Linking Lean Manufacturing and Reliability

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The concepts contained within Lean Manufacturing are not limited merely to production systems. These concepts translate directly into the world of maintenance and reliability.

At the core of Lean Manufacturing philosophy is the concept of elimination of waste. It is about getting precisely the right resources to precisely the right place and at the right time to make only the necessary products in the most efficient manner possible.

The concepts of the elimination of waste can be easily traced to Benjamin Franklin. Poor Richard encouraged the concepts of elimination of waste in numerous ways. Adages like "Waste not, want not", "A penny saved is two pence clear…Save and have" and "He that idly loses 5s. [shillings] worth of time, loses 5s., and might as prudently throw 5s. into the river." Yes, it was Benjamin Franklin that educated us about the possibility that avoiding unnecessary costs could return more profit than simply increasing total sales.

It was Henry Ford who took the concept of the elimination of waste and integrated it into daily operations at his manufacturing facilities. Mr. Ford's attitude can be seen in his books My Life and Work (1922) and in Today and Tomorrow (1926) where he describes the folly of waste and introduces the world to Just-In- Time manufacturing. Mr. Ford cites inspiration from Benjamin Franklin as part of the foundation of these concepts.

However, it wasn't until Toyota's Chief Engineer, Taiichi Ohno systematized these concepts and the concept of pull (kanban) into the Toyota Production System and created a cohesive production philosophy focused on the elimination of waste, that the world was able to see the real power of Lean Manufacturing. Interestingly enough, when Mr. Ohno was asked about the inspiration of his system, he merely laughed and said he read most of it in Henry Ford's book.

Part 1 of this paper will focus on one very specific Lean Manufacturing method known as 5S. This section will detail how a 5S initiative focusing on a plant's preventive maintenance program can immediately unlock resources within that maintenance department and make the preventive maintenance process significantly more effective and efficient.

Part 2 will look at the Deadly Wastes (muda) of manufacturing and how elimination of these wastes is also a focus of the reliability process.

Part 3 will discuss the overall objectives of Lean Manufacturing and parallel them with the overall objectives of the reliability process.

Part 4 will discuss Poka-Yoke (mistake proofing) and see how several standard maintenance techniques are, in fact, poka-yoke techniques. A brief discussion of kaizen and how both Lean Manufacturing and Maintenance and Reliability initiatives share these very same goals and objectives will summarize the article.

Part 1

5S is the name given to the Lean Manufacturing method for the clearing out of all unnecessary things to allow room for the acquisition of tools and parts in the fastest and easiest manner. A comparison of 5S methodology with an evaluation and optimization of a preventive maintenance program at a plant quickly shows how similar these processes are.

Seiri - Sort (tidiness and/or organize)

Lean Concept: The workplace is rid of anything that is unnecessary. Tools and parts are sorted, only the essential items are kept and they are then sorted and stored by frequency of use. This makes the workplace uncluttered, safer and enables organization for productive work.

Preventive Maintenance (PM) Application: Studies agree that somewhere between 30% and 50% of the tasks in most preventive maintenance programs are non-value added and should be removed. These tasks actually cost more to perform than the benefit they yield. The labor associated with the completion of these tasks can be reassigned to other maintenance functions like working down the ready backlog.

Seiton - Straighten (orderliness)

Lean Application: The workplace must be arranged in a systematic manner that will encourage efficiency and will reduce unnecessary travel and/or motion—a place for everything, and everything in its place, clean and ready for use with the minimum motion. Things should be placed where they best meet their functional purpose.[1]

PM Application: Another 30% of the tasks contained within most PM programs should be reassigned either to operations or to a lubrication route. Some of these tasks are generally classified as "Asset Care" tasks and should be performed by an operator. Other general inspection tasks should be reassigned to operators once they have completed task qualification training. Lubrication tasks should be reassigned to a lubrication route where a trained lubrication technician can ensure that the task is performed to industry best practices standards.

