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Volume 1 Edition 7 topics

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- **Can your spare parts be made locally?**

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Failure Analysis

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Snapping shafts tell a story of deflection.

- **Asset Management**

Planning maintenance well.
Making a world-class asset management organisation.

PREHEATING WELDS

ABSTRACT

Preheating welds. Weld preheating is the purposeful application of heat to warm metal to a desired temperature prior to welding. Preheating slows down the cooling rate of the weld and gives the metal more time to form a good microstructure, release internal stresses and dissipate hydrogen from the weld. Keywords: thickness, weld puddle, cooling rate, temperature.

WHY PREHEAT WELDS?

The cooling rate affects the weld's final properties such as hardness and ductility. Preheating prior to welding will:

- Reduce the chance of catastrophic cracking in the weld from micro-cracks and trapped hydrogen gas.
- Reduce the hardness and brittleness of the weld due to rapid cooling.
- Reduce the amount of distortion caused by the weld introducing stress into the part.
- Reduce the amount of shrinkage stress from the differential temperatures present between the weld and parent metal.

The metal in all three dimensions around the weld puddle is raised to the predetermined temperature (up to 300°C (570°F) for steel) before welding and then allowed to cool-off slowly once welded. Without adequate preheat, the cooling would be rapid and intolerably high hardness and brittleness would occur in the weld and the heat affected zone (HAZ) neighbouring the weld.

WHEN TO PREHEAT?

Common materials that require preheat are steels, cast irons, copper (and its alloys) and aluminium. Often the heat from welding is sufficient to preheat the metal. However preheating the weld is required when the metal:

- is below 20°C
- conducts heat away very fast (such as aluminium, copper and both thick and thin steel sections)
- requires slow cooling to form the correct microstructure after melting (like cast irons and thin steel sections)
- will be highly stressed when in use (pressure vessels, lifting equipment, etc)

The need for preheat increases as the following factors change:

- The larger the mass being welded
- The lower the temperature of the piece being welded
- The lower the atmospheric temperature
- The smaller the welding rod diameter
- The greater the speed of welding
- The higher the carbon content in the steel
- The higher the manganese content
- The greater the alloy content in air hardening steels
- The more the air hardening capacity of the steel
- The greater the difference in mass between two pieces being joined
- The more complicated the shape or section of the part

HOW TO PREHEAT

Preheating can be done with gas torches or banks of torches, by electrical heating elements strapped to the item, in ovens or furnaces, with induction heating by an electric field and by radiant heating from a short distance off the part.

The metal is preheated to the same temperature in all three dimensions for a distance at least equal to its thickness and to a minimum distance of 75 mm all around the weld point.

HOW MUCH PREHEAT TO APPLY?

Correct preheating practice considers both the temperature to be reached and the area to be heated in order to produce the required length of cooling time. The amount of preheat depends on:

- The metal's chemistry and composition (Alloying elements in a metal affect its microstructure)
- The thickness of material (Fast cooling causes cracking)
- The joint geometry, shape and complexity (Thin sections cool faster than thick sections)
- The restraint and rigidity of the members (Parts stressed by loads need careful control of the microstructure development)
- The preheating process (Each preheat method has different rates of heat input into the metal)
- The welding process heat input (Lower preheat temperatures are needed if the welding process introduces a lot of heat)

The amount of preheat is indicated by measuring the temperature of the metal before welding. Temperature can be determined by using:

- indicating crayons that melt at prescribed temperatures (use high and low temperature indicating crayons so both the upper and lower limit can be monitored)
- electronic pyrometers and contact thermometers
- thermocouples attached to the part and connected to a display read-out.

It is important to control the cooling rate of each weld pass. Usually a metal that requires preheating must be kept at that temperature between weld passes. Most times a weld pass inputs sufficient heat but on big welds or on long welds additional heating from torches may be necessary. The rule is to "keep it hot".

CONTROLLING THE COOLING RATE

Molten metal cooled-off fast freezes the microstructure in the wrong form and is hard, brittle and full of micro-cracks. Molten metal cooled down at a slow, controlled rate consists of well-shaped crystals with alloy elements well distributed throughout the microstructure and few micro-cracks.

