Proper Asset Maintenance Improves Safety, Reliability, and Profitability

The Importance of Equipment Maintenance in Mining and Other Heavy Industries

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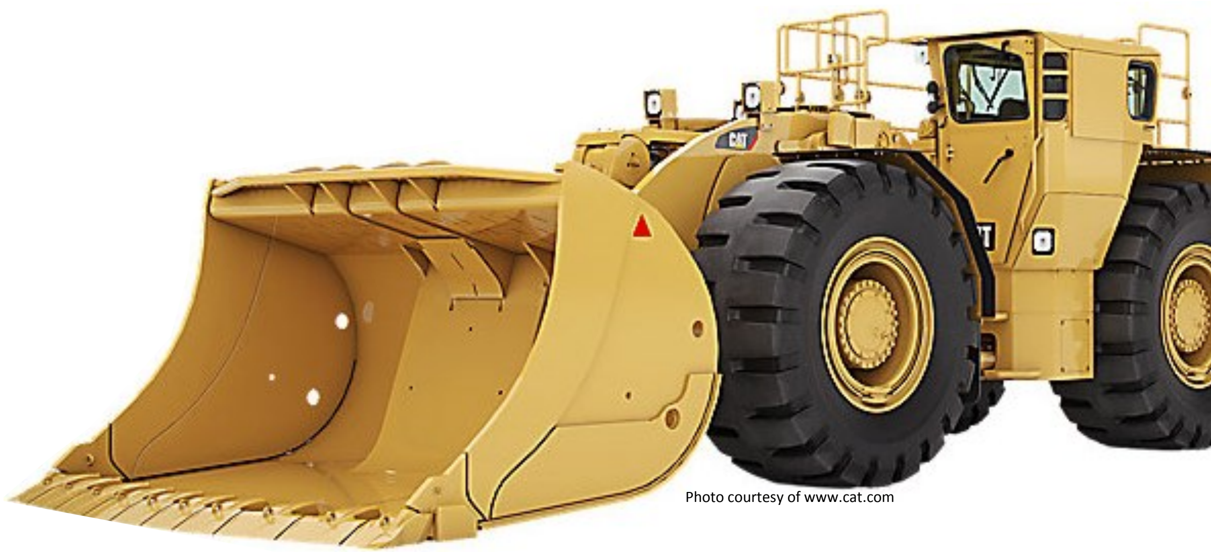

Photo courtesy of www.cat.com

USC Consulting Group, LP (USCCG) has implemented maintenance management programs at numerous mines and industrial sites throughout the Americas, and other parts of the world.

In this publication you will gain first-hand knowledge of strategies, processes, and methodologies used to develop a maintenance program for a mobile mining fleet at a large precious metals mine in the western U.S. You'll find that the lasting results are well worth the effort and are applicable to mining and industries with heavy equipment and revenue-producing assets.

Should you have any questions, please feel free to contact me directly at [jake.rivers@usccg.com.](mailto:jake.rivers@usccg.com)

About Jake Rivers

Jake has proven himself as one of the top Project Managers at USCCG and has quickly risen through the ranks. A graduate of Wilfrid Laurier University in Waterloo, ON with a Bachelor's Degree in Business Administration, he has led several successful underground mining projects, and his team was presented with the *USCCG Teamwork Award* for their outstanding performance in 2013.

Jake believes that "the quality of your work will define you", and he holds his team members to this philosophy. He enjoys the numerous challenges management consulting offers and is eager to continue his career working with clients to improve their profitability.

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A Changing Landscape

Innovation and technology are changing the landscape of industry. In the case of mining, addressing safety concerns to limit human exposure to the dangers of mining is paramount, and manufacturers are introducing mining equipment that places the operator further away from the activity.

Technology is being introduced in a multitude of new ways, constantly evolving the process by which we extract minerals from the ground. As the industry moves in this direction, it increases the amount of work that is done using non-human capital and changes the ratio of operators to equipment. What was once one or two operators to a piece of equipment, may now be one or in some cases zero. Asset management and total fleet maintenance is becoming increasingly important and will have an escalating impact on a company's bottom line as this ratio continues to change.

Given these changes, a robust asset maintenance program is no longer a luxury, but necessary for profitability.

Challenges in Underground Mining

Mining is tough work, and mining underground adds some additional challenges found in very few industries, these include:

- **Extreme Working Conditions** – Many factors impact working conditions and productivity in an underground mine that are typically not found elsewhere. With zero natural light underground, workers are required to rely on the use of their headlamps and lights that have been outfitted to their equipment. There is also a temperature differential between the deep underground air and the air from the surface. When these two temperatures meet they can have some interesting effects on the visibility in the mine. Some areas of the mine may be consumed with a thick fog. As a mine is driven deeper, the temperature will begin to increase. Conversely, mines at a higher altitude will experience lower temperatures and possibly lower oxygen levels. These drastically varying working conditions can have a high impact on the productivity of the jobs requiring physical labor in the mine.

- **Confined Working Space** - There is a significant cost associated with every ton of rock broken and moved in a mine. For that reason, roadways, tunnels, and drifts are engineered to a minimum specification. Equipment can be damaged in the tighter areas of the mine by hitting the walls or even in some cases, the top of the tunnel if they do not have the proper clearance.

- **Strict Government Regulations** – Working in a mine has historically been an inherently dangerous profession. In response, governing bodies, such as MSHA (Mine Safety and Health Administration) in the U.S., have been developed to legally bind mining organizations to the adherence of safety regulations. Standards may include training specifications, the use of protective equipment, emissions, and workplace housekeeping. Firms in the U.S. devote significant amounts of time and money to ensure their mine sites conform to all safety regulations.

- **Equipment and Capital Intensive Operations** – When handling thousands of tons of rock, the reliance on equipment and machinery is one hundred percent. Operations cease if critical pieces of equipment are not functioning properly. Critical equipment such as drills, bolters, LHDs (Load Haul Dump), and haul trucks are very specialized pieces of equipment that are expensive to purchase, expensive to operate, and expensive to maintain. In addition to the cost of the mobile equipment, stationary equipment represents a large portion of capital investment for any mining company. Mine infrastructure, crushing plants, milling plants, and smelters all require a large amount of capital investment before production can even begin.

