Total Productive Maintenance

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1. Introduction to TPM:

In today's global economy, the survival of companies depends on their ability to rapidly innovate and improve. As a result, an increasing search is on for methods and processes that drive improvements in quality, costs and productivity. In today's fast changing marketplace, slow, steady improvements in manufacturing operations will not guarantee profitability or survival. Companies must improve at a faster rate than their competition if they are to become or remain leaders in their industry.

Western products, practices and methods were long considered the best in the world. This perception is constantly changing as a result of new competition and economic pressures. Arrogance or self assurance has devastated specific sectors of our manufacturing base. For example, the Japanese now own the consumer electronics industry. Changes in the automotive industry are well documented, and for the first time Western dominated industry such as computers and aviation are facing serious challenges by foreign competitors. Other companies and cultures have proven they can compete successfully in the world marketplace with western manufacturing. To confront this challenge, enlightened company leaders are benchmarking their organizations' performance and improvement processes against domestic and international competitors. They are adopting and adapting best in class: manufacturing practices and improvement processes. As part of these benchmarking efforts Total Productive Maintenance (TPM) has been identified as a best in class manufacturing improvement process.

Moreover cultural differences in both Japanese and Western countries can alter implementation strategies. TPM is a complex. Long term process which must be sold to the workforce as a legitimate improvement methodology. A sales pitch is created is created more easily for single homogeneous market segment than for a large diversified audience. For TPM to succeed in any industry, both management and the workforce must address issues strategically while operating in an environment of trust and organization. The improvement process must be recognized as benefiting both the company and the workers. The ultimate responsibility for success or failure of the TPM process rest more with management than the plant floor employees.

2. History of TPM:

The term "Total Productive Maintenance" was first used in the late 1960's by Nipponese, a supplier of electrical parts to Toyota. At the Time it was a slogan for their plant improvement theme "Productivity Maintenance with total employee participation. In 1971, Nipponese received the Distinguished Plant Award (The PM Prize) from Japan Institute of Plant Maintenance (JIPM). Nipponese was the first plant to receive the award as a result of implementing TPM and this marked the beginning of Jim's association with the improvement methodology. Eventually, Seiichi Nakajima, a vice chairman of JIOPM, became known as the father of TPM, since he provided implementation support to hundreds of plants, mostly in Japan.

Nakajima describes TPM as "Productive Maintenance" carried out by all employees through small group activities. He considers it an equal partner to Total Quality Management in the attainment of world class manufacturing. According to TPM principles, the responsibility for optimizing equipment lies not just with the maintenance department but with all plant personnel. Although many definitions for TPM had been gathered, for the purpose of this report, we shall define TPM as follows

TPM is a plant improvement methodology which enables continuous and rapid improvement of the manufacturing process through the use of employee involvement, employee empowerment and closed looped measurements of results.

Figure 1: Seiichi Nakajima, Founder of TPM

TPM is a method for bringing about change. It is a set of structured activities that can lead to improved management of plant assets when properly performed by individuals and teams. The culture of a plant does not evolved solely from TPM but may also be a reflection of other improvement processes that are underway such as TQM, Six Sigma, Lean, Kaizen, Root Cause Analysis etc., A critical aspect of TPM is that improvements should be rapid as well as continuous. Today's marketplace requires new paradigms. The story between the race of the hare and tortoise had to be modified. Current and future winners in industry will combine the quickness and speed of the rabbit with the perseverance of the tortoise. To attain or maintain a leadership at a rate that is much faster than their competition.

Performance target must be always be dynamic, not static. If a company sets goals and measures to reach performance levels of their best in class competitor in two years, they will lag behind, since their competition will have improved over that same period of time. To be the best in class, a company must leap-frog its competition by setting goals beyond where their competition is projected to be.

Likewise, in TPM, employee involvement is a necessary part of the TPM process. The goal is to tap into the expertise and creative capabilities of the entire plant or facility through the use of small group activities. The total involvement of plant personnel generates pride and job satisfaction as well as financial gains for the organization. Despite the advent of self managing teams employee involvement is still new and starting in most western countries. TPM requires employees to take a more active role in decision making and to accept responsibility for the plant and its physical condition. They have a heightened role in defining their job content, along with work systems and procedures. The intent of TPM is that each employee must takes pride in their equipment and all efforts must be directed the plant's objectives. For example, JIPM recommends that management adopt the theme of "My Plant" to increase the level of autonomous maintenance.

