Breakdown Takedown

5 steps to keep your equipment out of the shop and on the jobsite

Produced for Chevron by Preston Ingalls and Randall Reilly.

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Introduction

You depend on your company's heavy equipment to get the job done – every day. A machine breakdown can spell disaster, from both financial and customer-relation standpoints. When a component degrades to the extent it causes equipment failure, the repair will be costly and time consuming, and damage to other parts of the machine might occur as well. The entire project could be held up (potentially affecting other contractors and your customer) while you work to dispatch a replacement or rental machine to the site.

At Chevron, we know a strong, predictive and proactive maintenance approach can reduce costly equipment failures. That's why we've teamed up with noted construction-equipment-maintenance specialist Preston Ingalls to provide you with knowledge he has gained through decades of research into practices proven to maximize uptime.

When equipment managers follow the five steps outlined in this eBook, 98 to 99 percent of all maintenance can be planned, Ingalls says. The steps are based on a version of the P-F curve model Ingalls customized for the heavy-equipment industry. The P-F curve model employs a rigorous engineering process to detect and correct problems before consequential failures occur.

We hope you can implement the techniques and key practices described here to better manage your maintenance activities, lower costs and significantly reduce unplanned downtime.

About the Author

Preston Ingalls, president and CEO of TBR Strategies, has more than 45 years of maintenance and engineering experience. Based in Raleigh, North Carolina, TBR Strategies has guided hundreds of organizations to improved efficiency and reliability through better asset management.

Ingalls holds undergraduate degrees in manufacturing engineering and engineering operations and a master's degree in organizational development. He is a member of the Association for Equipment Management Professionals, Society for Maintenance and Reliability Professionals and the Association of Energy Service Companies.

STEP 1

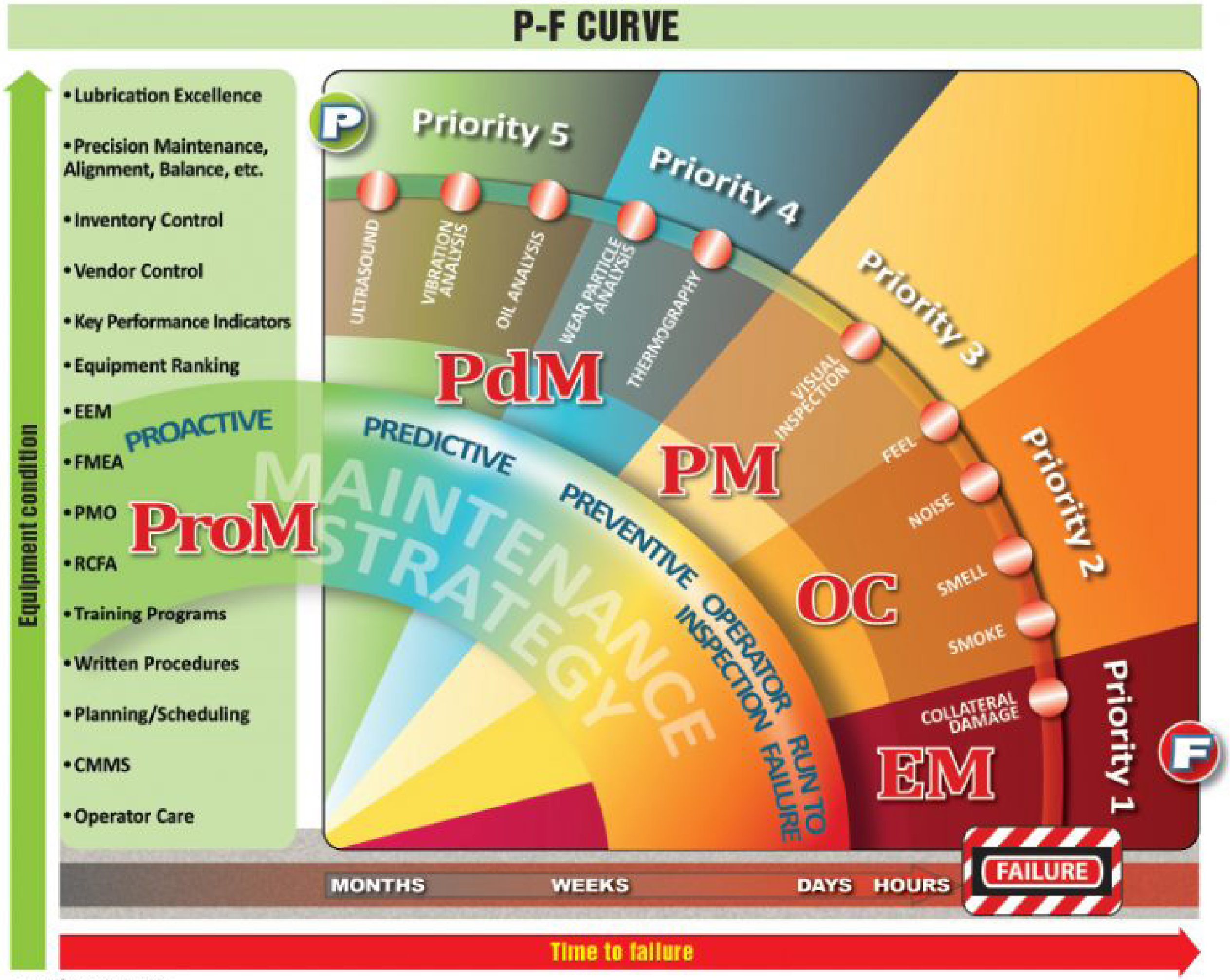
Using the P-F curve to improve equipment maintenance and management