Challenges in Underground Mining

- **Remote Locations** – There are certainly mining locations that are much more remote than others. Some geographic regions such as Northern Quebec and Ontario in Canada for example, are incredibly mineral rich. The result of these mineral rich locations is the development of infrastructure to support a high level of competition. Combined with the proximity to a large market place such as Toronto, these conditions are ideal for mining companies. Not all locations experience the same beneficial factors. The location of each mine is dependent purely on where the sought after mineral is located. Remote locations pose many challenges when sourcing materials, scheduling deliveries, and acquiring a stable workforce. The coordination and transportation of the entire workforce is also a large factor.

Combined, these factors make it fairly evident that organizations striving to enhance profitability in underground mining should place a large emphasis on asset management.

Having a strong maintenance philosophy will improve the bottom line of a company on both sides of the value equation. Reducing the number of breakdowns will lower costs in materials used and labor hours consumed. It will also maximize the productivity of the operator using the equipment, and therefore increase the overall quantity of the mineral being mined, thereby increasing revenue.

To produce a positive result on the bottom line from an Asset Maintenance Program:

1. **Ensure that when the equipment is running, it is running reliably.**
2. **Ensure the equipment runs reliably for as long as possible.**
3. **Ensure that all required equipment repairs are done as quickly as possible.**

Planned vs. Unplanned Work

Understanding the Types of Work

As a typical rule of thumb in maintenance, planned work will consume roughly one third of the resources (labor cost, materials cost, and costs associated with equipment down-time) as unplanned work will consume[1]. Therefore, the first objective of any maintenance program can be simplified as maximizing the percentage of time and resources spent on planned maintenance, and reducing the amount of unplanned maintenance or repair work resulting from unexpected breakdowns.

Planned work can be broken down into two main categories: preventative maintenance and planned repairs. Preventative maintenance includes all the work done not in response to a failure, but to prevent future failures from occurring. This work is typically outlined by the manufacturer in terms of frequency and work that must be performed (oil change, lube, and filter). If the fleet size remains constant, so will the level of preventative maintenance. Planned repairs are work that must be done as a result of wear and tear in which the equipment has not yet failed and can still run reliably until the maintenance department is set up with the required materials, labor, and shop space to adequately address these repairs. Because of the travel time in underground mining and the requirement in most cases to have repairs done in the shop after a wash, these two types of planned work are best done together to minimize the mechanic's trips to and from the equipment.

Given that the level of preventative maintenance will remain considerably flat, as both the materials required and time required can be predicted and cyclical, the only way to effectively increase planned work as a proportion of total work is to increase the level of planned repairs. The first task is to shift the balance of planned maintenance and unplanned maintenance. That is, to convert as much of the resources spent on unplanned work as possible into resources spent on planned work.

Converting Unplanned Work into Planned Work

The first step is to create a backlog, a master list of all known repairs that must be made to each piece of equipment in any given fleet. It consists of repairs necessary to components that are in a partial state of failure, but have not yet failed. The size of a backlog and how well it is managed will provide some valuable insight as to the overall health of your fleet. A complete detailed backlog will also provide other benefits to management when taking a closer look at each type of equipment and analyzing which components require more attention than others. If repairs to equipment must be done before the equipment actually fails, the ability to identify or predict failures before they actually occur will be crucial. Coordination can then be made for the replacement of these components before failure occurs. This can be a very difficult and daunting

[1] World Class Maintenance Management, Terry Wireman, Industrial Press Inc., 200 Madison Av., New York

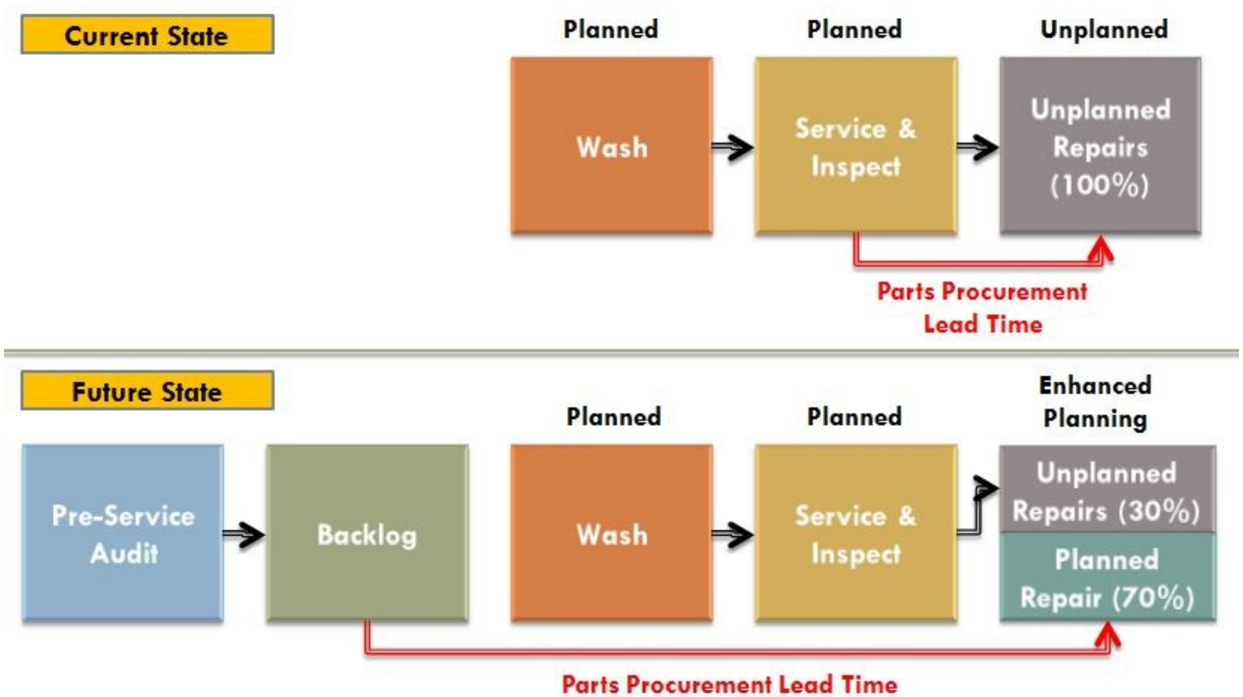
Planned vs. Unplanned Work

task when considering a large fleet with complex equipment.