Once a part is welded the rate of cooling in the weld and HAZ must be slowed to acceptable limits. Tables and charts specifying cooling rates are available from welding material suppliers. The usual practice is to wrap the area around the weld in insulation. If the section is thick and the cooling is done in a draft free area it may be unnecessary to use insulation.

WHAT IF PREHEAT CANNOT BE APPLIED?

If situations arise where preheat cannot be applied there are several options which can be adopted.

- Use low hydrogen electrodes to reduce the risk of cracking.
- Peen the weld as it cools off with a blunt pointed hammer. The hammer blows from peening the weld vibrate the microstructure and tend to break it up into finer crystals.
- Use multiple weld passes to seal the join. Each subsequent pass tends to heat treat the preceding welds and provides a cover to reduce the rate of heat loss.

Mike Sondalini - Maintenance Engineer

Can your spare parts be made locally?

ABSTRACT

Can your spare parts be made locally? When spares cannot be purchased easily it becomes necessary to manufacture your own. Local fabricators, foundries and machine shops can often make the item if you provide them with a design and specification. Keywords: casting, reverse engineering, metallurgy, original equipment manufacturer, second hand.

When you need a spare part for equipment made overseas be prepared to pay up to three times what it is worth. Wasting that sort of money puts 'a chill' up the spine of a maintenance manager. The logical thing is to ask if the part can be made cheaper locally. In a lot of cases it can be with both a better price and faster delivery. Reverse engineering, as this process is often called, can offer opportunity to lower maintenance costs and improve equipment operation.

THE COST OF SPARE PARTS

The cost of a part brought from overseas or interstate will include shipping and freight charges, possibly customs duties and taxes, profits for various middlemen and one-off production costs for the manufacturer if the spare is made from design drawings. The supplier also knows that you are in no position to bargain. And people being people, he will add on a premium because he knows you have no choice but to pay up. Fortunately the high price affords you an opportunity to absorb the development cost of a replacement part within the cost you would have to pay to the original equipment manufacturer (OEM).

Difficulties also arise if the equipment is an old model and it is out of production or if the machine was a one-off-special design. OEMs will not supply spares for their machines indefinitely. Some manufacturers will have spares available for up to 25 years while others will only carry spares for 10 years. Obviously it is in their interest to get you to buy new machines instead of keeping the older models in use.

REPLACEMENT DECISIONS

The decision to replace a machine is an investment decision. You need to determine if the cost of replacement will lower operating costs for a sufficiently long period of time to recoup the money required for maintaining the existing machine over the same period of time. This explains why machines are kept in service for decades and why there is a second hand equipment market. It is very difficult to justify replacement purely on maintenance costs. Once your money is spent on equipment - you're stuck with it. The best option, if the machine is a 'dog', is to design out the problems yourself.

WHAT PARTS CAN BE MADE LOCALLY?

The sorts of parts that can be made locally depend of the technical skills available in the local industry. Are there foundries that can cast various materials? Are there fabrication shops with the equipment to make the part? Do the machine shops have machinery of the right size and type? Will the skills and abilities of the local tradesmen produce quality work? Do they have systems in place that control the quality of their production?

Shafts are probably the easiest item to get made locally, as a sample is usually easy to provide. If you don't have copies of the manufacturer's fabrication drawings the dimensions can be measured from the original. Tolerances for bearings, seals, sliding surfaces and interference fits must be determined for the fabricator and machine shop.

Small cast parts are also often easy to get locally made. Examples are pump impellers, mill hammers and liners, open gears, rollers, etc. A sample can be provided to the foundry to determine material composition and method of construction.

WHAT TO DO TO MAKE PARTS LOCALLY

Often the material from which a part is made is unknown. In such situations you need to contact a materials specialist to conduct tests on its composition. For example a metallurgist can do a spectrograph test on a piece of metal and tell from the percentages of the constituent elements the metal and its grade. With this information you can contact the local foundries and fabricators to find out if they are able to supply and work with the material.

REDESIGN THE PART IF NECESSARY

At other times you may need to redesign the part. Often a part performs a function that can be satisfied in other ways to the method used by the OEM. To permit local workshops to use their existing equipment and methods you may need to make a small adjustment to the design. You still end up with the function required but the item can now be made locally.

Can the part be made from alternate materials and by different methods? Perhaps machined or fabricated instead of cast in one large piece. Usually ingenuity and creativity finds a way.