Yet another way to look at this concept with regard to 'order' is the concept of load leveling the PM tasks, operator care and inspection tasks and lubrication tasks. The tasks are grouped by functional area within the plant and then arranged to insure that each person has about the same load or amount of tasks to complete and that the tasks are grouped and arranged to be completed in the most efficient manor possible.

Seiso - Shine and Scrub (cleanliness)

Lean Application: The workplace must always be as clean as possible, giving the workplace a tell-at-a-glance visual so that a visual "sweep" reveals any out-of-place item. Waste and trash must be dealt with quickly. Machines must be kept clean making leaks and other defects more easily recognized.

PM Application: When “cleaning out” a preventive maintenance (PM) program, it should be scrubbed of all tasks that do not specifically address a failure mode or do not pass a simple cost/benefit analysis. More specifically, it should be a failure mode that is appropriate for preventive maintenance tasks. Weibull analysis of failure data should show a strong Wear Out curve. This means that it truly is a wear out mechanism and a traditional interval based activity, or PM, should be applied to properly combat it. Failure modes that exhibit a Weibull shape, indicating random failure patterns, are not good candidates for interval based PM activities. For these failure modes, a comprehensive inspection program is more appropriate. Condition monitoring technologies like infrared thermography, vibration analysis and oil analysis are very powerful tools for just such failure modes and easily pass a cost/benefit analysis.

Seiketsu - Standardize

Lean Application: Everyone agrees to and documents critical standards for how the workplace is organized and who has responsibility to maintain that organization.

PM Application: All of the tasks that remain in the PM program should follow the same agreed-to standard for format and content. All of the tasks should include a clear definition of the task, specific steps, necessary safety warnings, appropriate tools and required parts. Additionally, the tasks should contain a revision tracking mechanism and should have been through a technical review and approval process. Also, the procedure should always provide for a feedback mechanism for the crafts personnel to make suggestions and corrections about the procedure. This mechanism creates a continuous improvement loop for the task procedure.

Shitsuke - Systematize, Sustain

Lean Application: Maintaining a culture of discipline. Workplace standards are maintained day after day, and there is a system in place to ensure that 5S is sustained. Once attained, the workplace is kept safe and efficient.

PM Application: Creating a culture of discipline in the PM program requires systematizing the program, requiring the tasks be of a nature that not only encourages craft personnel response, but includes tasks that supervisors and managers perform to ensure that craft personnel know and follow the standards. PM programs where the comments and recommendations of the crafts personnel are not acted on quickly become ineffective. In creating a systematic, sustainable PM program, all of the tasks should be quantitative in nature with specific, measurable activities that detail nominal measurements with minimum and/or maximum allowable limits. PM inspections should require the use of measurement tools such as calibers, micrometers and torque wrenches. “As Found” and “As Left” comments should be required fields and their responses catalogued in the CMMS program.

Lean Manufacturing Definition	Japanese Name English Translation	Preventive Maintenance Evaluation Definition
Organized: Distinguish between the less essential and the necessary.[1]	Seiri "Separate"	Step 1: Eliminate all non-value added tasks from the PM.
Neat: Put things where they best meet their functional purpose.[1]	Seiton "Straighten"	Step 2: Reassign appropriate tasks to operations or to lubrication routes.
Clean: Inspect for and eliminate waste, dirt and damage.[1]	Seiso "Scrub"	Step 3: Eliminate all tasks that do not directly address a specific failure mode.
Standardized: Maintain known, agreed upon conditions.[1]	Seiketsu "Standardize"	Step 4: Insure all remaining tasks follow a standardized format including clear definition, specific steps, necessary safety warnings, appropriate tools and required parts.
Disciplined: Practice the habit of doing what is required even if its difficult.[1]	Shitsuke "Systematize"	Step 5: Make sure all tasks are quantitative in nature with specific, measurable activities detailing nominal measurements with minimum and maximum allowable limits.[1]

1 - A Second Look At 5S, James Van Patten, Quality Progress, October 2006

Table 1 - Summarization of 5S concepts and their inter-connectedness.

