World Class
Maintenance Management

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To

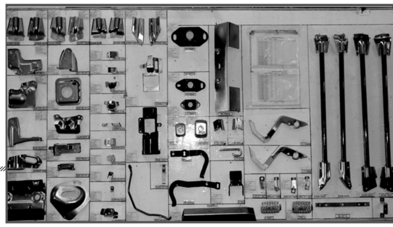
My Wife Jaya

Who encouraged me to write this book

On

World Class Maintenance

and gave me relentless support to help me in completing this manuscript



Preface

In the modern competitive world there is a continuous need to reduce manufacturing costs.

There is humungous pressure on the manufacturing function to come out with innovative ideas to cut costs. However, due to ever increasing labor cost, material cost, and overhead costs, the pressure to save money always persist. All functions in manufacturing generate cost saving ideas every year and implement them. This becomes a constant endeavor and such "cost saving" projects are essential for the survival of the business.

However, many industries do not understand or they are not aware of one big opportunity area. That is achieving major maintenance cost reduction and thereby achieving huge manufacturing cost reduction. This is done by implementing a "World Class Maintenance Management System" in the manufacturing plant. This is not understood clearly by many industries. They know that there is an opportunity to reduce cost of maintenance by reducing wastages in maintenance function. However, the huge opportunity to reduce the manufacturing cost especially in a plant where there is capacity crunch is not appreciated by all. "Zero-breakdown" is not just a buzz word but reality today and this zero breakdown concept can bring about huge saving in manufacturing cost.

In the industrial world, the awareness about the importance of maintenance function is rapidly increasing. However, in practice, the effectiveness of the maintenance function varies a lot. In some industries there is enough importance given to this function and the results show for themselves. In some other industries, it is even today considered to be a department which incurs a lot of expenses year after year. The maintenance function is considered to be a back of the house function.

There is no proper accountability for the work. Mainly the work is attending breakdowns. Whenever the production department calls upon for help from maintenance department, the maintenance crew attends the breakdown and fixes the problem. So maintenance crew waits for the breakdown to take place and then act. This is reactive response rather than proactive response.

The objective of this book is to emphasize the need for a full fledged maintenance management system. The captioned subject is getting a lot of importance in the recent years. Objectives, like achieving zero breakdowns, enhancing the life of critical components, analyzing the breakdowns using appropriate tools and reducing cost of maintenance are clearly laid out. Availability and reliability of plant and equipment are getting tremendous importance. In this book an attempt has been made to provide a comprehensive system for an efficient and effective maintenance management. The objective here is not just to provide a few tools for doing good maintenance, but here honest effort has been made to provide a comprehensive system in order to completely revamp the ancient maintenance management system from the basics. This kind of all encompassing system is very useful when you are starting a new plant or whenever a complete revamping is needed in an old running plant.

Maintenance is considered to be an expense department. We realize that it is not a profit center. However, if you go into details of wastages (or losses) taking place due to breakdowns in a busy manufacturing plant it is obvious that a big amount of savings can be achieved by just eliminating breakdowns. Often we find that the maintenance budget is slashed and this function is put under tremendous pressure to cut costs. However, by implementing world class maintenance system not only the maintenance cost comes down but also the manufacturing cost comes down drastically and such savings directly go to the bottom line. There have been cases where savings to the tune of 10% to 25% of the manufacturing costs have been achieved.

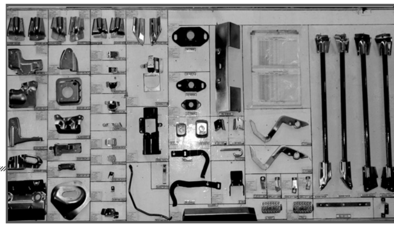
The top management needs to understand the importance first. They then institute a good maintenance system and start implementing it. This is not rocket science. However, changing the culture of the organization needs relentless effort from the management. This may need to bring about a change in the leadership style. This may also need focus on training to develop a good system including training on some good maintenance skills.

There is a saying that good maintenance starts at the design stage of the equipment. The question is how on earth the users of equipment, contribute to the design of equipment which is generally done by the manufacturer of the equipment. If you need a trouble free equipment with all the defects on operability, maintainability, reliability and easy to inspect properly addressed in the design stage itself and then delivered to the user, you as a user need to get involved in developing the design. This is called MP design and the user needs to get involved in that MP design.

The world class maintenance system is not “one size fit all” kind of system and needs a lot of work in conceiving, designing and implementing this system as per the business need of your organization. This takes about one to two years to do this. So initially there will be an “investment” for a year or two and later after two years there will be harvesting and that continues forever. However, in order to get the savings year after year sustenance becomes very important. A good sustenance system should be in place in order to continuously achieve savings in future.

In this initial period there has to be a thorough leadership drive to implement this system. The science of maintenance is ever developing and one needs to be in touch with the latest developments in the field of maintenance in order to sustain results. In this book it has been addressed as to “How to Sustain” good results achieved in detail.

The author humbly expects that this world class maintenance system will be of use to your organization in reducing the manufacturing cost by achieving zero breakdowns and enhancing the life of equipment.



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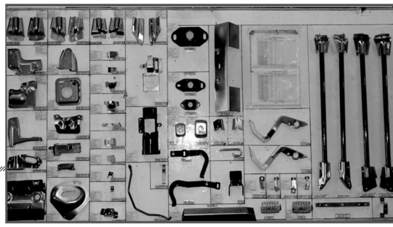


World Class Manufacturing Company

What is a "World Class Manufacturing" company? It is the organization which is recognized as a benchmark by its industry sector and for some key measures by other industry sectors too. World class manufacturing organizations consistently deliver exceptional results and often exceed expectations.