Be prepared to work with the local shops to get what you want. You may need to experiment with designs, methods and materials. The aim is to get your parts at a better price or delivery than buying them from the OEMs. Provided it is cost effective, there is value in working through the problems that normally arise in doing something differently.

CAN YOU ON-SELL YOUR PART?

Once you have manufactured the parts and developed the drawings and material specifications you are in the position to become independent of the OEM. If the OEM no longer carries the parts, or is not prepared to make the parts, you may be able to make and sell them to other remaining users of the machine. Be careful you do not infringe copyright or patents and other similar proprietary ownership issue.

CHALLENGE FOR DESIGNERS AND PURCHASERS

If you are a designer of machinery or the person responsible for procuring equipment in your company, you are in a unique position to affect the long-term maintenance costs of the equipment users. Your choices will continue to affect people for possibly the next 30 years and in some cases up to 60 years after you make them. This means you must endeavour to keep your designs or equipment selections as simple as possible. Use the most common materials and construction techniques available that will satisfy the duty.

Much equipment is sold second-hand. Users of older equipment usually have to operate them without support from the OEM. If you have designed or selected easily maintainable equipment made of commonly available parts and materials then you have made good decisions that will benefit people for decades to come.

Mike Sondalini - Maintenance Engineer.

From the mechanical workshop.

Failure analysis of a gearbox, fan, bearing and shaft.

ABSTRACT

Failure analysis of a gearbox, fan, bearing and shaft. When equipment breaks unexpectedly it is good practice to investigate why it happened so that the root cause can be rectified and the problem prevented from again happening. There are no mysterious causes, only poor systems or system failures. It is not often that people intentionally sabotage plant and equipment. By analysing why a thing happened the lesson can be absorbed and changes made to business systems to reduce its probability of reoccurrence. In this article four equipment failures are reviewed and investigated to determine their cause and the resulting necessary changes.

Keywords: root cause failure analysis, failure mode.

We missed the gearbox oil leak and the motor burnt out.

On New Years eve the drive motor on a critical bucket elevator burnt out after 20 years of operation. Oil from the gearbox had leaked onto the windings. The oil-covered windings could no longer be cooled by the forced air draft from the fan. The motor cooked. I don't know how, but 4 of the maintenance crew came in to fix it. We had no spare. Unbelievably, and to their great credit, our supplier came in too, took a look at the drive, opened up his warehouse for us and dropped off a new drive. Just short of midnight the bucket elevator was going again.

An impressive effort by all concerned. But what happened to cause the failure? It turned out that the gearbox was not on a preventative maintenance inspection round. It had been but was taken off the list, as there was a three weekly lubrication round to grease the head pulley shaft bearings beside the gearbox. The greasing was diligently done, but the oil leaking over the motor from the gearbox was missed. Everyone thought that the person during the greasing round would look about and note any obvious problems. To be fair about the situation you should know that someone had in the past wrapped Denso tape around the leaking gearbox flange to try keeping the oil in the box. But that's where it had stopped. They may even have reported the leak, but it never actually got fixed. Everything fell apart on New Years Eve.

Are your people walking around with blinkers on? What are they missing that they should be seeing? When your people report a future problem what happens to insure it gets fixed?

In this case the gearbox and motor went back onto a 3 monthly inspection round with a comment on the checklist specifically asking if oil was leaking. The other gearboxes throughout the site had the same inspection added to their checklists. And the tradesmen were asked to not only report a problem but to raise a work order request to get it fixed.

Which way are your centrifugal fans spinning?
A fan was run in reverse and when the direction was changed the motor overloaded.

People make the mistake of thinking that when a fan goes backwards it will suck and not blow. This is true for axial flow fans but not for centrifugal fans.

Centrifugal fans, like centrifugal pumps, will force product out no matter which way they turn. If they are running backwards you will still feel a draft but the flow is very much less than it should be. When centrifugal fans are commissioned take the gas stream velocity readings and calculate the flow from the formula:

Flow (in m3/sec) **= Velocity** (m/sec) **x duct area** (m2)

Then check the flow for the fan against the design value to be sure the motor is wired in properly. If you think the 3 phase motor will handle it you could reverse two of the wires and measure the air velocity for each direction.