The first element to be considered when creating and managing a backlog is where the backlog work will be sourced from. Where will the maintenance planners get the information to create backlog list? Each time the equipment is inspected, an opportunity is provided to gather backlog. In an underground mining environment, some of these touch points include the preventative maintenance services, planned repairs, and operator circle checks.

An additional inspection can be strategically added to generate a greater and more detailed amount of backlog. Figure 1 below depicts the impact on parts procurement time of an inspection conducted by a mechanic in a predetermined time frame before the equipment is scheduled to come into the shop for a preventative maintenance service.

Figure 1—Current State vs. Future State with Backlog



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Planned vs. Unplanned Work

Once the backlog list has been developed, the repairs can then be strategically scheduled alongside the preventative maintenance services while the equipment is already in the shop with shop space and labor assigned to it. Additionally, once these repairs have been scheduled, parts and materials can be ordered, packaged, and delivered to the shop where the repairs will be completed.

The supply benefits of planning repairs before failure are amplified in underground mining as the remote locations can be difficult for suppliers to deliver to. Even once on site, the materials must go through a complex supply delivery system to make their way underground. Planning these repairs ahead of time allows the equipment to run for the duration of this prolonged lead time. If the equipment is run until failure, it will remain down for the entire duration of this lead time until the needed parts can be delivered.

In generating and completing the backlog list against each piece of equipment, failures and breakdowns that would normally occur can now be discovered before failure and repaired on average much quicker than if the equipment would have broken down. The backlog system is working towards converting unplanned maintenance work into planned maintenance work, and therefore consuming one third of the resources on each repair converted as would normally be expended.

Reducing Overall Breakdowns

Avoidable vs. Unavoidable

There are many precautions that operators can take to minimize the impact on the equipment they are using. However, to a large degree, the environmental stresses presented in underground mining result in an inevitable level of required maintenance on all mobile equipment being used. The most important aspect when analyzing breakdowns is to identify which breakdowns are unavoidable and which are avoidable, if changes are implemented. In order to accomplish this, detailed data must be collected on each breakdown to identify trends such as frequency and severity. The intent and end use of this data is to compile it all together to understand what failures are uncontrollable and the failures can be controlled through enhanced procedures or changes in the way the maintenance department conducts business.

Root Cause Analysis

One of the most effective methods of analyzing break-downs is to conduct a Root Cause Analysis (RCA). Some of the data needed in order to drive the analysis includes all of the unplanned failure work orders, which component required repair for each work order, and how long each work order took to complete. This analysis can be conducted on each individual piece of equipment, an entire fleet of the same type of equipment, an entire fleet of the same piece of equipment purchased in the same year, or the entire fleet as a whole. Each Computerized Maintenance Management Software (CMMS) will calculate these values in its own way. The more specific to each individual piece of equipment, the better; however, total fleet size and time constraints may not allow for each piece of equipment to be analyzed on an individual basis. The objective of the RCA is to select a failure that is having a substantial impact on the equipment in question. This can either be based on frequency or severity. Frequency being the amount of times the failure occurs within a given period. Severity being the cumulative time it takes to make the repairs within a given time period. Ideally, one or more types of failures may have a high frequency and a high severity. Collecting this data alone may uncover some surprising results. For example, some quick and easy repairs that do not take long can add up very quickly if the frequency is high enough. This can come as a shock when the total time spent on this one repair is tabulated.

Reducing Overall Breakdowns

Take, for example, the case of the Dead Battery (Figure 2). This repair on average may only take between half an hour and an hour for a mechanic to complete, including mostly drive time and a quick battery boost. It is such a quick, straight forward solution that it may not have captured much of management's attention. Nevertheless, when you consider how many times a dead battery has occurred in the last three months and total the hours involved in correcting this issue, it may show up as the number two consumer of the maintenance department's human resources (mechanics labor hours). Management must be critical at this point of statements such "that's just the work environment." Questions need to be asked about what can be done to improve the failures that drain the greatest amount of the department's resources.

An important element to consider is that there are always multiple root causes for any given failure. The intent of conducting the RCA is to uncover all of the individual root causes that may lead to the failure of the component in question. The true root causes are rarely uncovered at the first layer after asking "Why?" for the first time. Each answer provided must then be analyzed all over again, and this process must continue until all avenues have been explored and the group has arrived at a tangible end. It will often take five "whys" to uncover the true root cause of an issue. Once the session has uncovered all of the possible root causes of the failure in question, a solution must then be presented to address each one individually.