If you're finally at the point where you realize poor maintenance practices cost you money (and good maintenance is well worth the money you invest in it), congratulations. You're on the right path. But a lot of people struggle to move beyond the basic premise of "preventive maintenance." For some, all PM entails is fluid and filter changes.

There's a lot more to it than that, including more cost savings and uptime, if you use the following chart as a basis for your strategies and actions moving forward.

The P-F curve originated from research performed by United Airlines and the Department of Defense by engineers Stan Nolan and Howard Heap. Nolan and Heap discovered that the traditional approach (using nothing but typical preventive maintenance) was a poor way to manage equipment. Instead, they applied a rigorous engineering process to identify ways to drive down costs, increase uptime and prioritize maintenance activities.

If you search "P-F curve" online, you'll find a lot of variations on this chart. At the bottom right of the chart, you see the "Failure" sign. While component failure



sounds like something you would want to prevent, Ingalls stresses that some things are better left to fail. For example, the dome light in the cab of a truck. The part is inexpensive, and its failure does little to hurt productivity or efficacy. The economically sensible thing to do is to wait until it burns out, and then stop by the auto parts store for a new bulb.

The goal is not to eliminate all failures. You are trying to eliminate consequential failures.

What all these charts have in common is that they show how most failures can be detected in advance if effective inspections are conducted. They also illustrate the condition of components as they degrade and approach failure. To help you understand how to decipher the chart, we'll break it down into three main elements: the P-F curve, its relationship to maintenance strategies, and various proactive maintenance suggestions.

The P-F curve

At the top left of the chart above, the "P" represents the point at which component failure or degradation begins. If the degradation goes undetected or uncorrected, it continues down the chart until failure of the entire machine occurs, at the F point. The period of time between P and F, commonly called the "P-F Interval," is the window of opportunity during which an inspection can detect the pending failure and resolve it through corrective action.

■ **Priority 5.** *These activities can give you notification of a pending failure* months in advance. The first two, ultrasound and vibration analysis, are mostly used in industrial settings, such as to monitor the health of conveyor belts in quarry and mining operations. Oil analysis is a must.

