bearing frequencies (3 x gear mesh = approximately 43,200 CPM) as the upper limit, while the fan running speed (210 rpm) was used as the lower limit. The AC102-1A model, with a frequency response of 42 – 750,000 CPM, was the accelerometer selected for this application, due to its wide frequency response and low cost.

Mounting hardware selection

To provide the optimum vibration transfer between the machine surface and the accelerometer, a mounting system that utilized the full frequency span of the accelerometer needed to be found. A mounting target, to be attached to the prepared machine surface with an adhesive, was selected (the surface was prepared using an installation tool-kit – MHI17-1A – that can be re-sharpened for multiple installations). The adhesive-mounted target facilitates excellent vibration transfer, to the full frequency range of the AC102-1A accelerometer. Another advantage to the adhesive-mounted target is that the machine surface need not be drilled and tapped. A flat mounting target with a +-28 threaded hole, model MH130-1A, was selected for this function.

Cable selection

Because of the hostile environment of the cooling tower cell, the cable connecting the accelerometer to the switch box needed to be robust, chemical 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 would have to be replaced.

In this case CTC's low-cost, composite connector with a silicone o-ring and threaded locking-ring (type ^{3}A^{2} connector) provided the seal needed to keep out the environment. A chemical-resistant twisted shielded cable (CB102) was chosen to carry the signal from the accelerometer to the switch box. The CB102-A-020-Z (^{3}Z^{2}) is a blunt-cut termination to the cable to allow connection to the switch box) was the cable assembly chosen due to its low-cost and proven performance in cooling tower applications.

Junction (switch) box selection

The switch box provides the analyst direct access to vibration data coming from the previously inaccessible cooling tower components. The switch box should be located where the analyst can gain easy access to collect the vibration data. This location is often outside, exposed to the environment. A NEMA 4X enclosure with a water-tight cable entry 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 for vibration data collections. Today. CTC's accelerometers can utilize the power supply of the data collector and do not require additional line power supply due to the ultra-fast settling time of the accelerometers (model AC102-1A settles within 1 second after power-up). The

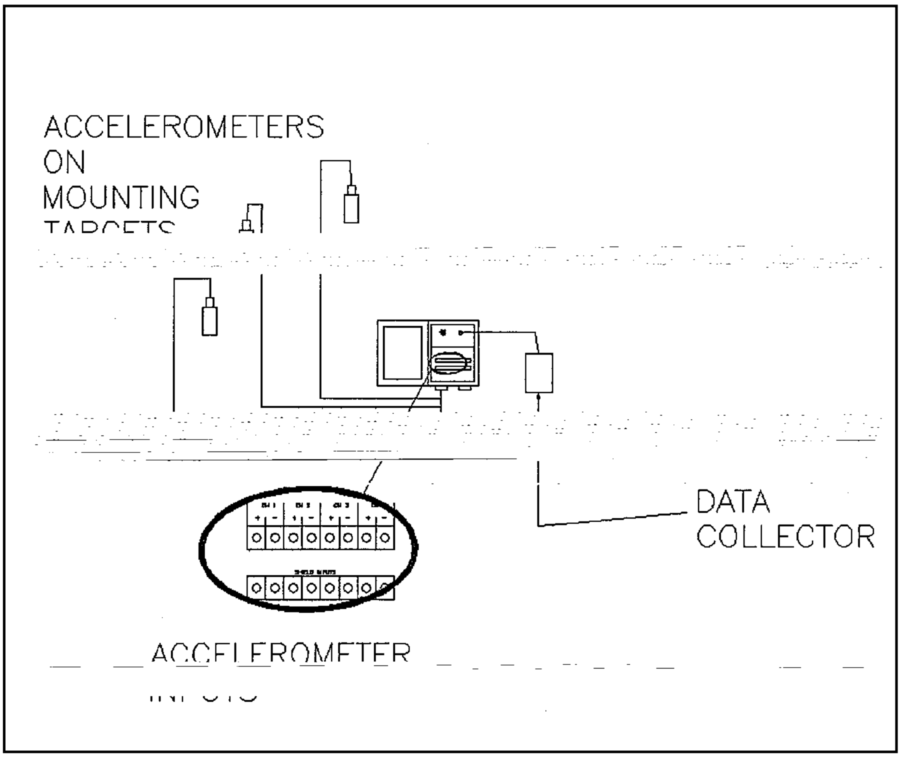

Figure 6. Hardware sketch for cooling tower vibration monitoring

Figure 7. Permanently mounted accelerometers

elimination of the duplicate power supply translates into cost savings. The low-cost, un-powered SB101-10C was selected to meet the above criteria. The enclosure is fibreglass, and features factory-installed cord-grips that provide the water-tight entry of the cable into the junction box. Figure 6 shows a layout that was approved and implemented by the Predictive Maintenance Department at Bristol-Myers Squibb (shown as a sketch with three measurement points being monitored).

Some of the benefits to this system are:

- The advent of permanently-mounted accelerometers increased the accuracy of data over a wide frequency span of the vibration data collected, while ensuring the repeatability of the measurement locations.

