Predicting Mechanical Systems Failures Using Infrared Thermography

Brian D. Susralski and Thomas Griswold
United Parcel Service, Hodgkins, IL

ABSTRACT

As thermographers, we understand the value of our infrared thermal imaging cameras for surveying electrical problems. However, we must realize it is also important to focus just as eagerly on mechanical systems as well. In an industrial atmosphere electrical troubleshooting can also include mechanical systems as the cause of thermal anomalies. In most cases an improperly operating mechanical item, such as an improperly lubricated system, can cause an increase in operating temperature which does affect the electrical thermal temperature. We must, as thermographers, remember that our troubleshooting techniques must include all factors of the operating system for us to be effective. This paper will demonstrate the need for this attention by using actual data gathered by the Root Cause Failure Analysis Team (RCFA) at UPS to eliminate a costly maintenance and customer service issue.

Our results show that improper setup and inadequate lubrication directly affect a mechanical unit’s operating temperature. This, in turn, directly affects the electrical control system and causes many operating problems, both electrical and mechanical. Data comparisons between our original findings and the post repair findings prove our assertions correct.

Our results prove that through careful, logical troubleshooting techniques, the source of thermal anomalies can be identified by infrared thermal imaging cameras, and repaired prior to equipment failure. This leads to a better predictive maintenance program and an overall maintenance and operational cost savings. Also, it leads to a more effective thermal survey for future use in data comparisons.

The direct data results indicate that lubrication at designated points on our mechanical system directly affected our operating temperature. Our data shows this to be a direct cause of system breakdown, whether mechanical or electrical, or both. A very hot mechanical system will cause an increase in electrical system temperature since there is a direct correlation between heat and amperage draw in an electrical system. We can then see that the bottom line is that a properly surveyed system will include not only electrical considerations but also mechanical as well for proper diagnosis and repair of a given anomaly.

Keywords: IR thermography, predictive maintenance, thermographer, thermography surveys, IR surveys of electrical equipment, ir surveys of mechanical systems

1. INTRODUCTION

What exactly is the job of a thermographer? Throughout our training and the course of our work, it becomes apparent that it is much more than locating and photographing a thermal anomaly with an infrared thermal imaging camera. Often we must use our experiences as thermographers to become troubleshooters to diagnose the cause of the anomaly for our work to be thorough. Many anomalies or “hot spots” are caused not by the component being viewed, but by a problem somewhere else within the electrical or mechanical system. The end result, the hot spot, demands that the thermographer understand basic physical principles such as heat transfer, heat reflection, and others. By familiarity with the theories of thermography and by experience within the field, it allows us to accurately locate and define not only the anomaly itself, but more importantly its root cause. In this way the thermal imaging system is utilized to its full potential as a Preventive Maintenance tool. Due to the fact that thermography is a fairly new technology at our facility, it was often times not considered a legitimate tool for the job of Preventive Maintenance (PM). The following case study is one that demonstrates the value of thermography not only as a PM tool, but also as a tool that provides considerable cost savings in man hours and facility downtime.
2. EVOLUTION OF THE CONVEYOR SYSTEM PM PROGRAM

As the largest package processing facility in the world, United Parcel Service’s Chicago Area Consolidation Hub (CACH) currently processes upwards of 1.75 million packages a day of all shapes, sizes, and weights. Our particular package scanning system requires an exact amount of spacing between each package in order to derive accurate shipping data. To accomplish this we employ a “metering” system, which is basically a series of four AC servo motor driven conveyors (Figure 1). These conveyors receive commands from an AC servo drive logic control unit, which slows and speeds the belts at varying times to create a package “gap”, or the required spacing for package data at the scanner. At this point is where the problem began to surface and the UPS Root Cause Failure Analysis (RCFA) team was called in.

Figure 1. Conveyor metering, a series of four AC servo motor driven conveyors

During times of heavy package flow in which the conveyors were working hard to process package flow failure of the servo motor, gear reducers, or servo control units were becoming more prevalent. Many times the maintenance records showed the control units diagnostics warning of a “servo overtemp” fault was present. Numerous contacts with our vendors revealed the same suspected cause, servo drive overheating. Due to the age of the units the proper repair seemed to be to remove and replace the servo drive unit and gear reduction unit, which initially solved the problem of the servo overheating. Repeated thermal scans showed that as the servo drive motors ran the operating temperatures would slowly increase to an unacceptable level, once again causing the servo control unit to shut down. In the cases in which the heating would cause the servo drive control unit or the drive itself to fail, it would disable the conveyor and cause sortation backup. In these cases the conveyor would be unusable for two to three hours to allow removal and replacement of the servo drive or the control unit. This is a considerable operational cost for the facility (See Chart 1) and more importantly could cause a late delivery for a customer’s package.
<table>
<thead>
<tr>
<th>Operational Cost per Breakdown</th>
<th>Flow Rate (3000 packages per Hour)</th>
<th>Loss of Availability (hours)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>$1400 (Estimated)</td>
<td></td>
<td>2.5</td>
<td>$3,500</td>
</tr>
</tbody>
</table>

Chart 1. Estimated cost per conveyor breakdown

3. INTRODUCTION OF THERMAL IMAGING

It was at this time a critical discovery was made via the thermal imaging system. While on a routine thermal PM scan in another area of the facility, the thermographer inadvertently changed the temperature span to view another component and had not changed it back. Thermal imaging of a metering conveyor drive unit immediately after showed a large thermal anomaly at the area of the gear reducer input bearing and coupling. After photographing the anomaly, the thermographer began troubleshooting to determine the cause of the hot spot.