■ **Priority 4.** *Complete within 30 days.* Wear particle analysis, for example, is a subset of oil analysis and looks specifically for wear metals in engine oil samples. Combining oil analysis and wear particle analysis will give you predictive capabilities. For example, when wear metals or particle counts start to rise, you can predict from these indicators that component wear or failure is on the horizon.

■ **Priority 3.** *Complete within two weeks.* When you get to this stage, you are actively looking for problems on a regular or daily basis with a pre-work walk-around checklist. Nothing fancy; just a visual inspection for leaking cylinders, worn undercarriage parts, or anything out of the ordinary. These inspections should correlate to scheduled PMs at specific intervals like miles, metered hours or tonnage.

■ **Priority 2.** *Complete within five days*. Continuing on with the inspection, your operators should report any abnormalities they see, hear, smell or feel when the machine is working. These can include excessive vibration, a funny feel to the controls or driveline, change in sounds, smells (such as unburned fuel or overheated engine oil) or visible smoke.

■ **Priority 1.** *This is when damage occurs.* You've already run the machine or component to the point of failure, and work ceases. There is no choice left but to repair it. •

Definitions of Maintenance Strategies

On the inside of the priorities shell on the P-F curve, you will see a series of acronyms that describe the maintenance strategies associated with those particular time frames. These include:

PdM: Predictive maintenance, sometimes referred to as condition-based maintenance. These are processes that use known engineering limits and technology to detect an alteration in equipment condition. Some examples include; oil analysis, vibration analysis, infrared and ultrasonics.

PM: Preventive maintenance. As time passes, you rely on preventive maintenance and visual inspection by maintenance personnel to detect changes in equipment condition. Although you may perform lube and filter changes and other adjustments, the key activity here is inspection at the prescribed intervals to ensure individual components remain in spec.

OC: Operator care. As you get lower down the curve approaching the failure event, many changes are more easily detectable. Operators, if trained, can detect those changes before failure occurs by using their senses of touch, hearing, sight and smell. The objective is to use a mixture of physical inspections and technology to detect changes early and prevent failures from occurring.

EM: Emergency maintenance. These are repairs you must make immediately to prevent a component failure from cascading into a larger, systemic problem.

STEP **2**

Training operators to service their machines


Image: Pat Ryan

Most people think modern construction equipment is more reliable. Yet in the 1950s the average breakdown rate was about 20 to 25 percent. By the 1990s that figure had risen to 60 percent.

Why, when the equipment was getting better, were emergency repair rates creeping up decade after decade? In the 1950s an operator was expected to be a fair mechanic and take good care of his machine. A well-rounded operator back then knew how to use his eyes and ears and sense of smell and his ability to detect unusual vibration to tell when something was starting to deteriorate.

Today, everybody is specialized. Operators operate and mechanics take care of the equipment. Trouble is, the typical mechanic or service tech may be responsible for dozens of machines and may only spend an hour or two with each one every few months. That's no substitute for the kind of care a well-trained operator can provide for a machine he works with 20 to 40 or more hours a week.

A properly trained operator can detect 70 to 75 percent of all potential failures. Companies that have trained their operators and have established auditing and accountability procedures substantially reduce equipment downtime and the cost of repairs.

Five elements

In an operator care program, you should train your operators on five basic things

1. Knowing how to tighten, lubricate and clean components and when to do so.

2. Inspecting, detecting and correcting deficiencies before a machine runs to failure.

3. Maintaining correct operating procedures. Teach them not just how to operate the equipment, but how the equipment operates. Accidents, neglect and abuse are substantial contributors to equipment failures.

4. Improving design issues. This isn't solely the operators' responsibility, but train your operators to communicate with mechanics and fleet managers. Encourage them to speak up about access problems, ergonomic issues, any design element of the machine they think isn't right. Form equipment improvement teams to collect these suggestions and take countermeasures where you can. You should also communicate these concerns to your dealers and OEMs.