Western plants typically emphasize performance measures that are related to production and financial results. Numbers are tracked, reported by accountants and made available to selected members of the organization. There are two problems associated with classical results measurements. First, the results are not reported to all involved parties and secondly, results that are reported do not effectively measure performance. In TPM, the plant establishes the key performance indicators that measure performance relative to plant goals and objectives. These key performance indicators measure results in areas over which the plant has control. Typically, they include availability, quality, productivity and cost efficiency as well as measures of the effectiveness of the improvement process itself. The indicators are reported in a closed-loop manner back to the individuals who have the power to impact them. Hence, information is passed on to everyone including the shop floor people.

Figure 2: TPM is people involvement

Employee involvement does not mean that all decisions are made by individual workers or small group of employees; certainly it will lead to chaos. Historically, upper management has played the key role in the decision making process. TPM increases workers roles in the decision making process. TPM increases roles in providing input and in making tactical decisions. The most difficult aspect of empowering employees is determining which decisions should be made by management and their workers. Empowering the workforce is the main goal of TPM, a workforce which is enthusiastic and motivated will definitely improve the plants goals and targets.

2.1 The Spread of TPM

As said that TPM took root in the automobile industry and rapidly became part of the corporate culture in companies such as Toyota, Nissan and Mazda as well as their suppliers such as Nippondenso. It has also been introduced by other industries such as consumers, appliances, microelectronics, machine tools, plastics and many others.

Having introduced Preventive Maintenance, the process industries then began to implement TPM. An increasing number of process plants have introduced TPM over the past few years in industries such as food, rubber, oil refining, chemical, pharmaceuticals, gas, cement, papermaking, iron, steel and printing.

Initially, corporate TPM activities were limited to departments directly involved with equipment such as production, however administrative and support departments while actively supporting TPM in production are now applying TPM to enhance the effectiveness of their own activities. TPM improvement methods and activities are also being adopted in product development and sales department.

This last trend underlines the increasing tendency to consider production processes and equipment at the product development stage in an effort to simplify production, improve quality assurance and enhance and reduce the start-up period for new production. These issues are of particular concern most especially in the process industries today as product diversification continuous and product life cycle shortens. Interest in TPM outside Japan has also expanded throughout the recent years. Many companies in the United States, Europe, Asia and South America are planning to or are now actively pursuing TPM.

2.2 Why TPM is so popular?

There are three main reasons why TPM has spread so rapidly throughout Japanese industry and why companies outside Japan are becoming interested. It guarantees dramatic results, visibly transforms the work place and raises the level of knowledge and skill in production and maintenance workers.

Companies practicing TPM invariably achieve startling results, particularly in reducing equipment break downs, minimizing idling and minor stoppages (chokotei in Japanese), and lessening quality defects and claims boost in productivity, trimming labor costs, shrinking inventory, cutting accidents and promoting employees morale as shown by the increase in improvement suggestions

Through TPM, a filthy, rusty plant covered with oil, mist and grease, leaking fluids and silt powders can be reborn as a pleasant, safe working environment. Customers and other visitors are impressed by these changes and their confidence in their products increases.

As TPM activities begin to yield concrete results which is improving the working environment, minimizing breakdowns, improving quality, reducing set-up and change over times and so on, workers become motivated, involvement increases and improvement suggestions proliferate. People began to think TPM as part of their day to day jobs making TPM a way of life for all people.

TPM helps operators understand their equipment and widens the range of maintenance and other tasks they can handle. It enables them to make new discoveries, acquire fresh knowledge and enjoy new experiences. It strengthens motivation, engenders interest in their work and concern for equipment and fosters the desire to maintain equipment in top peak condition.

3. TPM Eight Pillars:

TPM involves everyone from the organization and is structured through the 8 pillars which will be explained in details. Each pillar will have their own unique role in improving the plants performance.