The term "World Class Manufacturing Company" is not a status symbol or having once delivered exceptional results an organization does not become a World Class Company forever. The organization has to deliver consistent results often breaking their own record. For this the organization has to find innovative methods to compete with others and experiment new ways.

While on the subject each organization who would like it to be called a "World Class Manufacturing Company" needs to understand each and every aspect and before starting the journey assess itself as to where it is and set its journey.

Attention is drawn here towards the following 20 points (or questions) each organization has to answer so that the organization is clear as to where it needs to give attention and focus.

1. ARE YOU A WORLD CLASS MANUFACTURING COMPANY?

1.1 PRODUCT QUALITY

Is quality of your products and services recognized as a benchmark by your industry and you consistently enjoy number one or number two position in the market share?

The quality of the product delivered to the customer cannot stand alone. The quality has to be at all levels like: quality of incoming material (vendor quality), in-house quality during production operation within your plant and then the quality products delivered to the customer along with best quality service.

The world class organizations consistently deliver superior product quality as compared to its competitors. They enjoy a good customer confidence as a result of consistent quality and delivery. Obviously it shows up in the size of the market share too.

1.2 KNOW THE REQUIREMENTS OF KEY CUSTOMERS

Do all employees in the company know their important customers and the difference between their company's products and services and that of the competitor? Whenever there is a meeting with an important customer all relevant data and appropriate personnel attending it is also very important to maintain good relations with the customer.

The knowledge of key customers and their requirements is very important for continued success of business. An organization needs to share this information downwards so that employees at all levels are aware of the key customer's requirements. They need to know about the differences between the products and services delivered by their organization and that of their key competitors.

Awareness of the strengths and weaknesses of the company's product or service is a key factor for the involvement of everyone in the company and improving employee satisfaction.

1.3 PERFECT DELIVERY

Do you ship to your customers On Time Every Time against their latest schedule or delivery plan? Perfect delivery does not mean just On Time, but deliver fully the product mix ordered by the customer on time.

This is not just delivering the products on time as per the requirements of the customers but it also includes the complete product mix as stated in the order and the necessary documents in all respects. If you meet this requirement it is a "Hit" or else it is a "Miss".

All objectives are secondary to the requirement to ship what your customer expects, with all relevant paperwork complete, 100% of items shipped should reach the customer at the agreed time.

In the modern world inventory is treated as Waste or Non-Value Adding. So all companies are now operating on Minimum Inventory Principles. For such companies delivering on time and exact quantities as per plan is of utmost importance in order to avoid any production stoppages.

So, does your organization understand this aspect well and all employees who are responsible for delivery understand this concept too?

1.4 ELIMINATE INVENTORY AT ALL LEVELS

Has your organization eliminated the storage of raw and packaging material? Does your incoming material from suppliers and vendors directly go to the production line without inspection for either quality or quantity?

This is also called "Direct on Line" status of suppliers. This status does not come so easily. This is the result of constant endeavor of the buyers, quality assurance team and the suppliers.

Moving material from one place to another is non-value adding. So material should be delivered to the production line wherever possible. The users of material should be responsible for the storage of that material. They should also be able to check that replacement of stock shall be done by the supplier if the stock level goes low. Ideally, the supplier should be responsible for delivery to the point of use and should be able to decide when to replenish.

Further, what about the inventory of WIP and finished goods? The same principle applies in the shop floor. Is the layout of your manufacturing process streamlined so that "Work in Process" material does not have to accumulate on the shop floor? Is the production line or assembly line balanced in terms of capacity so that there are minimum bottlenecks?

Has the size of your finished goods storage been planned so that there is constant movement of material outbound? And also any intermediate storage has been reduced so that delivery to the customer takes place as planned?

1.5 EMPOWERED STAFF

Do all employees who are in direct contact with customers have the authority and empowerment to resolve customer complaints?

This does not mean that all employees get into resolving all customer problems all the time. The company has to establish contacts with all key customers and establish good communication. Then the relevant teams in the organization quickly get into resolving their problems and communicating back for closing the loop, till the customers are satisfied.

Managing the points of contact with your customers is the single most important success factor. A company can only consider itself to be a world class manufacturing company if all its customers are confident that any problems they have will be speedily resolved and they will be kept fully informed, preferably by the person they initially contacted.

1.6 MINIMIZE DISTANCE BETWEEN SEQUENTIAL OPERATIONS AND INCREASE PRODUCT FLOW

What is the layout of your factory? Have you made the layout of the majority of your machines and equipment so as to minimize the distance between sequential operations?

Do you believe in single piece flow? Have you arranged the machines in such a way that there is a concept of a "manufacturing cell"? Have you taken care of the layout such that there is reduction of "Non Value Added" (NVA) work?

You should always arrange machines and equipment in the sequence in which they will normally be used. Such a process based layout will sometimes decrease capacity utilization but the elimination of work in progress gives substantial savings with additional savings in quality, costs and administration. The people who are responsible for workplace layout are ideally the people who work in the area. They have to take the trouble to think through the work flows before laying out the work place. The line-of-sight communication between sequential operations is important.