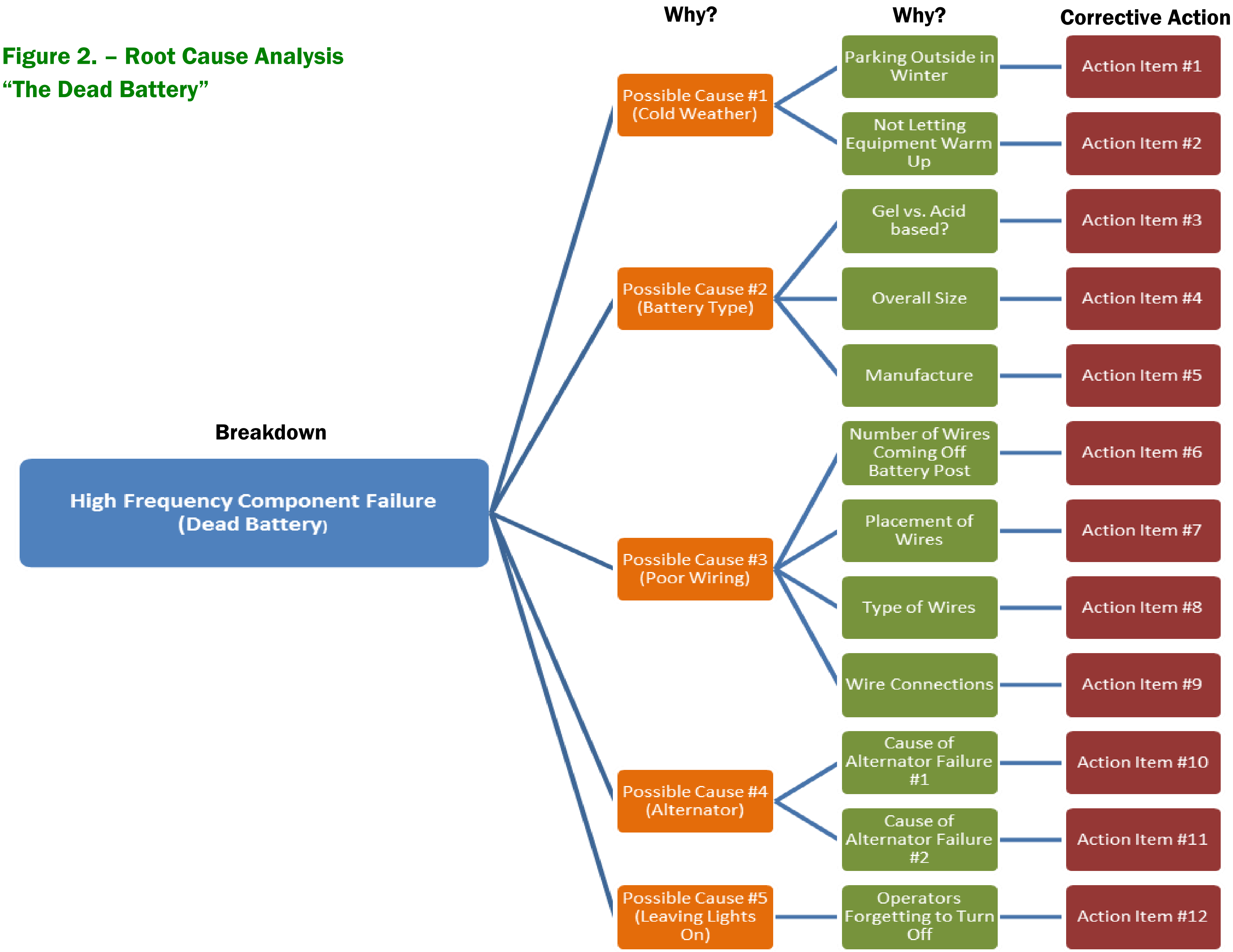
These solutions come in the form of action items which are reviewed at the end of the meeting by the management team, responsibility is assigned, expected completion dates are provided, and the method in which the solution will be accomplished is discussed.

After conducting an RCA, the management team will have a list of action items. All of which will have varying impacts on the equipment's reliability. It is important that the management team take the time to assess each item on two main criteria: how easy the item will be to complete and to what extent its effect is predicted to have on the equipment. Combining these two scales will provide a strong basis for prioritizing action items and deciding what to tackle first. The management team should begin with the high impact, easy to implement action items and leave the low impact, hard to implement action items for last.

An effective RCA session is best conducted in a room with a whiteboard large enough to draw the RCA chart, Figure 2. It is also ideal to have a knowledgeable and experienced representative from each key stakeholder group: mechanics, operators, equipment specialists, component specialists, and site management.

Reducing Overall Breakdowns

Figure 2. – Root Cause Analysis
“The Dead Battery”



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Reducing Overall Breakdowns

RCA Action Item Generation

When considering what corrective actions can be taken in order to solve the root causes of the failure in question, keep in mind the areas or touch points, as mentioned above, where changes can be made to affect the equipment. Again, these can be simplified as:

- *The Operator* (how the equipment is used)
  Change the process in which the equipment is used. Sometimes an operator is using equipment incorrectly or in a harmful way without knowing it. Added training will often improve these issues. It is common for operators to be required to inspect all equipment before use. This usually occurs in the form of a pre-use checklist. This checklist can be modified to draw the operator's attention to certain areas of the equipment where wear can be seen. Noting this wear, and informing maintenance, can prevent the component from failing during use.

- *The Mechanic* (how the equipment is repaired)
  Sometimes the method in which repairs are made inside or outside of the shop will affect the way the equipment operates. If the equipment's use is required at the time of breakdown, a mechanic may provide a "patch" to ensure it runs immediately. These "patches" however, will not always last until the next service date for the piece of equipment.

- *The Service* (how the cyclical services are conducted)
  Consider the actual activities performed on the equipment during its regular preventative maintenance service. Can these activities be changed or include more that would prevent the root cause in question? Perhaps a specific component that is failing often needs to be cleaned during the service or inspected specifically for signs of wear.

- *The Design* (how the equipment is designed or modified)
  In underground mining , equipment modifications are often required by law in North America before the equipment can even be commissioned. These modifications can vary depending on the type of underground mine. It is important to understand what impact these modifications have on the operation of the equipment. In the Dead Battery case example, maybe the equipment in question was outfitted with additional lights to make it safer to drive underground where it is pitch black. The addition of these extra lights places a larger strain on the battery and alternator. Have the battery and alternator been upgraded to keep up with this added strain as well? Figures 3 and 4 show the impact of equipment modifications: changing fan blades and wheel bearings on CAT and Trident Haul Trucks and Kawasaki Mules. These examples demonstrate how simple, inexpensive modifications were made to avoid larger and more expensive repairs down the road.