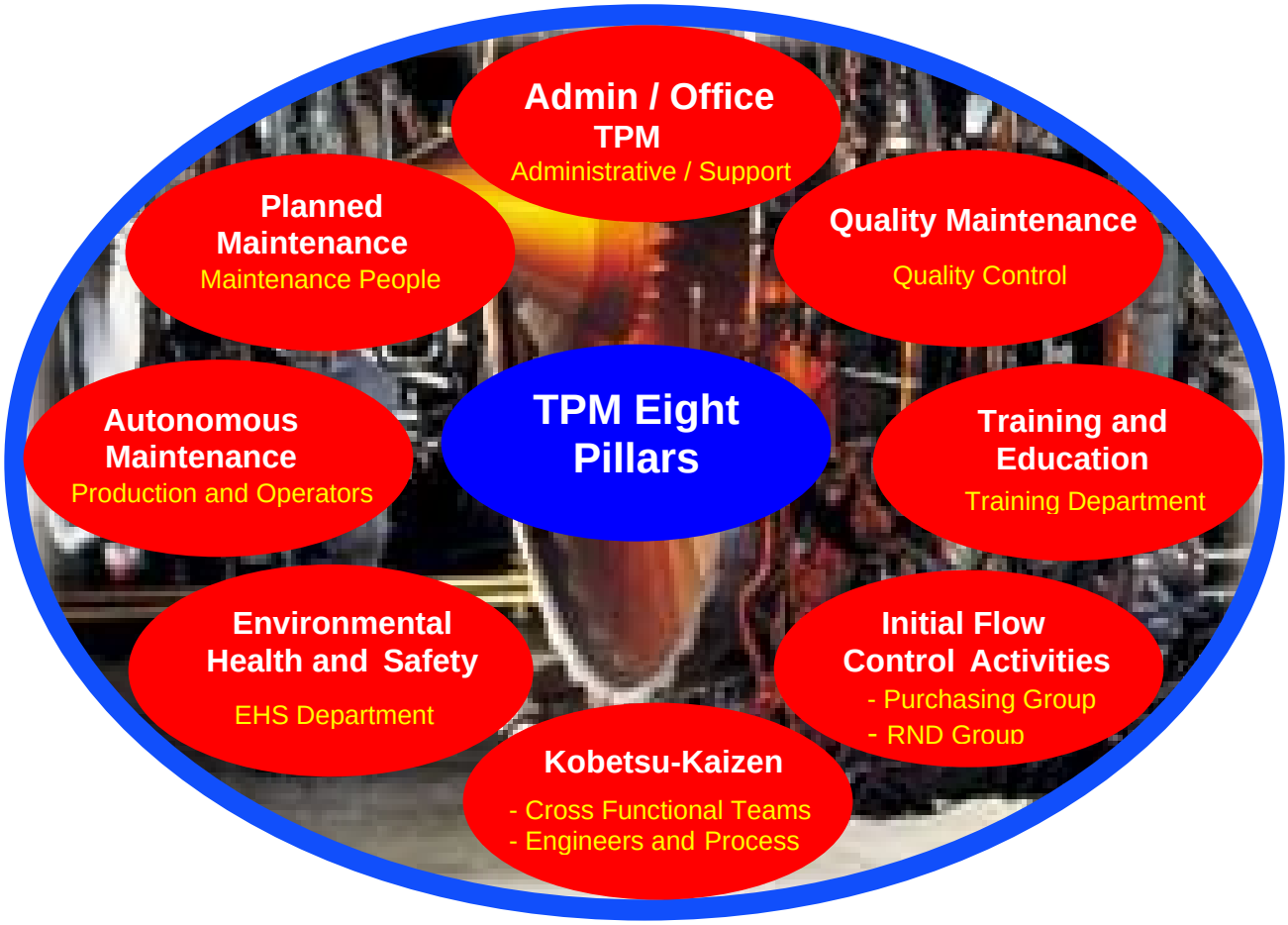

Figure 3: TPM Pillars

3.1 Training and Education:

A company's workforce is a priceless asset, and all companies must train their employees systematically. Industry workers are becoming scarcer, increasingly elite and more multi-skilled, so training must be an integral part of a career development system. Visualize the type of people you want your training program to produce. In other words, identify the specific knowledge, skills and management abilities you want them to have and then design a training program that will achieve this vision.

Training must also be tailored fit to serve the individual's needs. Assess each person to measure his or her grasp of required knowledge and skills and pinpoint weakness, then use the results to make the general training more effective. Workers and their supervisors should discuss the results of this assessment and use them to set the next year's targets and plan the next phase.