1.7 SET-UP TIME REDUCTION (SMED)

Have you reduced the set-up time between product changes? The set-up time is reduced to such levels so that the batch sizes the customer is demanding become economical to operate. So it is not a choice you have, it is imperative that you need to reduce the set-up time drastically.

Have you identified equipment where SMED technology can be used and the set-up time can be reduced to a minimum?

If at any stage of manufacture you produce in batch quantities that are larger than the shipment quantities required by your customers due to high set-up time, there should be an active set-up time reduction program. Wherever possible, equipment should be dedicated to one product to eliminate the time and cost of changing over from one part to the next. Where this is not possible, set-up time must be kept as short as possible. Wherever possible, batch sizes should be maintained the same throughout the process.

1.8 TRAINING AND EDUCATION

Do you have a training and education program in your organization? Do you have a running training calendar and you measure the efficiency and effectiveness of the training events? Do you educate the existing employees on the value of world class manufacturing?

World class manufacturing is a program of continuous change and change has to be carefully managed. It is important to carry everyone along with the changes and so that the change management program becomes successful.

All newly joined employees should have awareness and know-how to use the basic seven tools of quality (check sheets, process charts, Pareto analysis, Ishikawa or cause and effect diagrams, histograms, run charts and statistical process control). Do you have training on the process engineering when new employees join the company? Is there a proper qualification process for the employees and only after they pass through the test they will join the production line?

1.9 INITIATIVE

Do your employees have initiative to move quickly where attention is needed? Initiative comes from within. This happens only when ownership is developed. The level of initiative in a company or on the shop floor can be seen when problems arise or any bottleneck gets created. There is a direct relationship between employee satisfaction and initiative.

Employees taking initiative is a recognition of the "conscious worker" and helps reduce the level of direct supervision.

1.10 REDUCTION OF NON-VALUE-ADDING ACTIVITIES

Is there a program in place to progressively identify and reduce non-value-adding activities?

A non-value-adding activity is anything which adds cost but no value to the product or services provided by the company to customers. Non-value-adding costs are characterized by MUDA the seven wastes such as "overproduction, waiting, transporting, inappropriate processing, excessive inventory, unnecessary motions and defects".

Is it possible to totally eliminate non-value-adding activities? The non-value-adding activities are sometimes embedded deep within the processes. Hence, there needs to be a continuous effort to use some tools like process mapping or value chain mapping so that the hidden non-value-adding activities are exposed and then eliminated or at a minimum reduced.

1.11 RATIONALIZATION OF SUPPLIERS

Is there a program in place to reduce the number of suppliers? Do you have a process in place to do vendor rating? Do you have an ongoing process to communicate with the suppliers about their performance?

In the world class companies, the objective of the purchasing department is to keep a small supplier base of reliable companies working in partnership with them. This is started at the design stage. The supplier's involvement right from the design stage is important. However, that does not mean that all suppliers need to get involved. Involvement of key suppliers is needed.

They should focus on delivering as and when the customer needs and in quantities as per the latest plan, directly to the point of use. As it is not possible for one person to maintain a good relationship and understanding with more than about 50 suppliers, single source of supply is necessary. With single source you can get the genuine, invaluable involvement and commitment of your suppliers to your business. Long-term commitment to suppliers and single sourcing makes you as important as possible to your suppliers and allows the suppliers to engage in a continuous reduction of costs using, for instance, value analysis techniques. Delivery to the point of use is not possible without single source supply.

1.12 TOTAL QUALITY CULTURE

Do you have a culture of total quality? Do you have a total quality culture inculcated throughout the business? Every employee should focus on doing the job right first time and checking of the work done by him or her simultaneously. Here if the job is done right the first time by every employee then supervision is not required. This is true for all departments or sections of the organization.

The role of quality control is to audit quality and provide long-term process control information. The role of quality control in world class manufacturing is an audit role. The principles of total quality should permeate all activities. Every defect or mistake found should be seen as an opportunity to improve the quality of the product. The teams should get down to analyzing the root cause of problems and come out with solutions to those problems. Do you have cross functional teams (CFT) working on projects surrounding a problem? Do such cross functional teams use analytical tools to resolve root cause solutions?

Do your employees understand "internal customer concept"? Similar to your external customer, you also have internal customer. This is the person or teams who receive your work within your organization. Is the internal customer satisfied with your work? Is there a system in place to measure the satisfaction level of internal customers?

1.13 AUDIT

Do you audit the product and process quality within the specification limits? Do you use statistical process control in your company?

These days in world class manufacturing plants quality is stated in ppm (parts per million). You cannot get to parts per million quality levels if your quality checks only sort the good from the bad, the passes from the failures. Everyone involved must check whether the process is within the tolerance band and be able to take corrective action. By this it means operators have an early warning of possible failures so enabling the processes to be fine tuned. The technique generally used is statistical process control (SPC).

1.14 MISTAKE-PROOFING

Have you got culture of mistake proofing? Do you prepare and install "fool proofing" devices on the production line where human errors happen?

To reach parts per million quality standards, jobs have to be made fool-proof. Fool-proofing (called Poka-Yoke in Japan) means that either mistakes cannot be made or, if this is not possible, the equipment will automatically identify and/or stop when a defective part is produced. Fool-proofing requires imagination and commitment to quality. There is no easy way to measure your degree of fool-proofing except to ask yourself if the operations that could cause faulty products rely on human judgment.