At first, a loose coupling was thought to be a possible cause. This was quickly eliminated when torque verification was performed and at rethermo no temperature change was reported. Upon researching the Original Equipment Manufacturer’s (OEM) installation and service manual, it was noted that the input bearing itself should be greased every 1000 hours of operation. Since this was not part of our usual preventive maintenance inspection (PMI) it made the case for the gear reducer input bearing to be lubricated as soon as possible and the drive to be rescanned. At the first units inspection it was noted that the reducer had no zerk (grease) fitting, but instead had a solid plug installed. It was also noted that the reducers were leaking gear oil from the output seals of the gear reducer. Further research indicated that the reducer units were also to have a breather vent located at the top of the units to balance the pressure in the unit. The vent and zerk fitting, if installed in the unit and maintained, would result in longer seal life, less leakage, and prolonged life of the unit.

4. SERVICING AND PLUG REPLACEMENT

Once all information and specifications had been verified the RCFA team set to work to repair the problem. As a test, six gear reducer units were initially serviced. This service included filling the unit with lubricating oil up to OEM specifications, installing and lubricating the input bearing, and cleaning or replacing the breather vent. Again, during reducer servicing another discovery was made. Upon removal, vents on the gear reducers, which we believed were vented “breather” type inserts were not actually vents at all, but solid plugs, which had appeared to be vented (Figure 2). At servicing, all vent plugs were removed and replaced with the OEM breather vent (Figure 3).
Figure 2
Exterior View of Plug

Interior View of Plug
Solid plug which resembled breather vent

No Zerk fitting

Figure 3. Vented plug placement

Vented Breather

Zerk Fitting
Upon completing of reducer servicing, the gear reducer units showed an average temperature drop of 18.9 degrees Fahrenheit as indicated in Chart 2.

<table>
<thead>
<tr>
<th>Conveyor</th>
<th>Temperature Before Service</th>
<th>Temperature After Service</th>
<th>Change In Temp.</th>
</tr>
</thead>
<tbody>
<tr>
<td>S18-5A</td>
<td>155.7</td>
<td>150.0</td>
<td>5.7</td>
</tr>
<tr>
<td>S18-5B</td>
<td>164.3</td>
<td>139.2</td>
<td>25.1</td>
</tr>
<tr>
<td>S18-6A</td>
<td>160.4</td>
<td>151.2</td>
<td>9.2</td>
</tr>
<tr>
<td>S18-6B</td>
<td>165.7</td>
<td>135.1</td>
<td>30.6</td>
</tr>
<tr>
<td>S18-7A</td>
<td>153.3</td>
<td>145.2</td>
<td>8.1</td>
</tr>
<tr>
<td>S18-7B</td>
<td>170.0</td>
<td>135.1</td>
<td>34.9</td>
</tr>
</tbody>
</table>

Average Temperature Drop: 18.9

Chart 2. Gear reducer temperatures after reducer servicing

As a control, all reducers were tested in the same manner. Gear reducer units were run for one hour to bring them to a normal operating temperature and then photographed with the thermal imaging camera. The gear reducer was then serviced to OEM specifications. Upon completion of servicing, the unit was run for one hour again to establish normal operating temperature and then re-photographed with the thermal imaging camera. In this way our results could be accurately recorded and used as proof of our conclusions as shown in Fig.4.

5. SUMMARY AND CONCLUSIONS

As a result of our findings and subsequent repairs, the decision was made to begin to service all of our 572 metering conveyor gear reducers within the facility. Also, it was decided that servicing of this type of reducer would also be added to our semi-annual Preventive Maintenance inspection matrix. In this way, the OEM specifications of lubrication at 1000-hour intervals would be adhered to.

This preventive repair has resulted in significant cost savings to the company in several ways. Since the repair inception, the facility breakdown report shows three facility breakdowns related to the servo issue (March through June) as opposed to sixty-seven the previous year. The cost of the breakdown and the breakdown repair are quite high compared to merely servicing the unit as illustrated on Chart 3 below.
In addition to the facility breakdown cost savings, even more important is the saving of a valuable customer who receives shipment on time. It is in this way quite easy to see the value of a thermal imaging system as a preventive inspection tool. With our thermal technology we proved that inadequate lubrication of the mechanical system not only affects the mechanical system, but can cause undesirable heating of the electrical systems also. Only through our thorough troubleshooting did we discover the root cause and rectify a costly problem.

In our particular facility the thermal imaging system was primarily obtained for a simple scanning of conveyor drive motors, bearings, and conveyor belting. Due to the success of the in house RCFA team at UPS and our work with the thermal imaging system, we have expanded to include electrical control systems and almost all mechanical operations equipment. With our experience in thermal imaging growing every day, we experiment with variables such as ambient temperatures, varying emissivities, and also the effects of wind cooling. Further proof of our success has seen the introduction of other forms of preventive maintenance systems such as vibration analysis, oil analysis, and ultrasound. The combination of these technologies supports the thermographer in his troubleshooting and repair within the facility. Most importantly, we have demonstrated that thermal technology, if used by a trained and thorough technician, is an extremely valuable asset to any PM program in industry.