Also set firm schedules for achieving program targets. Decide the kind of people you want to have in how many year's time, then draw up a comprehensive plan for on the job and off the job training design to achieve this which also includes seminars and workshops.

Training also inevitably plays a major role in any improvement process. The continual investment in employee by upgrading their skills and capabilities is as critical as investing in plant equipment. People with the right education are an organizations most important asset. Their importance is recognized and promoted by the TPM process.

The traditional roles of the production operator, maintenance craftsperson are being reinvented. Operators are accepting greater responsibility for the health and performance of their equipment as they take on certain maintenance tasks that historically were performed by maintenance craftspeople. The craftspeople, in turn are relinquishing many routine maintenance tasks such as checking, adjusting and lubricating the equipment. Their efforts are increasingly allocated to higher value added activities such as Predictive Maintenance and Analyzing failures. Rather than simply being repairmen, they now are problem solvers performing the highly skilled analytical tasks of root cause analysis, reliability-centered maintenance and redesign. These changes in responsibilities for operators and Maintenance craftspeople have required new

Figure 4: Training and Education

Training and education plays a very important role in TPM. A training needs analysis should be performed for the different people working in the plant. Each pillar such as Planned Maintenance should be trained on maintenance related courses while Focused Improvement group should be well versed on different analytical tools and techniques. Likewise operators should be trained with proper operation and safety on their equipment. Education and training is a continuous process and should be provided to all employees.

emphasis on both basic and advance technical training. Besides the additional technical skills development, behavior, modification and process training is facilitating the change in historical work practices. This type of training usually focus on the change process and covers such subjects as group dynamics, communication workshops one point lessons and the use of disciplinary systems and procedures. Education and Training is being established to elevate the skills of operations and maintenance. It is not only limited to classroom training but also aid in the use of visual controls and one point lessons. Training group identify level of knowledge needed, prepare training curriculum and finally assess the skills of their people.

3.1.1 Four Levels of Skills:

Level 1: Lack both theoretical and practical ability (needs to be taught)

Level 2: Knows theory but not in practice

Level 3: Has mastered practice but not theory

Level 4: Mastered both practice and theory

3.2 Autonomous Maintenance:

TPM improves corporate business results and creates pleasant and productive workplaces by changing the way people think about their work with equipment through their company. Autonomous Maintenance which is performed by operators is one of the most important basic building blocks of any TPM program.

Two keys to developing a successful autonomous maintenance program are thoroughness and continuity. A further decisive factor is smooth integration with two other TPM pillars which are Planned Maintenance and Training and Education Pillar of TPM. The production department's mission is to produce good products as cheaply as possible. One of its most important roles is detecting and dealing with equipment abnormalities promptly, which is the goal of a good maintenance program. Autonomous maintenance includes any activity performed by the production department operators that has a maintenance function and is intended to keep the plant operating efficiently and stable in order to meet production plans. The goals of an autonomous maintenance program are:

- Prevent equipment deterioration through correct operation and daily checks
- Bring equipment to its ideal state through restoration and proper management
- Establish the basic conditions needed to keep equipment well maintained

Another important goal is to use the equipment as a means of teaching people new ways of thinking and working.

3.2.1 The Need for Autonomous Maintenance

In the past, plant operators in process industries were expected to keep their equipment working by checking it regularly and performing minor services. Although different companies had different practices, many expected operators to perform strip-down overhauls of equipment such as pumps. In general, plants practiced a high degree of autonomous maintenance.

During the high-growth era of the 1950s and 1960s, however, equipment became more sophisticated and complex as process plants grew larger and production technology advanced. With the introduction of preventive maintenance, equipment maintenance became increasingly specialized and more sophisticated... At the same time, many companies were making significant technical progress in automation and centralization. Faced with two oil price explosions in succession, Japanese companies reduced the number of plant operators in the aim of reducing costs. For many years now, production departments have played an exclusively supervisory role, concentrating on production and leaving maintenance to specialist which traditionally is known as:

I Operate, You Fix Syndrome

The future is uncertain, however, many companies hope to survive by cutting costs to boost their compete-ttiveness. As a result, autonomous maintenance has become an indispensible program in the drive to eliminate losses and waste from the production floor.