Performing a Preventive Maintenance Evaluation (PME) identifies the amount of waste in a PM program and also helps sort out which PM tasks can be reassigned to other teams within the maintenance and operations departments. It is a very quick and powerful assessment that can free up some manpower within the maintenance organization to be used for other things. Additionally, the PME process will identify how many tasks need to be optimized. A Preventive Maintenance Optimization (PMO) is the process of revisiting those tasks that will remain in the PM program and making sure all task procedures are systematic, standardized and contain all of the necessary information for the task to be completed in the most orderly and efficient manner possible.

The PME and PMO are a very powerful combination of techniques that can be performed on a PM program. Once completed, the PM program will be rid of unnecessary tasks, tasks that don't address a specific failure mode and tasks that are more appropriately assigned to other teams within the maintenance department or to other departments. Remaining tasks will be optimized for efficient completion.

Table 2 details the analysis of a PM program and the number of craft personnel that can be freed up, reassigned or used for other things such as condition monitoring.

PM Task Action Recommendation	# of Tasks	% of Tasks	Man-Hours Represented
Reassign to Operator Care	1,380	6.9%	5,605
Reassign to Lube Route	2,856	14.3%	11,600
Replace with PdM	6,437	32.2%	28,222
Re-Engineer	5,200	26.0%	26,221
No Modifications Required	2,487	10.4%	8,987
Totals	20,000	100.0%	87,297

Table 2 - Detailed analysis of a PM Program

Many maintenance organizations complain about having insufficient manpower to be able to reduce their maintenance backlog. These same organizations also complain about not having enough manpower to staff an internal PdM effort. And these same organizations complain about having a PM program that is too big, too difficult to manage, and does not produce any results, i.e. doesn't reduce unplanned downtime. By applying the 5S analogy to their PM program, companies more effectively achieve and sustain the benefits of their PM effort.

Part 2

Muda

Muda is "waste". In the context of Lean Manufacturing muda is the elimination of waste and is the core of the Toyota Production System. In maintenance and reliability terms, muda refers generally to the concept of wasted resources spent in inappropriate maintenance strategies and poor execution of daily maintenance activities.

Before wastes can be eliminated they must be identified. And for each type of waste there is a specific strategy surrounding its elimination. Toyota's Chief Engineer, Taiichi Ohno originally named 7 'deadly wastes' but 2 more have since been added. These are:

Part 3

Overproduction

Lean Definition: Making more than required by the next process, sooner than it is required, or faster than required.

Maintenance and Reliability Application: An analysis of a typical maintenance department finds a tremendous amount of 'over maintenance'. Traditionally, time-based rebuilds or component replacements have been used in an effort to combat premature equipment failures. Not realizing the random nature of the failures, a sense of frustration is felt with each emergency repair. So the frequency of the time-based replacement is increased. Maintenance costs continue to rise and failure rates are unaffected.

Elimination Strategy: The best way to eradicate this deadly waste is to gain a better understanding of the true nature of the equipment's failure patterns, and then adjust the maintenance strategy to match.

Transportation

Lean Definition: Any movement of people, materials, or information.

Maintenance and Reliability Application: The concept of transportation as a waste in a maintenance context refers directly to the amount of time that crafts personnel spend doing "go gets" whether they are getting parts in the storeroom or information for the supervisor or planner. While some "transportation" is necessary, much of it can be eliminated. Excessive transportation is most often a direct reflection of inadequate job planning or incomplete Bill of Materials (BOM).

Elimination Strategy: Improved maintenance job planning and improved job plan procedures. Create an accurate Bill of Materials for each asset. Insure parts are stored, maintained and transported in a manner that does not reduce their life cycle.

Waiting

Lean Definition: Idle resources that cannot move forward due to a delay in a downstream or upstream process, and resources waiting to be processed.

Maintenance and Reliability Application: Waiting in the maintenance context is very similar to the definition above. Instead of people waiting for work to do, it is people waiting to do work. This slight variation in statements reflects a very common problem for maintenance crafts people. Where the amount of time spent doing value-added work (a.k.a. Wrench Time) is low, it is very typical to see a maintenance crafts personnel standing around and waiting for the opportunity to work. The job is planned and may in fact be planned well, but the timing with operations was poorly coordinated. The inter-functional coordination was non-existent or at best disconnected.