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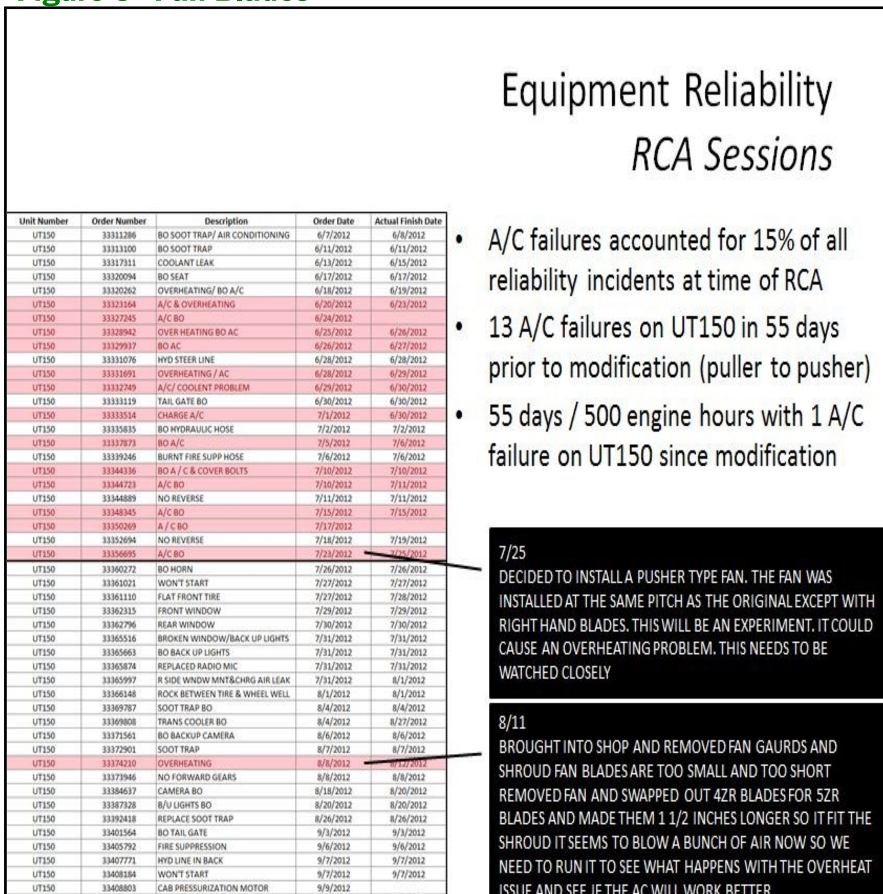
Reducing Overall Breakdowns

These are the areas that the department has complete control over. An organization cannot control the weather, but they can understand what effects the weather has and correct them at their root. Winter brings cold temperatures; cold temperatures make it difficult for equipment to start.

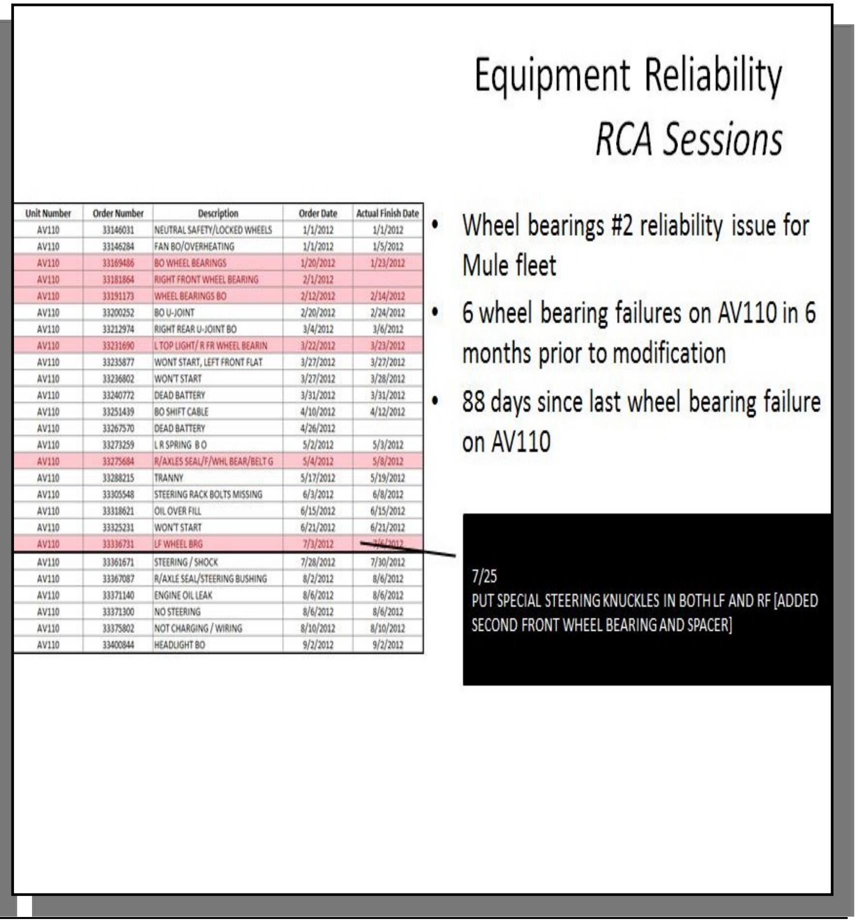
The temperature cannot be changed, but where the equipment is parked can be. Can they be stored in a heated area? Could block heaters be installed at low cost? These are the kinds of questions that must be discussed in the RCA session with all stakeholders in the room.