Participation of the production division in maintenance activities is one of the features of TPM. The importance of maintenance activities recognized anew for the corporation to survive in the fierce competitive environment. Resultantly, review of the operator's role and the maintenance operations becomes much more necessary.

Under these circumstances, QC circles and ZD (Zero Defects) campaigns have been gaining wide popularity in every enterprise and the concept that one's work should be voluntarily maintained by oneself has taken root and developed into the Jishu Hozen or Autonomous Maintenance concept of owning the equipment by oneself.

Autonomous Maintenance is the activities in which each worker performs daily inspections, lubrication, parts replacement, repair, troubleshooting, accuracy check and so forth on his own equipment, aiming at achieving the goal of keeping ones own equipment in good condition by oneself.

With the advancement of technologies, equipment has become more sophisticated and complex, and with expansion in the operation scale of enterprises, the maintenance functions have been divided into specific areas. The so called I operate you fix syndrome in which the operation division only engages in production while the maintenance division only takes care of maintenance had been disseminated throughout the production. As a result, many people came to think that the people who were engage in production should only handle the work and check their quality and such activities as the maintenance of equipment, lubrication and other care of machines and equipment should be left to the maintenance people.

Such critical attitudes such as the poor practice employed by the maintenance division and improper introduction of equipment by the division should be blamed for the trouble and we don't have any responsibility for the problem to be discarded. A little attention to additional tightening, lubrication and cleaning can often prevent trouble in advance or a little touch or care of the machine and equipment would often help to find any abnormality and prevent the trouble. In view of this operators are trained to be proficient in equipment mechanism. In order to satisfactorily perform Autonomous Maintenance, the operators should be knowledgeable with their equipment's. The operators won't be expected to merely be an operator and only sometimes be expected to initial TPM activities. In designating what cleaning tasks are of most value, the experiences of a qualified TPM trainer can be invaluable. Although individual tasks

are assigned, the small group retains total control over the project. Production operator who is regularly responsible for the machine operation must be part of the cleaning team if the group is to achieve and act as a maintenance man. The more the equipment is automated, the more the operator should be equipped with the ability to perform basic equipment maintenance.

What is important and required for an operator is to acquire the ability to find abnormality, the ability to sense abnormality of the equipment or products by feeling suspicious behavior. To acquire the mentality, the operator should have the following basic abilities.

- Ability to tell normality from abnormality precisely
- Accustomed to strictly keeping the rules of condition control
- Ability to take quick and proper action against the abnormalities

Those who have the knowledge and ability to perform this task can be useful in predicting signs of defect or failure and take the necessary steps to prevent such embryos from developing into serious problems.

Autonomous Maintenance development is performed by a team under the leadership of supervisors based on the process, primarily established in order to increase the level of equipment and workers performance efficiency step by step and to have the Autonomous Maintenance pillar performed positively in the end.

In order to maintain higher productivity equipment and to cultivate workers who are proficient with the equipment and capable of Autonomous Maintenance, a step by step development should be implemented accordingly in 7 steps. A preliminary step is quite an important one in which we can recognize why TPM is necessary through understanding the adverse effects of forced deterioration in their equipment. In order to have the concept, the source of motivation can be found in the process of action understood, the action is prerequisite. The preliminary preparation is made through considering the reason why forced or accelerated deterioration can occur and understanding the importance of such activities.

Hence, before getting down to the actual developmental steps, consideration should be given to predicted accidents and safety education should be completed. Listing of all of the predictable unsafe actions and unsafe conditions and the countermeasures for each predictable accident should be completed through the initial clean up stages.

3.2.2 Seven Steps of Autonomous Maintenance

Step 1: Initial Cleaning:

All around cleaning up of dust and dirt, centering on equipment implementation of lubrication and machine parts adjustment, discovery and repair of abnormalities found on the equipment the purpose of initial cleaning is threefold. First, small work groups are able to join together in accomplishing a common goal, the cleaning of a particular machine or process. Second, it promotes a better understanding and familiarity with the machine and third the actual machine cleaning regularly uncovers hidden defects that when corrected will have a positive effect on equipment performance. The activities associated with initial cleaning are typically performed by members of the small group as part of the full benefits of the activity. It is necessary for the team to acquire safety training before commencing on initial cleaning.