5. Elevating their skills. Give them the basic mechanical knowledge and skills they need to do simple maintenance, troubleshoot issues and understand how the machine works and reacts. Another part of this is ensuring they repair it with a "fix it right – fix it once" mentality.

There are typically three periods of time operators can perform these chores:

1. The beginning of the shift
2. During down time such as waiting for the trucks to deliver asphalt
3. At the end of the day, if you look at a typical day, eight to 10 hours, you can find 20 to 30 minutes. If you have time to lean, you have time to clean

Image: Pat Ryan

Measure and monitor

In addition to training operators, you need a process to monitor and record what they're doing. If you rely on paper or digital records kept by the operator, there is the temptation to pencil whip the results, checking off the boxes without actually performing the work.

To prevent this, you should train and field a group of auditors, people whose job it is to periodically inspect the machines and verify that they are well maintained and in good running order.

About a half-day of training is needed to create an auditor. These can be anybody in the company – executives, estimators, engineers, support staff, supervisors – not just technicians or shop personnel. It is recommended to not use operators or foremen for auditors. Operators tend to be less objective, and it's problematic to take a foreman off a busy job.

A typical construction company will need 10 or 12 percent of its employees to conduct audits. An average audit will only take about 30 minutes, and the average auditor should be able to handle three to five inspections a month.

Start with your critical equipment first, your mission essential machines. What your auditors are looking for is visible evidence that shows that the operator is maintaining this equipment to standard. Is the cab clean? Are the fluids at the proper level? Have the filters been changed? Is the machine clean overall? •

STEP 3

Training a proxy technician to help your overtaxed maintenance team

Everybody complains about the lack of diesel equipment technicians, but nobody seems to be able to do anything about it. The demand for diesel technicians is growing at 12 percent a year, yet trade schools aren't training nearly enough students to meet the demand. Contractors and fleet managers can't do much about the state of vocational education, but the help everybody needs just might be sitting right under their noses. They're called "proxy techs," and they're already working for you.

A proxy is someone who has the authority to represent someone else – for example, a medic filling in for a doctor on a battlefield. A proxy technician is an operations person who has the additional responsibility of performing or overseeing certain maintenance and repairs on equipment. They are normally rewarded or receive extra compensation as an incentive. A proxy tech can be anybody in your company: operators, laborers, supervisors or truck drivers. With a little guidance, they can perform small, simple, routine maintenance tasks that take up much of a technician's workday. This frees up your trained and experienced technicians to tackle more complex problems and major repairs. While many, if not most, of your employees may say they're pedal-to-themetal all day and don't have time to work on equipment, don't forget there are plenty of rain and weather-related delays in which many on the crews are sent home. Properly trained proxy techs could use this downtime to strengthen fleet maintenance.

Elements of a program

The key to tapping into this hidden potential in your workforce is to set up a program.

Here is a 10-point list of what you need to develop a good proxy tech program:

1. Define the tasks, boundaries and limits of what your proxy techs should do.
2. Assess the skills and knowledge needed to accomplish these tasks.
3. Develop a process to train proxy techs.
4. Set up a selection and screening process.
5. List the tools and resources needed.
6. Detail the parts needed, something like an "uptime kit."
7. Develop evaluation protocols.
8. Create a system to record the work being done by proxy techs.
9. Develop key performance indicators to prove value with beginning baselines.
10. Develop compensation and reward standards.