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

- The remote switch box allowed the analyst to access the vibration data without having to physically enter the cooling tower cell so that safety concerns were improved, and data collection time was greatly reduced.

- Start-up and shut-down of the cooling tower fan for vibration data collection was eliminated, saving time and money.

- The data can be collected without shutting down the cooling tower at all – a major improvement.

- The need for co-ordination between the department supervisor and cooling tower operating engineer was eliminated, thus removing variables that were outside the vibration analyst's control.

- The unconditional lifetime warranty provided by CTC on all of its vibration hardware eliminated the need to figure in replacement costs for the cables and accelerometers

Qty	Part Number	Description	Cost/Unit	Total Cost
9	AC102-1A	Multi-Purpose, 100mV/g accelerometers	$75.00	$675.00
9	MH130-1A	Mounting Targets	$ 6.00	$ 54.00
9	CB102-A-020-Z	Cable Assemblies for permanent mounting	$38.70	$348.30
1	SB101-10C	10 Channel Switch Box w/ cord grips	$555.00	$555.00
1	MH109-2A	Mounting Adhesive	$ 6.30	$ 6.30
1	MH117-1B	Installation Tool Kit, (can be re-sharpened and used for future installations)	$356.00	$350.00
	Labor	Labor for Installation	$768.00	$768.00
Total				$2756.60

Table 1. Vibration analysis hardware costs

when reviewing the financial analysis.

Financial analysis

The present analysis is based on the man-hours required monitoring three cooling towers versus the cost of hardware for permanent monitoring. In order to monitor the gearboxes and fans on all thirteen cooling towers, vibration data had to be collected on over 500 measurement points. A cost-effective alternative to the time-consuming data collection of measurement points on three cooling towers in the north east quadrant only was initially explored. The company compared the cost of the hardware needed to permanently monitor these three cooling towers versus the cost of having the predictive maintenance department collect vibration data for each inaccessible cooling tower component. The time required to monitor the three cooling towers was estimated at four hours, with a total cost of $576 incurring for each full day of collection. The overall hardware cost for the permanent mounting of the accelerometers and vibration hardware for the cooling towers (a total of nine measurement points) can be seen in the table above.

Based on these figures, the initial capital investment of the vibration hardware and labour was equal to the cost of the man-hours required to monitor the three cooling towers with portable measurements for approximately five days' worth of data collection.

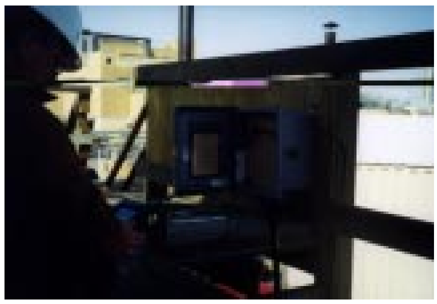

Figure 8. Accessing data from the switch box

Approval for cooling tower monitoring set-up

After financial analysis and review of all of the benefits for permanent monitoring, Bristol-Myers Squibb decided to permanently mount accelerometers for the gearboxes and fans for the three cooling tower cells in the north east quadrant, along with the other jack-shaft-driven cooling towers located throughout the plant. Based on the cost and safety benefits of the initial installation of permanently-mounted accelerometers in the three cooling tower cells, the company plans to outfit all of the inaccessible cooling tower components (including the fan bearings and motors in the belt-driven cooling towers). Pictured are the permanently-mounted accelerometers and the switch box that were installed and are currently in use at the plant.

Conclusion

There were five factors that were particularly important in convincing management that this investment would be useful to their predictive maintenance programme and should be expanded for all the cooling towers on site:

1. Less exposure of manpower to safety hazards
2. Reduction in data collection time
3. Ability to collect data on previously inaccessible cooling tower components
4. The low cost of vibration analysis hardware
5. Lifetime, unconditional warranty offered by the hardware supplier for all products.

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

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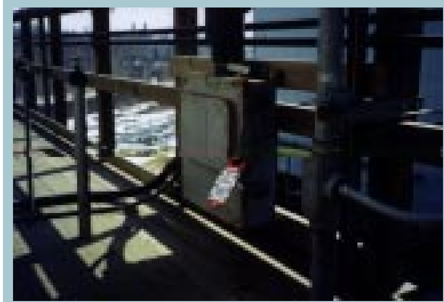
"The Way it Was" - Bristol-Myers Squibb's Previous Cooling Tower Monitoring Challenges

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

- Safety considerations – when collecting data on the cooling tower components
- Scheduling and coordination considerations
- Data collection time considerations

Safety Considerations . Safety is paramount at Bristol-Myers Squibb. 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. Additionally 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 (*see figure below*).



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 were 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 were required. Hip waders (to walk through the sump pool) and a small ladder was required to access the bearing housings. Extreme care was 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 was present to communicate with the cooling tower operating engineer, who is responsible for starting and stopping the cooling tower fan. Finally, the maintenance planner could also coordinate any other work (electrical or mechanical) that needed to be done on the cooling tower cell. This 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 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 measurements 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 causes 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.