There are three levels of Poka-Yoke. The first one is the "indicating" Poka-Yoke. That means the fool-proofing device will indicate that there is something wrong and the operator takes care of such defect. The second one is "rejecting" Poka-Yoke. That means the fool-proofing device will identify the defect and reject it from the line. The third one is "correcting" type Poka-Yoke. That means the fool-proofing device corrects the mistake and sets it without the help of the operator.

This is a recent development and the employees working on the production line find it very enjoyable to create Poka-Yoke so that the problem or defect does not move further on the production line.

1.15 AUTHORITY TO STOP

Does everyone have authority to stop the line irrespective of hierarchy? It may sound ridiculous in the beginning but however instead of allowing the bad quality product to move on the production line further and then carry out inspection on that product, it is always beneficial to stop the line and take action then and there.

If quality is crucial to your success, there is no better way to drive up the quality than to give all employees the authority to halt the job or process if they are unhappy about quality levels. An employee must always choose to stop a process rather than pass on a known or suspected defect. Anyone who finds a defect must always pass it back to the person who made it. By this method there will be a sense of urgency developed at the place where the defect is noticed and things will get done faster.

1.16 USERS ARE EQUIPMENT "OWNERS"

Do you have equipment owners who take care of the equipment by cleaning, inspecting and lubricating the equipment and take full responsibility for the health of their equipment, by assessing and predicting the condition of the equipment?

Do you believe in the philosophy of zero breakdowns?

You cannot afford delivery schedules to be dependent on unreliable equipment. Users of the equipment are the best people to carry out inspection because they are the first to know when their equipment is not performing properly and should also be the best people to know when it is fixed. It follows that if they can be trained to come out with Kaizen to analyze and go to the root cause to resolve the problems in quality, safety and productivity. This will be the most cost effective way of reducing downtime. Users of the equipment should have a real sense of ownership.

Unreliable equipment is one of the most popular reasons for "safety stock" or "safety time" which increase costs and lengthen lead times. There should be a routine report of downtime widely circulated as well as a downtime reduction teams set up if required.

1.17 GOOD HOUSEKEEPING

Do you have an active housekeeping policy to keep work areas clean, tidy and uncluttered?

It has been seen time and again that tidy work areas reduce the frequency of errors and delays. Most world class manufacturing companies have regular inspections of their work areas and continually look for ways to tidy up their processes. Housekeeping must be the responsibility of the people who work in the area. A clean and tidy workplace also gives people working in it a sense of pride. You could not imagine a world class company being dirty and messy.

Are all the material, tools, jigs and fixtures identified and kept in proper place?

Are visuals used to indicate the right place so that the searching time is minimized? Is the workplace bright and well ventilated?

1.18 PRODUCT DESIGN TO INVOLVE ALL DEPARTMENTS

Does the design of products include a consideration of the manufacturability of the product? Do you use the concept of "concurrent engineering" or at least a cross-functional team concept working on developing the new products so that the product is easy to manufacture with better quality, cost and lead time.

The design of all products and processes should include manufacturing considerations such as the current equipment, suppliers, existing parts, subassemblies and ingredients. In many cases manufacturing, marketing and purchasing functions are involved at the design stage to ensure that the designs are easy to manufacture.

In most businesses it is difficult to optimize designs unless the suppliers of materials or components are involved at the design stage of the products. Improvements in materials and components should be evaluated also to see if your end product can be improved to keep your products competitive.

A key element in design for manufacture is evaluation of existing designs. Unless the designers are aware of changes required to current designs, future designs cannot benefit from the lessons learnt in the past. Self-inspection and rectification of your own mistakes is just as important in design areas as it is anywhere else.

1.19 CONTINUOUS IMPROVEMENT

Is there a culture of continuous improvement in the organization?

Do you have a Kaizen program where employees take part and come out with ideas to solve the problems in productivity, quality and safety?

The word "Kaizen" is a combination of two words: "Kai" and "Zen". In Japanese language Kai means change and Zen means for good. That is change for good. But practically in the organization it means "implemented suggestion". Further it is called Kaizen only after it is implemented by the same people who suggested it as an idea.

The one universal truth in all manufacturing companies is that customers are demanding higher and higher levels of product quality and shorter lead times. It is also true that in most industries suppliers are responding. If you do not keep on improving your product quality and your competitors do, you will lose out. Continuous improvement helps improving productivity, quality, cost, delivery, safety and finally morale of employees by job satisfaction.

1.20 FEEDBACK FROM CUSTOMERS AND EMPLOYEES

Is there a mechanism to quickly and effectively receive and evaluate suggestions from customers and employees? Are people motivated in the organization?

The organization must take continuous feedback from its customers to increase CSI (customer satisfaction index).

The employees must feel that any ideas they have for the improvement of any task they perform will be welcome, and resources made available to evaluate their ideas if necessary. A formal Kaizen program has to be developed in the organization to create a culture of innovation and creativity. This creates ownership and job satisfaction.

1.21 SO SIMPLY WHAT IS "WORLD CLASS MANUFACTURING"?

1.21.1 World Class Quality

Always compare yourself to the "best in class". This is not a status symbol. This needs continuous endeavor to compare and "benchmark" self with the best in class and keep doing it on a continuous basis and not one time as a project. As we discussed earlier, initially it may look as if we need to strengthen the quality control. Yes, it may look like that in the beginning, but it is the quality assurance which has to take the lead. The organization should establish good QA systems. This system has to cover all aspects. To begin with vendor selection and qualification, vendor development system, quality inspection methods, training on analytical tools and identification of the root cause and countermeasures. Also deliver products to the customer on time with proper product mix as per the order of the customer and handling customer complaints with 8D methodology. All these things do not happen so easily. If you want to sustain world class quality, you need to give 100% attention to all these systems on a continuous basis.