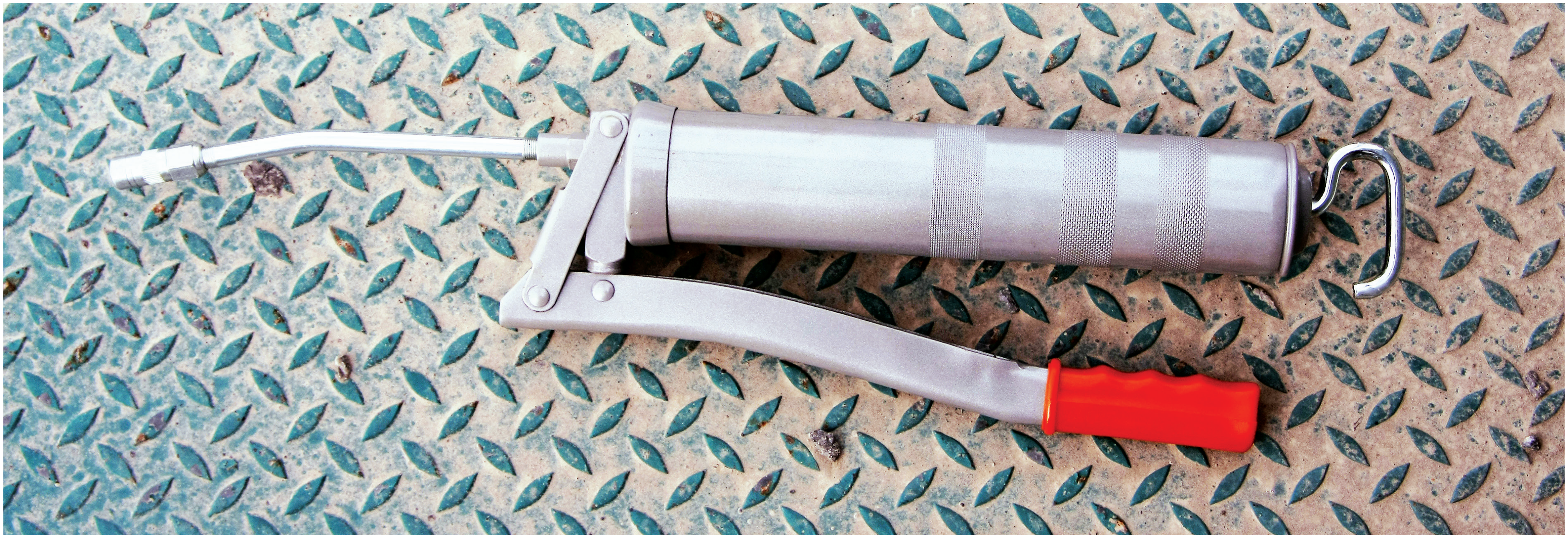
Possible tasks

Each company, its equipment and needs are unique, so you'll want to spend time on the first program element – defining what your proxy techs do – and look hard for opportunities. Here are some examples of simple tasks common to most earthmoving equipment, paving and truck maintenance facilities:

- Check and replace fuses
- Replace lightbulbs and beacon lights
- Change two-wire switches
- Replace batteries
- Check hydraulic quick connects, O-rings and hoses
- Drain fuel-water separator and change filters

Proxy techs can't replace good, well-trained mechanics – no more than an Army medic or Navy corpsman can replace a surgeon. But knowing you have someone on a dirt crew, bridge job or paving crew capable of performing basic maintenance can maximize the talent and productivity of your full-time shop technicians and reduce downtime in the field. •