Figure 3—Fan Blades



Unit Number	Order Number	Description	Order Date	Actual Finish Date
UT150	33311286	BO SOOT TRAP/ AIR CONDITIONING	6/7/2012	6/8/2012
UT150	33313100	BO SOOT TRAP	6/11/2012	6/11/2012
UT150	33317311	COOLANT LEAK	6/13/2012	6/15/2012
UT150	33320094	BO SEAT	6/17/2012	6/17/2012
UT150	33320262	OVERHEATING/ BO A/C	6/18/2012	6/19/2012
UT150	33323164	A/C & OVERHEATING	6/20/2012	6/23/2012
UT150	33327245	A/C BO	6/24/2012	
UT150	33328942	OVER HEATING BO AC	6/25/2012	6/26/2012
UT150	33329937	BO AC	6/26/2012	6/27/2012
UT150	33331076	HYD STEER LINE	6/28/2012	6/28/2012
UT150	33331691	OVERHEATING / AC	6/28/2012	6/29/2012
UT150	33332749	A/C/ COOLENT PROBLEM	6/29/2012	6/30/2012
UT150	33333119	TAIL GATE BO	6/30/2012	6/30/2012
UT150	33333514	CHARGE A/C	7/1/2012	6/30/2012
UT150	33335835	BO HYDRAULIC HOSE	7/2/2012	7/2/2012
UT150	33337873	BO A/C	7/5/2012	7/6/2012
UT150	33339246	BURNT FIRE SUPP HOSE	7/6/2012	7/6/2012
UT150	33344336	BO A / C & COVER BOLTS	7/10/2012	7/10/2012
UT150	33344723	A/C BO	7/10/2012	7/11/2012
UT150	33344889	NO REVERSE	7/11/2012	7/11/2012
UT150	33348345	A/C BO	7/15/2012	7/15/2012
UT150	33350269	A / C BO	7/17/2012	
UT150	33352694	NO REVERSE	7/18/2012	7/19/2012
UT150	33356695	A/C BO	7/23/2012	7/25/2012
UT150	33360272	BO HORN	7/26/2012	7/26/2012
UT150	33361021	WON'T START	7/27/2012	7/27/2012
UT150	33361110	FLAT FRONT TIRE	7/27/2012	7/28/2012
UT150	33362315	FRONT WINDOW	7/29/2012	7/29/2012
UT150	33362796	REAR WINDOW	7/30/2012	7/30/2012
UT150	33365516	BROKEN WINDOW/BACK UP LIGHTS	7/31/2012	7/31/2012
UT150	33365663	BO BACK UP LIGHTS	7/31/2012	7/31/2012
UT150	33365874	REPLACED RADIO MIC	7/31/2012	7/31/2012
UT150	33365997	R SIDE WNDW MNT&CHRG AIR LEAK	7/31/2012	8/1/2012
UT150	33366148	ROCK BETWEEN TIRE & WHEEL WELL	8/1/2012	8/1/2012
UT150	33369787	SOOT TRAP BO	8/4/2012	8/4/2012
UT150	33369808	TRANS COOLER BO	8/4/2012	8/27/2012
UT150	33371561	BO BACKUP CAMERA	8/6/2012	8/6/2012
UT150	33372901	SOOT TRAP	8/7/2012	8/7/2012
UT150	33374210	OVERHEATING	8/8/2012	8/12/2012
UT150	33373946	NO FORWARD GEARS	8/8/2012	8/8/2012
UT150	33384637	CAMERA BO	8/18/2012	8/20/2012
UT150	33387328	B/U LIGHTS BO	8/20/2012	8/20/2012
UT150	33392418	REPLACE SOOT TRAP	8/26/2012	8/26/2012
UT150	33401564	BO TAIL GATE	9/3/2012	9/3/2012
UT150	33405792	FIRE SUPPRESSION	9/6/2012	9/6/2012
UT150	33407771	HYD LINE IN BACK	9/7/2012	9/7/2012
UT150	33408184	WON'T START	9/7/2012	9/7/2012
UT150	33408803	CAB PRESSURIZATION MOTOR	9/9/2012	

Figure 4—Wheel Bearings



Unit Number	Order Number	Description	Order Date	Actual Finish Date
AV110	33146031	NEUTRAL SAFETY/LOCKED WHEELS	1/1/2012	1/1/2012
AV110	33146284	FAN BO/OVERHEATING	1/1/2012	1/5/2012
AV110	33169486	BO WHEEL BEARINGS	1/20/2012	1/23/2012
AV110	33181864	RIGHT FRONT WHEEL BEARING	2/1/2012	
AV110	33191173	WHEEL BEARINGS BO	2/12/2012	2/14/2012
AV110	33200252	BO U-JOINT	2/20/2012	2/24/2012
AV110	33212974	RIGHT REAR U-JOINT BO	3/4/2012	3/6/2012
AV110	33231690	L TOP LIGHT/ R FR WHEEL BEARIN	3/22/2012	3/23/2012
AV110	33235877	WONT START, LEFT FRONT FLAT	3/27/2012	3/27/2012
AV110	33236802	WON'T START	3/27/2012	3/28/2012
AV110	33240772	DEAD BATTERY	3/31/2012	3/31/2012
AV110	33251439	BO SHIFT CABLE	4/10/2012	4/12/2012
AV110	33267570	DEAD BATTERY	4/26/2012	
AV110	33273259	L R SPRING B O	5/2/2012	5/3/2012
AV110	33275684	R/AXLES SEAL/F/WHL BEAR/BELT G	5/4/2012	5/8/2012
AV110	33288215	TRANNY	5/17/2012	5/19/2012
AV110	33305548	STEERING RACK BOLTS MISSING	6/3/2012	6/8/2012
AV110	33318621	OIL OVER FILL	6/15/2012	6/15/2012
AV110	33325231	WON'T START	6/21/2012	6/21/2012
AV110	33336731	LF WHEEL BRG	7/3/2012	7/6/2012
AV110	33361671	STEERING / SHOCK	7/28/2012	7/30/2012
AV110	33367087	R/AXLE SEAL/STEERING BUSHING	8/2/2012	8/6/2012
AV110	33371140	ENGINE OIL LEAK	8/6/2012	8/6/2012
AV110	33371300	NO STEERING	8/6/2012	8/6/2012
AV110	33375802	NOT CHARGING / WIRING	8/10/2012	8/10/2012
AV110	33400844	HEADLIGHT BO	9/2/2012	9/2/2012