Elimination Strategy: Inter-departmental communication and coordination must rise to the top of the list of priorities.

Inventory

Lean Definition: Raw material, work-in-process, work waiting to be processed, or finished goods that are in excess of the customer demand.

Maintenance and Reliability Application: Organizations who continue to operate in a reactive manner never know what is going to break next. And as such, a large amount of spare parts need to be warehoused on-site or nearby to be available for the next emergency.

Elimination Strategy: The closer an organization moves to a proactive strategy, the fewer and fewer parts need to be kept on hand. As defects are discovered early and job plans are completed early, parts can then be ordered and delivered on-time and as-needed, instead of stored in the warehouse.

Motion

Lean Definition: Movement within a process.

Maintenance and Reliability Application: Once again we find ourselves focused on the wrench time of crafts personnel. Low wrench time is a major area where improvements can be quickly achieved. Most North American maintenance organizations are surprised to learn that their wrench time is 20% - 35% or less. And even more shocked to learn that World Class is 55% - 60%. Most people guess that their maintenance crafts personnel average 70% and that 95% is possible. Improvements such as lower overtime and lower contract labor costs are easily possible with improved wrench time.

Elimination Strategy: Wrench time studies should be scheduled every year to see how the situation has changed/improved and what adjustments need to be made to make even more improvements. Items like improved planning, scheduling and parts kitting can make huge improvements to a facility's wrench time percentage.

Processing Itself

Lean Definition: Stand alone processes that are not linked to upstream or downstream processes. Using complex machines and processes to do simple tasks. Not combining tasks to simplify the process. Essentially, 'processing itself' = process simplification.

Maintenance and Reliability Application: An excellent place to see the connection between Lean and Maintenance and Reliability for the concept of "process simplification" is the fact that there is no standardization of parts across like machines. Design engineers love to use the latest and greatest parts and designs. If there is truly a competitive advantage to be gained by using a new part, then like parts in the facility should be upgraded as well. If not, then the more standardized solution should be chosen at the time of design. Simply using a different seal or impeller, just because it is new, can lead to unnecessary confusion and downtime when a repair is needed. An example might be using two different seals for the same model pump in the same application, when standardizing on one seal would save time, money and confusion; especially when one of the seals has proven to be a better performer.

Elimination Strategy: Maintainability and parts standardization must become a major focus of design/redesign efforts.

Defects

Lean Definition: Any non-conformance in the product or service that does not meet the process specifications or customer requirements.

Maintenance and Reliability Application: For maintenance, defects are the deadliest type of waste. Not only do defects cause waste, but the way that the organization addresses defects can cause more waste. Processes such as eliminating intrusive inspections, using precision maintenance techniques and implementing a condition monitoring program can make very large impacts on the number of defects present in the asset base.

Elimination Strategy: The most important point to make about defects is that an organization has to be ready, willing and able to detect these defects at their earliest stages, immediately begin the planning process to deal with the defect and then identify and eliminate the root cause of the problem. This is the only way sustainable improvements in productivity and unit cost of production can be realized.

Safety

Lean Definition: Unsafe work areas create lost work hours and expenses.

Maintenance and Reliability Application: A decrease in emergency repairs always results in a decrease in safety incidents.

Elimination Strategy: And an increase in reliability has proven time and time again to produce a decrease in injury rates. (See Figure 1)

Information

Lean Definition: The age of electronic information and enterprise resource planning systems (ERP) requires current / correct master data details.

Maintenance and Reliability: Maintenance and reliability people and information are part of the resources that need to be planned. Good planning and scheduling and effective maintenance engineering relies on complete and correct machinery design and performance information. The more incorrect or incomplete the information is for a given asset, the longer finding the solution to particular problem will take to find and the more uncertain that solution will be upon delivery. Some of the information that needs to be current and correct is the machinery failure data, bill of materials (BOM) and machinery name plate information.