STEP 4 Using the grease gun like a soldier uses his rifle



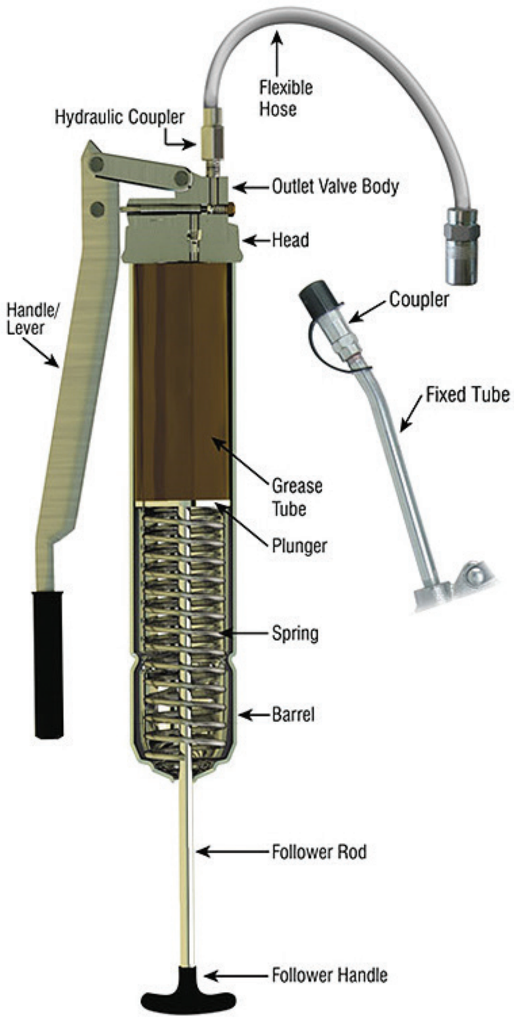
Friction is our enemy and lubrication is our ally, if applied correctly. As with any alliance, proper lubrication requires careful equipment selection and maintenance.

One way to approach lubricating construction equipment is comparing it to a soldier's responsibility toward his or her rifle.

Soldiers know to keep their weaponry in pristine condition. The ammunition has to be appropriate for the application as well, and also must be kept clean. Dirty ammunition can cause a weapon to misfire and jam — which also applies to grease guns and lubrication.

A grease gun is a deadly weapon capable of "killing" your equipment. Grease guns can produce up to 15,000 psi per stroke (shot); however, most bearing lip seals are unable to withstand more than 500 psi. Because of this, grease guns can generate significant pressure and, if improperly used, can ultimately blow out the seals designed to protect the bearings from external contaminants.

Asked why there was so much grease oozing out of a bearing, an operator once replied, "If one shot is good and two is



Anatomy of a grease gun

better, then isn't 50 wonderful?" No! A few well-targeted rounds are often more effective than "spray and pray." Overfilling bearing cavities can create major issues: Grease is forced outside the seals (path of least resistance) as the equipment heats up, and it is exposed to contaminants and moisture. When the equipment cools, the contaminated grease is sucked back into those same bearing cavities (part of thermal expansion and contraction) and can cause damage to the equipment. Overfilling the cavities also creates additional heat.

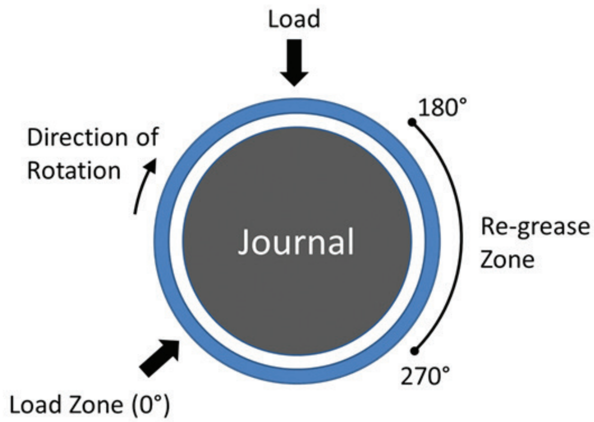
It's essential that grease is used as a lubricant because it adheres to equipment's moving surfaces without easily dripping or flowing away like oil does. Grease is a semifluid-to-solid mixture of a fluid lubricant and a thickener and may contain additives. Lubricants used in construction are either mineral oil (petroleum-based) or synthetic oil. Most grease today is composed of mineral oil blended with a soap thickener.

The location for 'firing our weapon' is not random. For a rolling element bearing there isn't much of an issue, but in construction equipment where many grease applications are bushings, grease should be applied within a 90-degree angle leading into the load zone.