1.21.2 Competitive Pricing

In order to compete in the marketplace you need to be able to have flexibility in pricing. That means cost of manufacturing to be the lowest to have flexibility in pricing. Having understood this, you need to also know how to reduce the cost of manufacturing. And how the cost of manufacturing will go down? It is done by eliminating wastes and non-value-added (NVA) activities. So attention is immediately drawn on how to eliminate the seven wastes which are prevalent in manufacturing plants.

1.21.3 Eight Wastes (*Muda*)

Japanese people believe in reducing these eight wastes in a manufacturing plant on a continuous basis. That means these wastes have to be identified and a process has to be established to reduce them if not totally eliminate them. These are the eight wastes (*Muda*):

Defects: Defect does not mean only the quality defects in the products. The concept of defects entails all defects, mistakes, failures, abnormalities, things which are not correct or not the way they should be. When you get a big picture of defects then start working on those to eliminate or reduce them using the MISER methodology.

M- "MERGE" operations to carry out two or more operations into one work station.

I- "IMPROVE" the existing operation by reducing minor stoppages and by implementing Kaizen in the plant.

S- "SIMPLIFY" the operation by technological changes or getting subcomponents procured from outside.

E- "ELIMINATE" some activities to reduce or eliminate non-value-added work.

R- "REDUCE" waste or activities so that the cost comes down.

Overproduction: This is another waste. This happens due to large batch sizes or due to large variability in reliability of the plant. Often large batches (more than it is required by the customer at that moment) are produced due to insecurity in the production process or even due to large variation in the supplier performance. We need to understand here that this is a big waste. This will remain as inventory in the warehouse or it can even become a non-moving inventory. The demand may suddenly vary and the inventory will remain with you for ever.

Transportation: Though we understand that transportation is not a waste as a concept, transportation costs money. This gets added to manufacturing cost. So, we need to reduce it to minimum. In a situation where you have an opportunity to establish and build a new plant, you have great advantage of locating the plant wherever you need to reduce transportation cost. However, in most of the cases it is decided by other factors and transportation cost will be high. In case you have to reduce transportation cost, locate the plant closer to the market or closer to the customer to reduce transportation cost. Another key idea to reduce transportation cost is to have ancillary units surrounding your plant. This is recently getting ground and many corporations are now trying to locate the dedicated supplier plants close to their site. There are also other ideas like "milk run" in automobile industries. This means like collecting the milk produced by farmers, a vehicle will go around and collect from the suppliers. This could be raw material or subassemblies and products for that day. This can even happen several times a day. This is the way the transportation cost is reduced.

Inventory: Inventory is not only a waste but a big evil. The waste could include, inventory carrying costs and cost of space required to store. This is only the direct loss. If you see other side effects of having large inventory is deterioration of the parts kept in inventory and also damages due to bad handling during shifting. So, inventory is a big waste. This also includes the work in process inventory too.

Motion: This means motion loss due to movement of operators of the plant in handling material in assembly shops or even in machine shops. Operator movement is a subject discussed for ages in the field of manufacturing but even today there are big opportunities in the plants in this area. Low cost automation is one immediate solution, but however in developing countries this depends on a number of factors. Ergonomics is coming into picture in a big way. That means science of human body movement is coming into the field of manufacturing and study is conducted to reduce human body movement and improve productivity. This will in turn reduce manufacturing cost.

Over processing: This means doing something which is not needed, but often this is done because either the customer has been promised that we will do it or it is the plant's normal tradition which is not a requirement.

Waiting: Waiting for a decision or waiting due to no requirement from the internal or external customer. Waiting means clearly wastage of time and other resources. This also could mean "work in process" material is waiting for the bottleneck to get solved which is created due to some reason.

An eighth muda has been added recently: Muda is a Japanese term for waste. As pioneered by Toyota and adopted worldwide as LEAN processing, top businesses strive to eliminate muda—any waste that does not add value for the final customer.

Seven *mudas* are traditionally recognized: defects, overproduction, transportation, inventory, motion, over processing and waiting. The eighth *muda* is the waste of "losing time, ideas, skills, improvements, and learning opportunities by not engaging or listening to your employees."

As for manufacturing cost we will briefly discuss later in elements of manufacturing cost in the next chapter. However, we need to understand the cost structure and find opportunities to reduce the cost. It is again a relentless exercise to find wastages taking place in the normal running plant and come out with Kaizen to save on cost without reducing value.

1.22 WHAT IS VALUE ADDED ACTIVITY?

This is an activity carried out in the manufacturing organization with or without the knowledge for which the customer is ready to pay. So what are those activities for which customer is ready to pay and what are those activities, for which customer is not ready to pay?

1.22.1 Operation

That means adding value to the product by cutting, welding, grinding, mixing, packing etc are the activities which give shape, size, finish and prepare the finished goods which finally works as a product for the customer. So operation is a value added activity. However, within the limits of the plant boundaries, there could be some non-value-added activities deep within operation activity. That means even if the operation is value added activity, there are chances that some opportunities are there to improve or reduce costs. Improving productivity in the same machine, reducing energy consumption, or changing the sequence of operation can be done to reduce costs.

1.22.2 What is Non-value-added Activity?

Non-value-added activity is one which is there in the plant and that activity is continuously carried out in the plant, but does not satisfy the customer need or the customer is not ready to pay for.