Figure 5: Team performs initial cleaning on their equipment

Training prior to performing such initial cleaning activities is critical. Initial cleaning is not intended to be an overhaul or turn around of the equipment or process area. The focus is to increase understanding of the equipment through the cleaning process. If one were to perform initial cleaning on an automobile engine, key tasks would include steam cleaning the engine exterior, checking the head gasket bolts for looseness and possibly replacing the fan belt and doing a compression check. But one would not remove the head, hone the cylinder walls or replace the bearings.

Key activities for initial cleaning include:

- Perform all activities necessary to shut down, isolate and make the equipment or process area totally safe to operated
- Obtain copies of equipment drawings, documentation, history and other relevant information. If drawing do not exists, prepare sketches of the equipment or scan photographs for use in documenting lube points adjustment points and process check points. This documentation is used in successive levels of autonomous maintenance to develop stands for lubrication and autonomous inspection.
- Document initial condition of the equipment through photographs. Prepare forms for documenting equipment defects and tags for making items needing further inspection.
- Segment portions of the machine or process area and plan how to clean the machine with maximum efficiency and effectiveness.
- Obtain hand tools, rags, brushes, solvents, mops, brooms, scrapers and other tools required to perform the cleaning tasks.
- Clean each machine segment in a methodical manner. Remember that the goal is to put the machine back into as new condition as possible.
- Remove all dirt, grime, dust, grease, oil, sludge, chips, mists, trash and excess materials. Note any equipment abnormalities such as broken switches, bent guards, missing bolts and leaks. Cleaning is also inspection. Take the time needed to do a thorough and complete job. Speed is not nearly as important as understanding and working together as a team.
- Tag and document all equipment abnormalities. Address easily corrected abnormalities immediately and write work request for other abnormalities found.
- Re torque all bolts including hold down, fasteners, adjustment and structural bolts. Mark all bolts by painting a stripe across the stud head bolt and the bolt to indicate the relative positions of both when properly torque. Any future slippage or loosening of the bolt then can be noted easily as the marks will no longer line up together.

- Repaint areas if necessary according to predetermined specifications. The purpose of repainting is not just to prevent corrosion but to provide a surface that can be examined easily for cleanliness. Color code the piping, utilities, and guards for ease and observation.
- Note and mark all lubricating points. Document the points on a lubrication chart and mark the point physically on the machine. Color coding can be performed by painting a small colored circle in close proximity to the lubrication point. Some plants use plastic colored sticker to mark the position and lubricant type instead of a paint circle. The color of the circle designates the type of lubricants to be used. Lubricant containers can be color coded by painting the container the same color as the lubrication point circles.
- Photograph the clean machine or process area and compare with a before and after photograph to verify the machines progress on initial cleaning.
- Formally turn the equipment or process area back to production for startup and operations. Have the small group participate in the setup and startup activities for greater understanding of their equipment.

The time required to complete the above steps may exceed available time for a given shutdown period. It may be necessary to schedule the above steps over several shutdown periods to accommodate operating requirements.

Dozens of equipment abnormalities or improvement suggestions may result from the initial cleaning activities on a single machine. Many of the equipment issues will be fixed or improved immediately during the initial cleaning activities. Others will be backlogged as work request to be performed by skilled trades or external contractors.

Depending on existing equipment conditions, initial cleaning activities may require a major commitment of time and resources. Most companies underestimate the size of the commitment. Once they recognize the extent of resources required they either cut back on the amount of equipment to be included or perform only superficial cleaning. Some companies invest as much as 160 hours per plant employee on initial cleaning activities. This will inevitably depend on the size of the equipment.

Step 2: Address Sources of Contamination and Inaccessible Areas:

Initial cleaning activities identify contaminant that resides in the machine or area. Each contaminant type should be identified and documented. Typical contaminant type should be identified and documented. Typical contaminants include leaking process fluids, leaking lubricants, dust, corrosion, process, scrap, material handling scrap, worker generated trash, and other external pollutants. Contaminant identification cannot always be accomplished during the initial cleaning activates. Much time, due to the volume of the contaminant and the years of buildup, the initial clean-up activity can identify only that a contaminant exists. An example is seen in a discreet manufacturing plant that was built a few years ago. Management was concerned that the plant was not able to match the productivity numbers of its sister plants in Europe, even though the European plants were at least twenty years older. The plant had hundreds of grinding machines. Each machine was equipped with a catch basin, which was loaded with metal shavings, oil, cigarette butt, and candy wrappers. It was impossible to identify whether the oil was cutting oil, hydraulic oil or another type of lubricant. When ask why the catch basin was not clean in an attempt to increase machine reliability, the tour guide reply was, they would just get dirty again. People in this plant failed to understand that clean

machines lead to improve equipment performance.