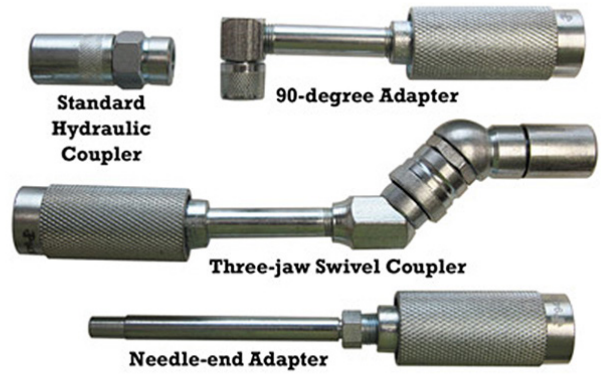
Sighting-in: calibrating the grease gun

Just as soldiers sight-in weapons to tighten the shot group, operators need to calibrate grease guns as well. Studies have shown that an individual stroke or "shot" of grease from a grease gun can vary from .5 grams to 3 grams. That is a 600-percent difference. In other words, three strokes from one grease gun may produce 1.5 grams of grease while three strokes from another could produce 9 grams.

How do we minimize this issue? It is important to calibrate each grease gun and note the volume of grease each gun delivers with one full pump or stroke. One of the common ways to calibrate grease guns is to measure the weight of one slug of grease using this method: Take a Post-it note sheet and place it on a scale. Measure its weight. Now, shoot 10 full strokes or shots of grease onto the Post-it. Deduct the weight of the paper and divide the balance by 10. That is the weight per stroke. Mark that on the grease gun, i.e. "2.5 gm/shot." It's ideal to standardize the type and therefore, the weight/stroke, on all grease guns used.



On construction equipment, grease should be applied at a 90-degree angle leading to the load zone.



Grease guns come with a variety of adaptors and couplers for different jobs and angles of application.

Weapon attachments: connectors, adapters and couplers

A grease gun may come with the standard connection adapter, such as a hydraulic coupler. However, there are several variations depending on the application. The standard hydraulic coupler is the most commonly used. A 90-degree adapter is ideal for fittings in confined areas that require a 90-degree bend. A needle-end adapter provides a thin, precise amount of grease for tight places, while a three-jaw swivel coupler offers a variety of locking positions for different applications.

The weapon barrel: flexible hose versus fixed tube

The decision about whether to use a flexible hose or a fixed tube depends on a machine's grease-fitting type and ease of location, as well as the type of grease gun used. For example, a hard-to-reach location would benefit from a flexible tube. On the other hand, lever-style grease guns require both hands to pump the grease and would favor the fixed-tube alternative.

Additional accessories

Grease-gun meters can be retrofitted onto a grease gun to help optimize lubricant consumption. Plastic caps provide benefits such as preventing corrosion and debris. They also can be color-coded so that cross-contamination does not occur. Color-coded caps can also indicate the preferred frequency of application. Other accessories such as sonic/ultrasonic devices are also available.

Are they rounds or bullets? The grease fittings

Grease fittings have several names, such as a Zerk fitting, grease nipple or Alemite fitting. This is the lubrication point where the grease connector is attached. The standard hydraulic grease fitting is most commonly used for standard applications. It can be either upright or angled. The button-head fitting is ideal for good coupler engagement when large volumes of grease are being added. A flush-type grease fitting is preferred when space is limited for standard protruding fittings, while the pressure-relief vent fitting helps prevent higher pressures that could lead to damaged seals.

Malfunctioning weapons and other issues

RAPID FIRE ISSUES: High grease gun pressure: A high-pressure manual grease gun is designed to deliver from 2,000 to 15,000 psi. Applying too much pressure while greasing will damage the bearing seals, which rarely can handle more than 500 psi. Symptoms of high grease gun pressure include collapsed bearing shields, damaged bearing seals, grease driven into electric motor windings, and safety and environmental issues.

RELOADING: Re-greasing frequency: Matching re-greasing frequencies to optimal conditions is necessary to avoid long-term machine health problems. If the frequency interval is too long, symptoms may include lubricant starvation, which promotes wear, friction and grease contamination. If the frequency interval is too short, excessive grease consumption and safety and environmental issues may occur. OEM recommendations should be examined and coupled with historical data from your computerized maintenance management system.