Elimination Strategy: A culture of information discipline must be fostered.

Key Principles of Lean Manufacturing

A summary of Lean Manufacturing contains six Key Principles. It doesn't take a detailed analysis to find that all of these key principles are common to both Lean Manufacturing and Maintenance and Reliability.

Lean Manufacturing Key Principle #1: Pull processing: products are pulled from the consumer end (demand), not pushed from the production end (Supply). The signal that triggers pull is known as kanban.

Maintenance and Reliability: In the maintenance realm, the concept of pull is used in the design of the maintenance strategy. The potential failure modes of the equipment and the effects of those failure modes on that asset's ability to perform its function, and on the system at large, determine the maintenance strategy. Failure modes and their effects pull the maintenance strategy into existence. The OEM recommendations are not pushed as the maintenance strategy of choice. Some people may become confused at statements like these and infer that the maintenance strategy is reactive. Nothing could be further from the truth. Just like kanban is not a reaction to customer demand, neither is an Equipment Maintenance Plan (EMP) based on failures. It is based on failure modes. Failure modes are how equipment might fail or is expected to fail. The differentiating factor becomes when this analysis of failure modes and effects takes place. It is always to be done before the failures occur. It is something that is done proactively not reactively. While there is a slight difference in these two concepts, the implications of this slight difference are enormous.

Lean Manufacturing Key Principle #2: Build quality in: quest for zero defects, revealing and solving problems at the source.

Maintenance and Reliability: It is the identification and elimination of the root cause of machinery defects that drive the continuous improvement of the maintenance strategy. Procedure-based organizations use quantitative, documented procedures for both regular maintenance jobs and the preventive maintenance tasks to drive consistency and quality in the maintenance process. Additionally, these same organizations employ precision maintenance techniques to deliver right first time results. The combination of these three powerful forces has a large impact on the quest for zero defects.

Lean Manufacturing Key Principle #3: Waste minimization - eliminating all activities that do not add value & safety nets, maximize use of scarce resources (capital, people and land).

Maintenance and Reliability: 30% - 50% of the preventive maintenance tasks in a typical North American maintenance organization are non-value added tasks. Additionally, most maintenance organizations operate in a very reactive mode, and in doing so, waste a tremendous amount of valuable resources. Most studies agree that on average, 30% of the labor and 50% of the parts and materials used in unplanned jobs is wasted; not to mention the amount of unplanned downtime associated with such jobs. Those same productivity studies agree that the combination of these three items (labor, parts and downtime) along with other benefits (increased safety, decreased spares inventory, etc.) can account for as much as a 30:1 return on investment that most North American facilities have heretofore been unwilling to reach for.

Lean Manufacturing Key Principle #4: Continuous improvement - reducing costs, improving quality, increasing productivity and information sharing.

Maintenance and Reliability: At the core of every good maintenance and reliability person exists the concept of continuous improvement. Continuous improvement is an attitude and a way of life. They are always striving for a better technique, a better designed part, an improved methodology or an easier way to get Part 3 www.uptimemagazine.com 15 it done. Every maintenance person looks for a solution that makes assets easier to maintain and more reliable. And every reliability person looks for a solution that makes asset availability and plant productivity increase, and life cycle cost and unit cost of production decrease.

Lean Manufacturing Key Principle #5: Flexibility - producing different mixes or greater diversity of products quickly, without sacrificing efficiency at lower volumes of production.

Maintenance and Reliability: Flexibility is the key to keeping up with the changing business environment. It is no different for maintenance and reliability. As the market changes, so does the mix of products and volume. While the core function of a manufacturing facility rarely changes, the requirements for its operation do change and consequently the reliability and criticality of different machines can change almost on a daily basis. The onus is then on the maintenance and reliability function of a facility to create systems and processes whereby changes in the market place do not create such drastic changes in the daily execution of the maintenance process that the process itself becomes dysfunctional.

Lean Manufacturing Key Principle #6: Building and maintaining a long term relationship with suppliers through collaborative risk sharing, cost sharing and information sharing arrangements.