Before setting the motor overload protection check that the fan is running in the right direction.

Bearing temperature rocketed but there was nothing wrong.
The operator rushed into the maintenance shop saying that the hammer mill bearing was running hot with boiling grease spitting out of the bearing housing shaft seals. Damn, not again – the bearing was replaced just 4 weeks ago. Sure enough you couldn't put your hand on the bearing. My spit didn't boiler, so about 85 - 90C. (It turned out to be 95C using the temperature gun.) The grease was black from being cooked.

One of the guys got the FAG hand-held bearing vibration monitor and checked the bearing. The vibration readings were fine; there was nothing wrong. But what had made it run so hot?

It was the drive end bearing and it was under a big load from the four vee-belts running off the 45kW 4-pole motor. But that had always been the case and the bearing did not have a history of failing. The only thing that wasn't changed last time was the bearing housing; maybe the outer bearing race was spinning in the housing?

It was late in the day and we had to do something! So it was decided to change-out both the bearing and housing for new. The top half of the housing was lifted of. No burn marks on the outer race! So the bearing wasn't spinning in the housing. Then the Mechanical Maintenance Planner said he would check the recommended bearing grease viscosity from a nomogram in the SKF general bearing catalogue to see if we were using grease that was too thick. Turns out he was 'right on the money'. We were using grease with 4 times the recommended viscosity at the operating temperature than what should have been in use.

We didn't have to replace the bearing after all; we just needed to get the right grease for the application. What a complete waste of time and effort in replacing a perfectly good bearing and housing!

If you find your bearings running unexpectedly hot then be sure to check if the grease is of the right viscosity for the normal operating temperature. If it is too thick it will cause friction as the rolling elements push their way through it. If it is too thin the temperature will rise from the metal-to-metal contact between the rolling element and the raceways.

Snapping shafts tell a story of deflection.
The screw conveyor (auger) shaft was broken in half right at the center. It was a 3200 mm long, 50 mm (2") diameter, Schedule 40, 316 stainless steel pipe with the 1:1 pitch screw flights stitch-welded to it. The break was dead in the middle between the two end-supporting roller bearings.

An identical break had happened only 2 months previously. What was causing the brand new shaft to break?

A close examination of the screw conveyor trough told the story. Product had built up 10 – 15 mm thick on the bottom of the trough. It was caked on and would only come off when hit with the blade end of a pinch bar. When the screw had been in place in the trough, it was forced to ride over the thick crust, while the two ends were held tight in the bearings. The crust produced a deflection in the shaft. The biggest deflection was at the center of the screw where it caused the greatest bending stress.

As the screw turned during operation, the highest cycling stress was in the middle at the point of maximum deflection. The stress in the bar changed from tension to compression during each turn of the shaft. Exactly like you bending a paper clip up and down until it breaks. The shaft failed for the same reason – metal fatigue due to cycling stresses caused by the crust build-up bending the shaft.

If you have screw conveyors in use on crust-building product, make sure the crust on the bottom of the trough is regularly cleaned out. Otherwise be ready to change out the shaft. If you are experiencing any shaft breakage at the mid-point between end supports, check to see if the shaft is experiencing excessive deflection under cyclic or fluctuating loads. (You will soon get a fully comprehensive article in the UP-TIME monthly flyer on the analysis of this failure along with complete coverage of the development of bending stresses in beams supported at both ends.)

QUESTIONS

This e-mail arrived during the month.

Dear Sir,

I read your mechanical seal article at web site - http://www.r-t-o-l.com/learning/feedforward/mechseal.htm. Under the heading '1 Introduction' the statement below is included:

"With the *mechanical seal* faces rubbing together as they turn, no path exists for the contents to escape."

"This is wrong, because –"

"...faces rubbing together...." No; the seal faces must never rub together or failure will occur within seconds due to heat from friction. (There are some special dry running seals but that is not what is being discussed here)"

"..no path exists for the contents to escape..." No; in a healthy seal there is always a path for leakage. Mechanical seal faces must always leak in order to work. In a healthy seal, some of the barrier or pumpage fluid must always leak across the faces to lubricate and cool them."

You should re-word this, as it is a very basic item. A lot of seal system understanding depends on understanding this principle."