FIRING FOR EFFECT: Over-greasing and under-greasing: It is important to know the exact amount of grease necessary for your greasing application to avoid over-greasing or under-greasing. Symptoms of over-greasing include damaged seals and motor windings, environmental issues, and fluid friction, which lead to increased heat generation, higher grease oxidation rates and higher energy consumption. Symptoms of under-greasing include bearing starvation, which results in friction wear and increased contamination.

To overcome this problem, it is necessary to calculate the amount of grease that is released from a grease gun per stroke. Refer to the calibration method mentioned earlier. •

STEP 5

Using oil analysis to tell if your engine is healthy

Lubrication is the life blood of mechanical equipment. And just as our body's blood can become anemic or experience an imbalance of blood cells or platelets that signal biological issues, the equipment's 'blood' can show signs of wear and contamination. Where hematology is the science of blood, tribology is the science of lubrication, wear and friction control.

Oil analysis and lubrication experts at Noria Corporation cite several "illnesses" that can be detected from oil analysis:

- A spike in iron and aluminum levels warn of piston and cylinder wear before a major failure.
- Bearing wear rates can be determined before the crankshaft becomes badly scored.
- Fuel dilution, coolant leaks and water contamination can be detected before they become major problems.
- Contamination and combustion soot can indicate a restricted air intake system, ineffective oil filters, poor combustion or a rich air/fuel ratio.

And it's not just engine oils. Noria also emphasizes the importance of analyzing routine oil samples in hydraulic systems, transmissions, gearboxes, differentials and other non-combustion lubricated systems. These may include:

- High aluminum levels that indicate hydraulic pump or converter failure.
- High chromium levels that reveal hydraulic cylinder rod scoring or gear and bearing wear.

Parameters of analysis

Oil analysis is also critical to determine proper oil drain and filter change intervals in all types of engines and equipment. Many parameters are vital to proper oil analysis interpretation, including:

- Viscosity
- Oil type
- Hours or miles of service
- Make and model of the component or system from which the sample was taken

This information should be printed on a card usually provided in the oil sample carton, with oil samples taken at regular intervals. As with any mechanical system, it should reach its operating temperature before the sample is taken, to ensure the sample has completed full-system circulation. In addition, the sample should always be taken from the same place in the system, such as a pre-filter, valve-mounted oil return line.

From the air into your engine

Mark Barnes, vice president of Des-Case's Equipment Reliability Services team, makes the following compelling point about particle contamination in engines:

"Perhaps the biggest engine killer is external contamination in the form of dust and dirt sucked into the engine each minute of operation through the air intake. Particle contamination can be lethal for engines – even microscopic particles no bigger than a red blood cell can result in a significant reduction in an engine's life expectancy."

Barnes added that many engine OEMs, like GM and Cummins, have proven that particles smaller than 10 microns are three times more likely to cause wear in critical piston rings and bearings than larger particles. These particles – a tenth of the size of a human hair – can easily pass through the air filter into the engine air intake manifold.

Shelf life

With reciprocating and sliding components, lubrication is a vital fluid to engine efficiency and longevity. Like blood, lubrication does not have infinite shelf life. Most lubricants have recommended shelf lives based largely upon the lubricant's additives. For example, lubricants containing rust inhibitors may lose performance after as little as six months in storage due to additive degradation.

On the other hand, some lubricants with a light additive amount may be kept for up to three years. Shelf-life information is available from lubricant suppliers and manufacturers. •

Summary

In most cases, implementing these five steps does not mean a company must embark on a total overhaul of its maintenance program and practices. You are probably conducting many of these activities already. Maximizing results might mean tweaking your program by adding inspections, putting more effort in certain areas such as operator training and oil analysis, and ensuring general equipment upkeep is taking place.

You might be surprised how relatively small changes can make a huge difference for your company’s bottom line.