Material movement: It means movement of material within or outside the manufacturing plant is a non-value-added activity. This does not mean that there should be no movement of material within and outside the plant. However, since this activity does not add value to the customer it has to be reduced to a minimum by changing the layout, line balancing, single piece flow and using some modern methods in automation and transportation.

Quality inspection: It means producing the product and rejecting the product at the inspection stage as it does not meet the quality standards. Just imagine the products are produced without any defects or mistakes in the first place, the inspection stage will have no work. Though in a manufacturing plant quality inspection is needed, producing products without defects or mistakes is more important. How do we do that? It means the machine has process capability to produce the product as per quality standards. Also quality is built into the product; which means every time an activity is performed, there is a check done by the operator so that there is no defect or mistake for the inspection stage. In this sense the quality inspection is considered to be non-value-added activity. This is how the cost of manufacture will come down by reducing defects in production process itself in the first place. We call it first time right.

Inventory or storage: It means storage of raw materials and packing materials, Work in process (WIP) material and storage of finished goods. Inventory is non-value-adding. It does not add value to the customer and he is not ready to pay for the huge inventories you have in your plant. Does that mean that there should not be any inventory in the plant? This varies from plant to plant and product to product. However, since it is non-value-adding we need to reduce it to a minimum. This will reduce the cost of manufacture by reducing the inventory carrying costs and reducing space needed to store.

Decision making: It means activity of thinking and taking decisions with relevant data. Does this activity add value to the customer? As managers we may think that decision making is the most important activity. However, it does not add any value to the customer. In this respect it is considered to be a non-value-added activity. But how do we reduce. By instituting good systems so that the manager does not have to take decisions on day-to-day activities, like deploying people, handing over the production schedule, product change over, etc. All these are routine activities and the system can take over. The manager's time can be utilized in a better way. In this way the costs will come down.

We have discussed about eight wastes and also the non-value-added activities which are happening every day in the manufacturing plants. Japanese believe in eliminating these eight Mudas and Americans believe in eliminating non-value-added activities. There are some items which are common like inventory. The message here is you need to be able to identify these wastes or non-value-added activities and try to reduce them on a continuous basis. This will help in reducing the manufacturing cost and have an edge over the competition.

1.23 JUST-IN-TIME DELIVERY

Consistently deliver on time every time. Just-in-time delivery is not given enough importance in some plants. But, however, if you would like to have your customers' loyalty, you need to take care of deliveries on time. This not only means delivering on time, but delivering the complete product mix and quantities as mentioned in the order every time. This needs to be tracked as one of the Key Result Areas or performance measures.

1.24 TOTAL FLEXIBILITY

Flexible production schedule as per the need of the customer goes against the large batch size production we used to have in the olden days. It is good to have economies of scale when you have large batch sizes. The availability and capacity utilization of plant and equipment are the highest when you use large batch sizes. But the realization is that by doing this there will be large inventories and despite having large inventories, still the customer's needs are not met as there will be considerable delays to deliver what the customer exactly needs. In addition large inventories are waste.

So we need to build plant and equipment where a number of products are made on the same production line and we need to have minimum set-up time. Reduction of set-up time is a science today and by employing this piece of science there will be large reduction in product change-over time or set-up time.

1.25 SHORTEST CYCLE TIME

It means "Just-In-Time (J-I-T) Manufacturing" and low inventories. This is to simply say "produce when the customer needs the product and stop the production line when there is no order". This looks very simple but is difficult to put into practice as a production line cannot be started and stopped so many times a day or a week. There needs to be a balanced production planning so that production lines run in a predetermined speed as far as possible continuously with less inventories. This is done by having "production cell" concept of layout and just-in-time inventories of raw materials and packaging materials. The raw and packaging materials should arrive directly from the supplier to the production line and no prior quality check is needed. To do this the vendor or supplier has to be qualified as direct-on-line (D-O-L) supplier. The throughput time is constantly measured and teams working on reduction of cycle time by eliminating NVA activities.

1.26 SPEED TO MARKET

It means fast introduction of new products. There is a saying "early bird always wins". In the consumer products and consumer durables industry, if you do not launch a product on time, there will be your competitor who will be doing it before you and obviously the company which comes into market first with a new product or a new variant of the old product will always succeed in business. At this juncture it is not out of the subject to say that the cost of new product introduction comes down drastically if you do it on predetermined time frame.

1.27 LEARNING ORGANIZATION

Learn new technologies and new methods. Always keep learning new things including competitor's activities. This is not an easy task again. To get competitors' information is not a simple work. However, this is all included in the game of business.

It is important to note that the "learning" takes place at all levels in the organization and there shall be enough encouragement to create a culture of learning.

1.28 BEST CUSTOMER RELATIONS

Providing good after-sales service and having continuous interaction with the customers is important to maintain best customer relations. The question is do you measure customer satisfaction to see how happy are your customers?

These results are a culmination of on-time-delivery, meeting customer's needs by having sufficient flexibility built into your manufacturing system and providing good after-sales service.

1.29 WHAT ARE THE PRESSURES ON MANUFACTURING FUNCTION?

Now let us have a look at what are the pressures normally encountered by the manufacturing plant in an organization.

1.29.1 Highest Capacity Utilization

Capacity utilization in an organization means the ratio between actual production volume divided by the product of ideal rate and calendar time. The owner or investor of a business would always like to have maximum capacity utilization. This is achieved by having maximum availability and maximum reliability of plant and equipment.