John Hogan
Fluor Daniel Canada
Rotating Equipment

Reply

John is absolutely right! There must be a very small amount of fluid crossing the mechanical seal faces. This fluid lubricates and cools the faces. The fluid can be either the product in the pump, if it is clean and environmentally safe, or a purposely introduced barrier fluid at a higher pressure than the product.

Mike Sondalini – Equipment Longevity Engineer

Asset Management

MAINTENANCE PLANNING – Make your Planner successful!

ABSTRACT

Maintenance Planning – make your planner successful. The efficient use of men, materials and external resources requires coordination and preparation. When a job starts everything needed to do the job must be at hand and must be right to use. The maintenance planner does the preparation required prior to the start of a job. The planner's focus is to prepare everything needed to execute a job through to its successful completion and have it ready and on-hand before the job starts. How well the planning job is done directly affects how efficiently the men do the work and how long it takes for it to be done.

Keywords: job scheduling, breakdown work.

BACKGROUND.

Why plan? Planning maintenance work maximises the benefits from the time, money and effort that go into a job. There is plenty of evidence around that proves the great value gained from maintenance planning. The "MAINTENANCE PLANNING AND SCHEDULING HANDBOOK" by Doc Palmer, published by McGraw Hill, presents clear evidence of the benefits that accrue by planning the work for your maintenance crew.

The difficulty people have with the planning process is to decide where planning starts and stops.

THE KEY CONCEPT BEHIND PLANNING.

The Chinese philosopher Confusus said - "In all things success depends on previous preparation and without such preparation there is sure to be failure."

Confusus was right. If you want things to be done successfully they must be prepared, and made ready, before doing them. The job of a maintenance planner is to prepare for the work of doing maintenance. The job of a maintenance scheduler is to prepare for the people to do the maintenance. The planner first organises everything in readiness for a job to be scheduled. But he cannot schedule the job! The persons responsible for providing the people, and the access to the equipment, must do the scheduling.

When the planner hands over a complete work pack his job is done. He is successful at the point of hand-over. He has compiled and assembled the parts, tools, resources and information needed to successfully do the work. He has done his job! He then goes back and starts preparing for the next lot of maintenance work.

A planner's job perspective and requirements are to.

- Plan first.
- Plan in detail.
- Plan then purchase.
- Hand over the completed work pack to Maintenance.
- Go back and plan the next job.
- Maintenance supervision schedules the planned work with Production supervision last.

The Planner's time scale is 5 days away and longer. Planners cannot help with breakdowns and rush jobs. It is already too late to plan! In a breakdown you can only react to what you find during the repair. The maintenance crew leading hand looks after breakdowns and those 'must-be-done-today' jobs.

Don't bother your planner if it's a breakdown or if the job must be done within the next 5 days. His role is to get ahead of today's problems and prepare for next week's successes. If you stop him from doing that you will stop having future successes. The planner's success today is everyone's success tomorrow!

THREE QUESTIONS.

What exactly is maintenance planning?

To satisfy Confusus' advice, maintenance planning is about preparing to achieve success. Do what ever is necessary to guarantee successful outcomes.

What exactly should a maintenance planner do?

To maximise the benefit from time, money and effort the planner must do all the thinking, reading, procedures, investigation and procuring so that the maintainers spend more tool-time on the plant and equipment. Good planning means high tool-time, it means machines are fixed quickly, they are fixed well and with less people and supervision.

Where exactly is the maintenance planner located so that his job can be done properly?

The planner's time focus is 5 days and longer. He cannot sit where the maintenance time focus is today and tomorrow. He must sit in an area where he is not disturbed by day-to-day issues. He also needs to be in contact with Production so he can get a feel for their priorities and production schedule. The planner sits in the Production office.

The planner must report to people whose time focus is longer than 5 days. He cannot report to workshop supervision whose time focus is today and tomorrow as the planner will then become the 'goffer' for rushed work and never find the time to be ahead of the work load. The planner reports to the Maintenance Manager and not to 'shop floor' supervision.

CONCLUSION.

Let me say it one more time, because it is so important to your success –

"The Planner's job is to get ahead of today's problems and prepare for next week's successes. If you stop him from doing that you will stop having future successes. The planner's success today is everyone's success tomorrow!"