Step 3: Establish Cleaning, Inspecting and Lubricating Standards:

The development of cleaning and lubrication standards is a natural progression from the previous two levels of autonomous maintenance. Once a clean work environment is established and steps are taken to prevent deterioration, new, higher standards can be set and documented, the goal is to combine inspections for cleanliness with lubrication checks so that both activities can be performed together as efficiently as possible. Standards for lubrication and cleanliness also should be developed concurrently.

Small groups should be responsible for developing standards for equipment in their areas. The concept that should guide their work is that cleaning and lubrication are both forms of inspection. Many potential equipment problems can be spotted visually prior to their causing a deterioration in performance. For example some people establish a standard for the cleanliness and lubrication of their automobiles. In accordance with this self imposed standard, they periodically open the hood of their car to inspect fluid levels and check or change the lubricant. They also may inspect the engine block for cleanliness to ensure it is free of spilled oil and road grime. While the hood is up, a quick glance identifies whether the head gasket is leaking and whether there are any loose belts, or hoses. Those are simple activities that anyone with minor training can perform. The car owner is motivated to meet these standards of cleanliness so that he can avoid future repair bills. An individual who follows through with this type of inspection is also more likely to exercise greater caution in the operation of his vehicle. He would recognize that it is an acceptable risk to drive a car with a leaking head gasket to the repair shop, but he would not start a car with a broken oil pump in the process.

The format of cleaning and lubrication standards should be similar to that of good preventive maintenance procedures. The exemption is that they are developed by and for equipment operators as opposed to maintenance people. Visual images or pictures are excellent for communicating the designed standard. Some standards are developed in the format of a checklist for the production operator.

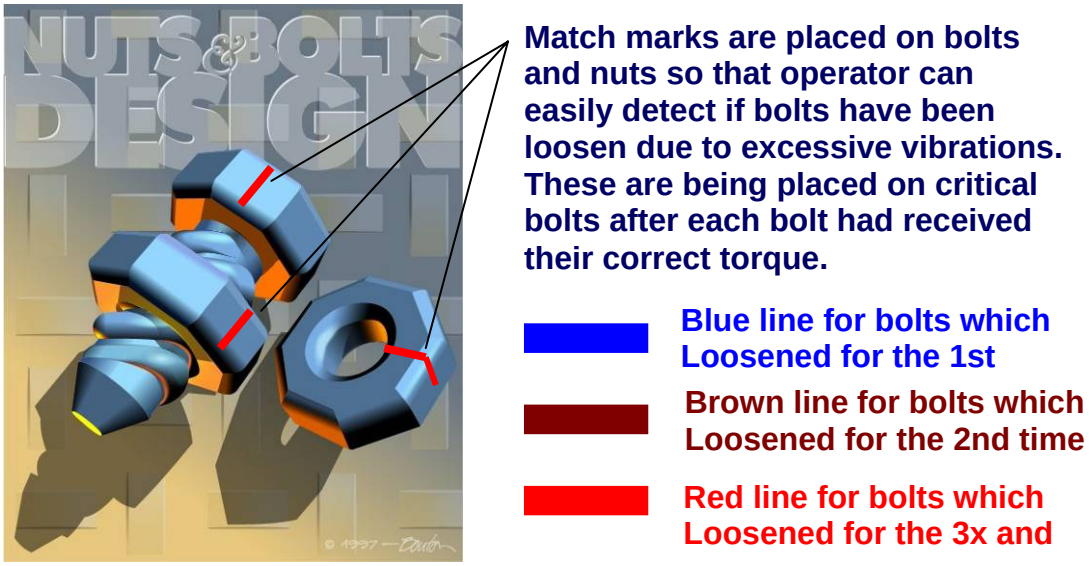

Figure 6: Use of Match Marks

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