1.29.1.1 Availability

It means the ratio of the time available for actual production to the calendar time. Depending on the practices established in a manufacturing site it could be lower due to loss of time to turn to work, labor allocation time, machine start-up time, absence of workmen, poor planning, material non-availability, holidays, shutdowns, etc. This ratio varies largely from 100% in continuous process industries to as low as 70% of calendar time in some batch process industries or engineering industries.

1.29.1.2 Reliability

It is a measure of machine performance without any breakdown. A machine is said to be reliable when it performs full time without any failures when it is called upon for service and the reliability in such a case is 100%. Reliability is a result of good machine design, good operation and maintenance practices, good lubrication and continuous improvement.

So, we need to give maximum attention to improve availability and reliability. In other words, there should be minimum downtime in the plant such as equipment breakdowns, material shortage, people shortage, improper planning, minor stoppages, power outages and set-up-time, etc.

1.29.2 Best Quality

It means the whole organization expects manufacturing function to produce and deliver best quality products consistently. In order to deliver consistently good quality product the quality system in the plant needs to be flawless. The quality of incoming material has to be within specification limits and suitable for taking it directly to the production line without prior inspection at the plant. This will happen only when all the key vendors are enjoying the direct-on-line (D-O-L) supplier status and are continuously improving quality at their plants.

Secondly, the in-house-quality (quality of goods produced in our own plant) has to meet quality specifications and rejection levels are zero or zero PPM levels. This needs good quality assurance and quality control systems. Every rejection is considered to be an opportunity and needs analyzing to the root cause and take countermeasures. This is also a relentless effort, but the PPM levels have to continuously drop and achieve lower and lower rejections.

Thirdly, the quality of products delivered to the customer has to have an edge over the competition. That has to be a winner at the marketplace. On-time-delivery (O-T-D), flexibility and good after-sales service are key strategies to be the winner in the marketplace and attract customer satisfaction. Finally, the system of handling customer complaints; analyzing the root cause, take corrective action and close the information loop till customer gets a feedback and gets satisfaction is very important.

1.29.3 Lowest Cost

The sale price is decided by the market and so the only way to increase profit is to reduce the cost of manufacture at all stages; buying, inventory, production, work in process and logistics. This is in turn done by proper sourcing of materials to take advantage of the economies of scale. This is also done by eliminating all wastes and reducing throughput time by optimum utilization of resources.

We shall dwell upon this topic with details in the next chapter where we will understand the elements of manufacturing cost and how to reduce it. But this is also an ongoing effort and continuously the plant has to undertake projects to reduce cost by eliminating non-value-added (N-V-A) activities and thereby reduce cost and increase value to the customer. This needs "MISER" methodology as described in 1.21.3.

1.29.4 Product Mix as Per Demand

As has been discussed earlier the manufacturing organization should build good amount of flexibility in order to deliver the products as per the demands of the customer. Rapid change over (SMED technology) and single piece flow are key strategies the plant has to focus on.

1.29.5 On-Time-Delivery

On-time-delivery is important to the customer in order to maintain customer loyalty. This needs proper planning and adhering to the schedules.

1.29.6 Best Safety Record

The safety of people, plant and equipment and safety of the processes is an important aspect for the plant. All over the world there has been so much awareness about safety and so the plant has to lay more emphasis on safety.

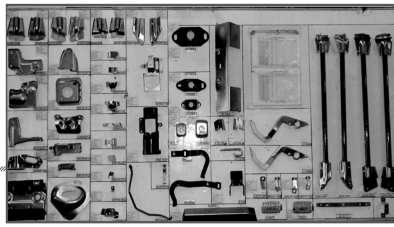
1.29.7 Quick Introduction of New Products

This is another area where the plant faces tremendous pressure in order to quickly install the plant and equipment, commission them at a fast pace and streamline the production so that the new product is introduced in the market quickly. If the product developed can be made on the existing lines it becomes somewhat easier, but buying new equipment, starting new production lines and deliver volumes is another key factor for the manufacturing plant.

1.29.8 Always Smiling

Always ready to listen to changes no strikes, no problems and no issues.

CHAPTER 2



Elements of Manufacturing Cost

First of all we need to understand as to why we are discussing about the manufacturing cost. Before getting into world class maintenance, we need to understand that the very purpose of implementing "world class maintenance" is to support "world class manufacturing". This is to understand the focus areas to reduce losses and save on cost. Also we need to understand the role of maintenance function in reducing these losses.

2.1 COST OF RAW MATERIALS AND PACKAGING MATERIALS

The cost of raw materials and packaging materials varies largely from plant to plant. However, in most of the industries it is as high as 70% to 80% of the sale price. If you see a standard cost sheet prepared by a manufacturing company for a particular product the major portion is raw material (RM) and packaging material (PM) cost. So the focus generally is on the RM and PM costs. Since these are the major costs, companies devote a lot of energy and time in this area to save cost. So the higher management has to focus on the areas mentioned below.

2.1.1 Sourcing Plan

This is achieved by putting together the volumes of the big ticket items for the entire corporation and using economies of scale to negotiate the price of those items. In recent times, the purchase department is divided in two teams. The frontrunner is the sourcing team and the second team is called logistics team. The sourcing team identifies the main sources for raw material and sometimes even packing materials. Then they put together the volumes of all the plants and negotiate the price. This has to be done carefully as the transportation cost may be higher and becomes a show stopper. However, generally, the company can save on costs in a bigger scale.