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Measuring Performance

Key Performance Indicators

There are many options to consider when selecting which key performance indicator (KPI) will be the best measure of a department's performance. These selections will also vary according to company structure, mobile fleet size, workforce size, and equipment purpose/use. For example, there can be times where there is more equipment than actually necessary. Organizations will sometimes purchase more equipment to offset the downtime experienced from unplanned breakdowns instead of addressing the problem at the source. Why are there so many unplanned breakdowns? Or why is equipment only used for an hour or two per shift? In both cases the *Utilization* of the equipment will be extremely low. These assets that the company has paid for are not being put to work as they should. Low *Utilization* will also skew *Availability.* When *Utilization* is low, it will provide a false sense of high *Availability.* For example, if a piece of equipment is only used twice per week for an hour and fails once per week taking roughly an hour to fix, *Availability* may show the equipment being available for 334 hours out of 336 for a two week period. Available 99% of the time and since the equipment is only required about 1% of the time, production should not be impacted. The problem with unplanned breakdowns is that they only happen when the equipment is in use. Therefore, in the above situation, the equipment fails 50% of the time it is used for an hour. This paints quite a different picture.

Mean Time Between Failure and *Mean Time to Repair* are output indicators of how often equipment goes down, and how long it is down for. The answers to these two questions will show exactly how much downtime the equipment is experiencing and the level of production delays caused by the equipment.

Photo courtesy of www.atlascopco.com

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Measuring Performance

Mean Time Between Failure (MTBF)

The best measurement to surface the true reliability of equipment, when utilization is not close to 100%, is *Mean Time Between Failure.* This is calculated as the mean equipment hours at which the equipment can run before failing, regardless over what time period. MTBF will reveal how long the equipment can be used before breaking down and causing some form of production delay. Figures 5 and 6 show the impact of administered RCA action items. The "critical fleet" was the equipment considered to be critical to production and included: LHDs, Haul Trucks, and all Drills. Included manufactures were CAT, Trident, Atlas Copco, and Sandvik.

- For the Critical Fleet, MTBF increased from roughly 4.8 days between failure to 6.1 days, or an increase of 27%.
- For just the Kawasaki Mules, MTBF increased from 12 days to 18.2 days, or an increase of 51%.

Figure 5 - Critical Fleet - MTBF

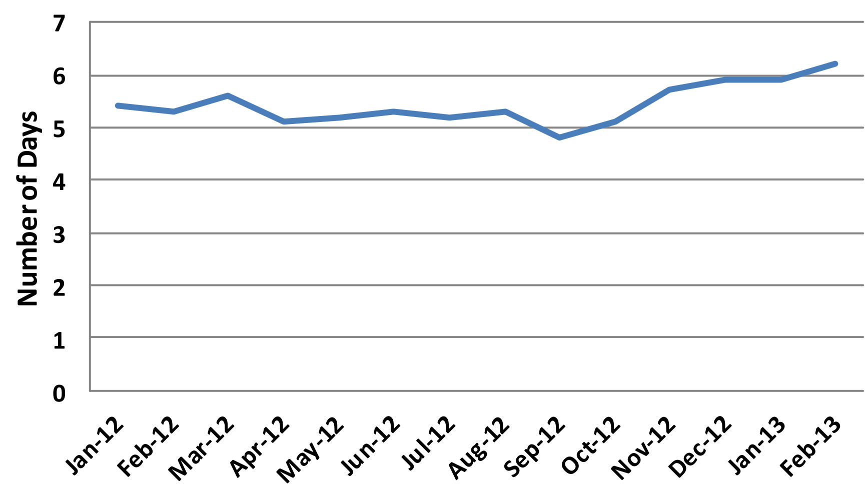
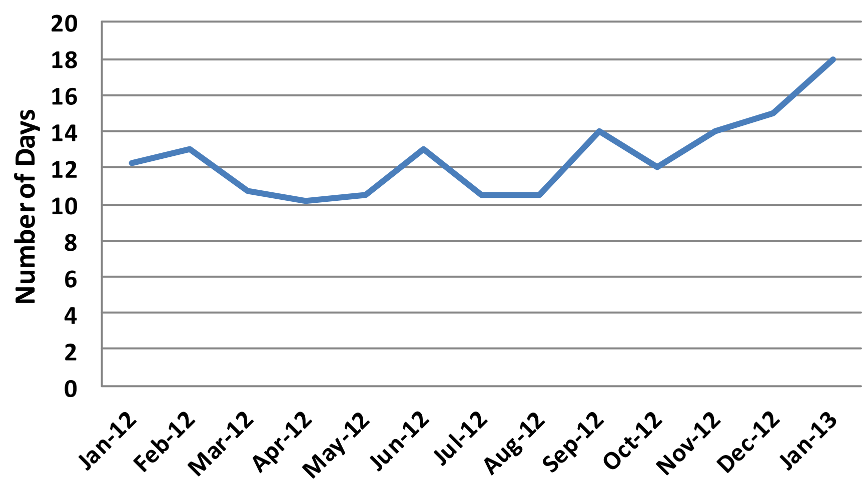


Figure 6 - Mules MTBF



Measuring Performance

Mean Time to Repair (MTTR)

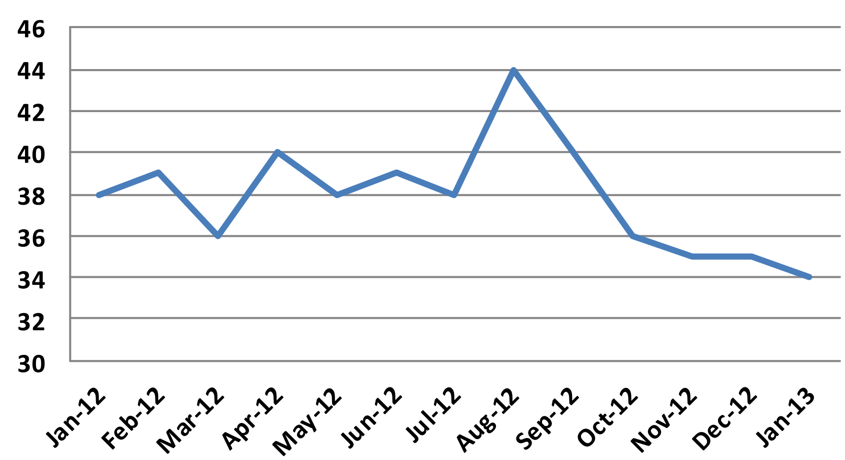
Knowing how long the equipment can run before it breaks down is an important indicator of how *effective* the maintenance program is. Knowing how long the equipment is down for is an important indicator of how *efficient* the maintenance program is. The equipment will be out of service for as long as it takes a mechanic to travel to it, assess the cause of the problem, gather the parts required to make the repair, and finally complete the repair. This can sometimes result in an extended amount of time, especially when parts are not available and must be ordered. Calculating the *Mean Time to Repair* will provide the mean time at which it takes to fix any repair on the equipment. Becoming more efficient, or conducting more repairs as planned repairs, will reduce the MTTR and therefore reduce overall downtime (production delays).