Maintenance and Reliability: In the sentence above, simply replace the word 'suppliers' with the word 'operations'. Now it reads: Building and maintaining a long term relationship with operations through collaborative risk sharing, cost sharing and information sharing arrangements. A partnership must be established between maintenance and operations. And as with any true partnership, it must be born of mutual respect and the attainment of common goals. A partnership that is based on 'winning and losing' or an attitude of "This is my plant and you work for me!" is destined for failure or, at best, mediocrity.

Part 4

Poka-Yoke

Poka-Yoke was first introduced at the Toyota Motor Corporation in 1961 by Shigeo Shingo, one of their industrial engineers. Originally named baka-yoke, 'fool-proofing' or 'idiotproofing', the name was changed to pokayoke or 'mistake-proofing' in 1963 to provide a more honorable, and less offensive, name. Poka-Yoke can take the form of a mechanism designed to ensure that proper conditions exist before a process step occurs, thereby preventing a defect from occurring. Poka-Yoke can also be a procedure designed to identify and/or eliminate defects as early as possible in the process. Essentially, poka-yoke is the concept of easily and quickly detecting and removing defects. There are many parallels between Lean Manufacturing and Maintenance and Reliability with respect to poka-yoke. The concept of detecting and removing defects is the very heart of maintenance and reliability efforts; and any technique that helps accomplish this easier, quicker or earlier in the process is a poka-yoke technique.

In explaining the origin of defects, Shingo said "The causes of defects lie in worker errors, and defects are the results of neglecting those errors. It follows that mistakes will not turn into defects if worker errors are discovered and eliminated beforehand". Additionally, he stated, "Defects arise because errors are made; the two have a cause-and-effect relationship."

Statistical analysis of machinery failures reflects essentially the same scenario. RCM studies from the 60's and 70's have shown that as much as 68% of failure modes detected in machinery are the result of poor maintenance and/or operating procedures; and another 14% are the result of random events caused by people's carelessness. Add to this another 7% for wear-in failures and a total of 89% of the failures are the result of people's lack of attention to detail or an incomplete understanding of their operations. This leaves only 11% of the failure modes to be the result of age, wear and fatigue. Studies from the 80's and 90's reflect that proper attention to procedures dropped the previously reported 68% to as low as 6%, but the 14% from random events climbed to as high as 25%. So while improving maintenance and operating procedures did lower the instances of infant mortality, carelessness in other areas related to operations didn't improve.

Three different types of inspection were explained by Shingo in the concept of pokayoke.

Judgment Inspection

Judgment inspection was identifying defective products or material after the completion of the process, essentially finding the defect when it is too late. Shingo warned that relying on this method isn't effective quality management and therefore judgment inspections should be avoided when possible. Maintenance and reliability personnel sometimes have no choice but to utilize this method of defect detection, as it is not manufacturing defects, but machinery defects, that are being sought. Best practices organizations use condition monitoring technologies like vibration analysis, infrared thermography and oil analysis to identify machinery defects. While there are some benefits to identifying these defects, and handling them in a proactive manner, the real benefit lies in using these condition monitoring technologies to help identify and eliminate the root cause of these defects. Not using these technologies to help eliminate the root cause of defects was the type of inspection that Shingo and the rest of the quality culture were warning against. Do not be satisfied with the fact that defects occur in your systems, and that you are able to successfully identify and eliminate them. You must move further back in the process to identify them and eliminate them at their source.

Yet another way that condition monitoring is considered a judgment inspection is in its use as a troubleshooting tool. Organizations that do not use condition monitoring technologies have to rely on the traditional troubleshooting techniques such as trial and error, disassembly and parts replacement. Utilizing condition monitoring technologies can give the crafts person a tremendous amount of information before the job has begun. Things like gear problems, electrical problems in motors and contaminant ingression can be highlighted and detailed before the machine itself is ever shut down. Using condition monitoring to help with troubleshooting, and to help identify the root cause of machinery defects, makes condition monitoring itself a very powerful judgment inspection poka-yoke technique.