Mike Sondalini
Equipment Longevity Engineer

Making a World-Class Asset Management Organisation?

ABSTRACT
Making a world-class asset management organisation. The very best asset managers have maintenance under control. Their entire organisation's systems and methods are tuned to preventing unplanned stoppages. They only do that which has first been thought through and prepared for. But most importantly they understand the key factor to excellent asset care and work toward it continuously and energetically.
Keywords: preventative maintenance, reliability-centered maintenance, rcm, total productive maintenance, tpm,

The universal solution to that poorly answered question of "What makes world class asset management?" was given serendipitously to me during a conversation about what makes a world class maintenance organisation. It's a question that many have tried to address but have only resulted in baffling people with theory, science and opinion and so totally missed the point. The truth is clear and simple to understand.

It was so startlingly simple when it was said that I almost dismissed it. Clearly obvious when thought about at greater depth. So straight forward in concept that any and every company can start achieving world class performance in a very short time after they firmly grasp the revelation divulged that day.

It completely explains what world class asset management is all about and how the truly successful companies achieve their world class results.

With this revelation there is now a universal strategy to adopt that will work in every company and industry.

It is simply that breakdowns overwhelm, but preventative maintenance can be planned. And planned work is the least expensive of maintenance strategies. The world class asset management organisations get their preventative maintenance up to more than 80% of their work load. This then is the clear and straight path to world class asset management – **strive to turn your maintenance around so that the vast majority of it is preventative.**

Of course the best use good-practice asset management. They have a corporate asset policy from which the production and maintenance objectives are generated and the performance measures derived. All of which is followed up with an audit process to check the degree of success in achieving the objectives.

The best practice asset managers take a lifetime view of their business. They document why and how they will use their assets to achieve their business goals. The documentation flows through the company to every level of the business defining, explaining and guiding people in their daily tasks and decision making so that everyone's actions are aligned to the lifetime business aims. The people in those companies know what they have to do; why they are doing it and the benefits that come from their efforts.

There is plenty of documentation now readily available that gives clear guidance on what is required to achieve world-class asset management performance. The most obvious and well-known one is the ISO9000 quality systems series. Others include the maintenance excellence award programs available from several organisations around the world. By following the recommendations listed in those systems a company will go a long way toward achieving asset management excellence quickly.

The good practice asset managers select reliability enhancing tools such as Reliability Centered Maintenance, Weibull Analysis and the like, which they need to improve their position. They use reliability enhancing systems and methods like Total Productive Maintenance, Kaizen continuous improvement, condition monitoring and their derivatives. **They proactively pursue low equipment failure strategies and practices.**

The supply and procurement practices used in world class operations can be summed-up in a few simple words. They work at buying the right materials at good prices, they have a high number of stock turnovers and they use supply contracts to their advantage to reduce business risk and develop proactive suppliers. They contract to the 'best of breed' suppliers and get the experts to look after specific types of equipment. Examples are using Original Equipment Manufacturers to service the complicated equipment and going to specialist, quality contractors to supply and repair routable equipment such as valves.

They may even outsource their warehousing and stock control to key suppliers under clearly understood performance based contracts and pay the contractor only for the stocked equipment actually used plus an annual management fee. The supplier manages and maintains a supply of critical spares on consignment at key locations in readiness for emergencies.

The world class players are great planners. They have a minimum 5-year plan that is cascaded down to 1-year plans then to monthly plans of major events and finally daily plans. The planning is done in detail for all activities. They check their own performance and review it weekly using Key Performance Indicators to learn what can be done better so that they continuously improve their results. They plan widely and deeply to maximise the 'wrench time' of their trades people and get great work force efficiencies.

When equipment failures occur they are analysed to find the root cause and corrected so that they will not reoccur. They have a life plan for their assets – long-term plans and short-term plans. They know how much money they should be making from each asset and can justify expenditure to keep their assets up to a specified level of performance. They use multi-skilled maintenance teams and develop the capabilities and abilities of each member in a supportive and encouraging environment.

But most of all they understand the universal worth of preventative maintenance. They know that to get world-class asset management results they must get maintenance under control, which means they need to have low equipment failure rates and so all their strategies and practices are targeted on that outcome.

Mike Sondalini – Equipment Longevity Engineer