Number of Failures

Measuring the number of unplanned breakdowns/failures, and more specifically the type of failures, will provide some immediate insight towards the effects of and changes made as a result of the RCA sessions. As unplanned breakdowns are converted to planned repairs, a reduction in the overall number of failures will also be seen. Figure 7 shows an impressive decline of the number of overall failures per day seen after an improvement program was initiated at the mine.

- ► Over the course of 6 months, the overall number of failures was reduced from roughly 44 per day to 33 per day, or a 25% improvement. Labor cost savings can be estimated by multiplying this figure by the MTTR.

Figure 7 - Number of Failures per Day



Measuring Performance

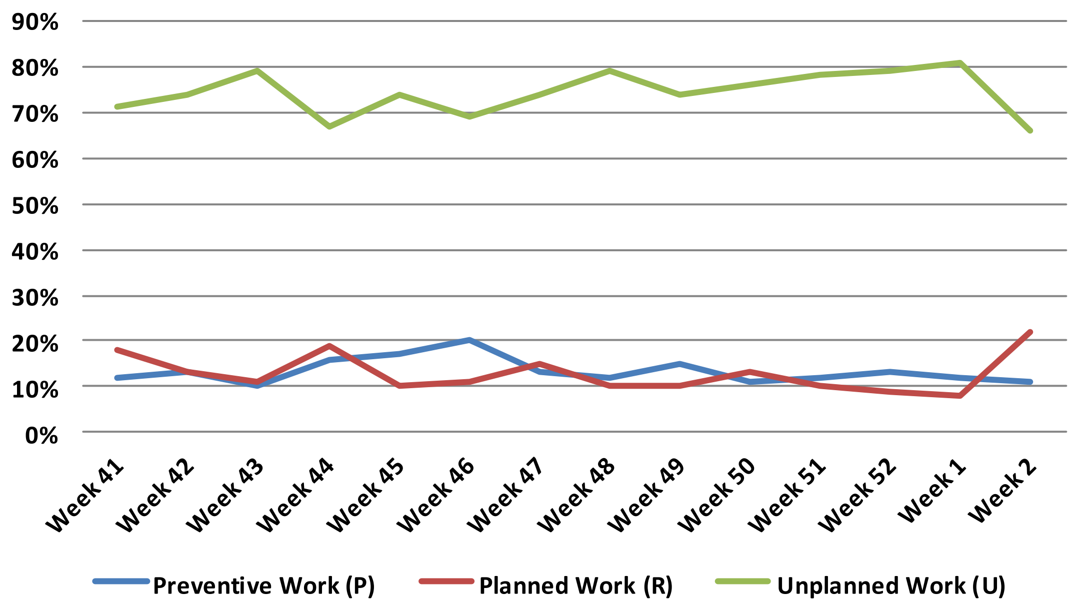
Planned Work Percentage

Planned Work Percentage is possibly the best leading indicator for *Mean Time Between Failure* and *Mean Time to Repair. Planned Work %* is calculated as the percentage of total labor hours spent on planned work (services and planned repairs) divided by the total available labor hours. As *Planned Work %* increases, *Mean Time Between Failure* will also increase and *Mean Time to Repair* will decrease.

As discussed, this combination of movements between these two KPIs will result in less overall production downtime, increasing revenues, and decreasing costs.

Figure 8 shows the relationship between the three different work types. The last data point shows the ideal trend with unplanned work decreasing and planned repairs increasing as a percentage of total work.

Figure 8 - Planned Work %



Equipment Maintenance Summarized

There are two simple goals to a successful mobile maintenance strategy for any industry that relies heavily on the use of equipment to produce or obtain their finished good.

1. To increase the reliability of the equipment by keeping it running for as long as possible
2. And doing so at the lowest possible cost.

Satisfying these two goals is instrumental to obtain profitability on both sides of the value equation. Increasing productivity will grow output and lower costs simultaneously.

Method: Convert Unplanned Work into Planned Work

To achieve the desired goal, it is important to first understand where resources are being allocated in terms of work type. What percentage of total labor hours are employees spending on planned work (services and planned repairs)? What percentage of labor hours are being spent on unplanned breakdown repairs? Keep in mind that time and resources spent on unplanned breakdown repairs could essentially be cut by 66% if they were known ahead of time and became planned work. The first task is to set up a backlog system whereby the portion of unplanned repair breakdown work can be converted into planned repairs conducted in conjunction with the periodic planned services. As more unplanned work is converted, more benefits will be seen in cost reduction (maintenance labor dollars and material dollars) and productivity (equipment will not fail unexpectedly). With planned downtime, replacement equipment can be arranged and production will be virtually unaffected.

Method: Reduce the Overall Number of Failures

There will be an unavoidable percentage of failures that will never be converted to planned work. Steps should be taken to reduce the number of these failures overall. One of the most successful methods of doing this is conducting an RCA of the high failure components for each piece or similar group of equipment. The RCA sessions should drive continuous improvement initiatives within the maintenance department and begin to impact the overall number of unplanned breakdowns. As changes are made, it is important to keep a close eye on the KPI trends and the impact of the changes. This will indicate the effectiveness of those changes.

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