Informative Inspection

The second type of inspection in the pokayoke system is the informative inspection. This type of inspection is used to prevent defects though utilizing data gathered from the inspection process. The most common example of an informative inspection is the use of statistical process control. Dr. Shingo offered two different types of informative inspection. The first method was for the very next station in the manufacturing line to perform a quality check or defect inspection on the material that just came from the previous station.

While this method was reliable and cost effective, the second method of informative inspection reduces the time and cost of the additional inspection to almost zero. And that was to have each station perform a pre- and post process inspection. Thereby simultaneously checking the quality from the previous station and checking the quality of their work before sending it to the next station.

From a maintenance and reliability perspective, an example of using this type of informative inspection would be performing Weibull analysis to constantly adjust the maintenance strategy for a piece of equipment or system within the plant. In doing so, the 'defect' that the inspection process is detecting is an inadequate maintenance strategy. Many organizations believe that using the mean time between failure (MTBF) as the proper interval for time based replacements and/or overhauls is the best method to cost effectively prevent unplanned downtime. This is not correct and results in higher costs than necessary. Weibull analysis shows that for a group of machines, by the time the MTBF is reached, 63.21% of the machines have already failed.

The better type of informative inspection would be to use failure data to populate a Weibull analysis model for the machine or system and let the analysis show the most cost effective time to perform the maintenance action. In the absence of a comprehensive failure history, a single failure point and some local knowledge about the frequency and types of failures can lead to some excellent approximations of the actual Weibull shape. This method is known as Weibayes and is a very powerful technique.

By using the failure data that comes into the CMMS system on a daily basis to keep the failure modes library and Weibull analyses up-todate, the maintenance strategies can be adjusted as more detailed information becomes apparent. Using statistical analysis in this way makes Weibull analysis an extremely effective informative inspection poka-yoke technique.

Source Inspection

The third, and final, type of poka-yoke inspection is the source inspection. Source inspection is the inspection of an operating environment or materials before the production process begins, to ensure that the proper conditions exist. Source inspections in the maintenance and reliability arena are very common. They take at least three forms when considered in the context of machinery repairs.

Precision maintenance techniques are a type of source inspection. Precision maintenance technique is defined as any technique that makes the likelihood of extended defect free operation more possible. Some examples of precision maintenance and reliability techniques might include:

•All rotating equipment will be balanced inplace to a minimum standard of 0.05 inches per second. This is significantly lower than most balance standards but not impossible. This tighter balance standard would lead to measurably longer bearing component life (in the absence of other issues).

•All rotating equipment will be aligned to <0.5 mils/inch. Just like the balance standard, this is tighter than most alignment standards and will lead to much lower radial and axial loading on the bearing and therefore longer bearing life.

•Milling the bottom of all cast frame motor feet so that they are all flat and co-planar. www.uptimemagazine.com 17 This technique makes the alignment process quicker and easier. It also helps prevent a condition called soft-foot which leads to warped motor frames, high frequency vibration in the motor bearings and reduced bearing life.

•All electrical connections will be installed using torque wrenches and will be torqued to manufacturer's specifications. Contrary to popular belief, tighter isn't necessarily better. Some types of electrical connections can be too tight, which spreads the individual strand of wire out more and creates the very problem that was trying to be avoided, a high resistance connection.

•All lubricant will be removed from the bulk container and placed into lubricant reservoirs via filter carts with a 3 micron filter. This prevents solid contaminants from being introduced into the machinery reservoir that would be detrimental to asset health.

By no means a comprehensive listing, these are just a few examples of precision maintenance techniques. Using these techniques extends the amount of time between machine commissioning and the point of defect ingression. As such, they are techniques that ensure the proper conditions are present for defectfree operation and are, therefore, a type of source inspection poka-yoke technique.

The most comprehensive source inspection poka-yoke technique is the use of procedures when performing machine repairs and inspections. Even with the most skilled crafts personnel, mistakes are made, steps are skipped and conditions are overlooked. A technically accurate, well constructed procedure decreases the conditional probability of a mistake being made. A feedback loop from the crafts person to the planner ensures the continuous refinement of the procedure. A technical review and approval process ensures that all procedures are correct and up-to-date. As these procedures are designed to help eliminate the possibility of a workmanship defect during a repair or inspection, it is a source inspection poka-yoke technique.

Another type of source inspection poka-yoke technique is the use of condition monitoring as a post-repair commissioning inspection. Technologies like vibration analysis, structureborne ultrasound, infrared thermography and motor circuit analysis are all excellent tools to certify repairs and new installations. Should workmanship defects like inadequate alignment or the presence of a bearing fault due to improper installation be identified, then the defect can be corrected before the machine is returned to service. Using condition monitoring technologies can help easily identify defects or conditions that will cause defects early in the process and is therefore a source inspection poka-yoke technique.

Kaizen

'Continuous Improvement' is the translation most often used for the Japanese word kaizen. Contrary to the popular use of the term, kaizen is not an event. Kaizen is a frame of mind or the attitude with which you address things. It means always looking at a situation with what martial arts instructors refer to as shoshin, which means "first mind" or "a beginner's mind". Beginners are always learning. With each moment of learning, improvements are made. With each improvement, more learning is desired so that more improvements can be made. This becomes a continuous cycle. With more learning comes more improvements. The moment learning ceases is the moment improvement ceases. The moment improvement ceases is the moment your competitors start to gain ground. The term 'expert' bears the connotation of "nothing left to learn". In an environment that embraces kaizen there is no such thing as an expert.

Just like kaizen, concepts like 5S, kanban, poka-yoke and muda are not single events. They are concepts that are practiced on a daily basis. Kaizen is an attitude; it is a way of life, and is the style with which Lean Manufacturing is managed on a daily basis. Kaizen is also the attitude with which maintenance and reliability should people operate on a daily basis. Just a few examples include:

•Improving maintenance job plans so that the number of side trips a crafts person has to make to acquire parts, materials and permits approaches zero.

•Improving the written maintenance procedures so that everyone, regardless of specific experience with that plant or machine, knows the proper steps to affect the repair.

•Improving the inspection process to identify defects closer to their point of inception, thereby giving the planning function more time to adequately deal with the problem.

•Improving the operations of the plant to reduce the variations in the process.

Numerous other examples could be cited, but suffice it to say the concepts of Lean and the concepts of improved maintenance and reliability go hand-in-hand. It is not just difficult to separate these concepts, it is quite frankly, impossible.

Reference 1. A Second Look At 5S, James Van Patten, Quality Progress, American Society Quality, October 2006

Andy Page is the Integration Director with GPAllied. As the Integration Director, he is responsible for combining the philosophies and daily practices of the two companies that came together to form GPAllied; General Physics and Allied Reliability. Most recently Andy was a Vice President for Allied Reliability and was responsible for the alignment of the daily practices with what was being taught in their Reliability Engineering training classes. Prior to being a Vice President, he was a Program Director for Allied Reliability responsible for the Mosaic account consisting of 27 analysts and technicians across 9 operations. Andy has 15 years in the maintenance and reliability field where he has played several different roles. First as a Maintenance Engineer for Noranda Aluminum where he was responsible for implementing a comprehensive PdM program and continuous improvements of the planning and scheduling function. Next he held the role of Regional Services Manager for CSI where he provided technical services to new customers and for the sales staff. After that he worked for Martin Marietta Aggregates as the Asset Reliability Manager responsible for PdM and maintenance improvement process effort across 23 plants in Ohio, Indiana and Michigan. Next he served as the Vice President - Operations for a small consulting firm called Reliability Solutions, Inc. in central Ohio providing PdM services primarily to the mining industry. Andy is well grounded in reliability and maintenance engineering topics with particular emphasis on PdM technologies to include advanced experience in vibration analysis and ultrasonics and Level 2 certifications in infrared thermography and oil analysis. Andy has an engineering degree from Tennessee Technological University and is a Certified Maintenance and Reliability Professional (CMRP) through the Society for Maintenance and Reliability Professionals (SMRP) and is a Six Sigma Black Belt.