2.1.2 Transportation Cost

This is another opportunity area to save on cost. A detailed study of the whole transportation system is necessary. However, since we are currently dwelling upon the incoming material cost, a thorough study of the cost of transportation for incoming material should be taken up first. Different companies are employing different methods. One such method used by automobile industries is called "milk run". A transport hired by the company shall take a big round of the whole town (or even on a bigger circle) and picking up all the material kept ready by the suppliers. The suppliers have to be closer to the company and there can be more than one round, if need be, to collect material from suppliers and bring it to the plant on time. This material directly goes to the production line (Direct On Line) and does not remain in the store as inventory. This does not apply to all the suppliers. If the supplier is far away in another town, normal way of transportation is used. In order to have cost saving, the transportation cost has to be lower and full truckloads of material to be transported to establish economy.

2.1.3 Ancillary Unit Concept

This is another strategy manufacturing companies are implementing in the modern world. This means have dedicated supplier units nearer to the plant location and all the important materials arrive at the plant without much transportation. Since they are dedicated suppliers, they are flexible in terms of volumes. This concept works well as you do not need big transportation arrangement. The materials can arrive in installments as needed in order to avoid any inventory at the plant. Also there is tremendous amount of ownership. Due to this the company and the suppliers meet and discuss ways and means to reduce inventory and thereby reduce the cost of materials.

2.1.4 Inventory Policy

This is essential to have competitive edge. Inventory, as we all know, is non-value-adding and to be reduced by all means. However, this also depends on the quality of suppliers and together a company can draw up its inventory policy and work out the strategy for reducing inventory. Just-in-time inventory has become the order of the day. Similarly, the finished product inventory also depends upon the reliability of the plant to deliver the goods on time. This is where world class maintenance can contribute in a big way to reduce cost.

2.2 DIRECT LABOR

This is the cost to company on the direct labor (the salary and benefits of people directly working on the production line). Generally, this is not a major cost in a factory where there is good amount of automation and mechanization. However, in some industries it may be higher if there is manual operation in making a product.

2.3 OVERHEADS

In a manufacturing plant, there are many other costs which are charged to the product. Since these are many small and big costs, it has been put under the caption called "overheads". These costs are direct costs attributed to each product or sometimes allocated to the product. Cost allocation method is generally used as the costs are incurred by the plant and so they will have to be allocated for each product by using logic. For example lighting cost has to be allocated on the basis of floor area in square feet. This is done by measuring the floor area for each product and then allocating the cost per square feet.

2.3.1 Maintenance Cost

This is the cost for maintaining the plant and equipment. Similarly, there is another cost which is also prominent. That is cost of building maintenance and real estate maintenance. However, in real life building maintenance and real estate maintenance is managed by administration department. So, we shall split these costs clearly. There is a portion of the maintenance cost which comes down by implementing world class maintenance system. This is the cost of maintenance of the equipment and this responsibility is handled by the maintenance department. The maintenance cost generally consists of cost of spares and consumables, cost of annual maintenance contracts (AMC), salary and benefits of maintenance staff, cost of lubricants, cost of tools and tackles, cost of training and cost of premium freight for urgent transportation of spares or local purchases, etc.

2.3.2 Cost of Energy

This is the energy bill. This consists of cost of electrical power, fuel oils like diesel, furnace oil, cost of water and other bills. By implementing world class maintenance energy bills come down and the manufacturing plant can have big cost savings.

2.3.3 Indirect Labor Cost

This is the cost of indirect labor. That is salary and benefits of maintenance technicians, quality control people and all other indirect labor like warehouse employees, etc.

2.3.4 Cafeteria Cost

This cost includes subsidies given on the food served in cafeteria.

2.3.5 Depreciation

Depreciation is also considered a cost in the books of account. The depreciation on buildings, plant and equipment, vehicles, etc., are all considered to be a cost. Strictly speaking depreciation is not a cost. But generally the depreciation is allowed to be treated as a cost for the purpose of providing incentive in the books of account.

2.3.6 Other Plant Expenses

Various contracts like house keeping, gardening, and transportation of employees and other plant expenses like cost of uniforms, uniforms washing, consumables like cleaning gear, rags and other chemicals, stationery, etc., are treated as other expenses.

All these costs are part of manufacturing cost and let us discuss as to how these costs trend downwards by implementing world class maintenance.

2.4 CONTRIBUTION OF "WORLD CLASS MAINTENANCE" TO THE BUSINESS

2.4.1 Expenses for Implementing "World Class Maintenance"

If and when you start world class maintenance, the first year is the investment year. That means a lot of expenses will come into picture which normally would not appear. The maintenance budget will go approximately 20% higher. When you start implementing world class maintenance methodology, the first and the foremost thing we do is "restoration", which generally needs huge effort and money. However, we know that it is an investment for the future. Therefore, the plant leadership is ready to spend an amount of 20% or higher in some cases of the annual maintenance cost in addition to the normal maintenance cost. This additional cost is incurred on spare parts and consumables, labor cost for restoration, and in many cases cost of management time spent as team members. There is also an element of cost for implementing Kaizen in the shop floor. These Kaizens could be lower level Kaizens (low jump Kaizens) or could be higher level Kaizens (high jump Kaizens).

The cost depends on the magnitude of the project. However, the Kaizen implementation is very necessary at this stage. We shall discuss more about Kaizen later in a separate chapter.

2.4.2 Reaping the Benefits

Saving of 10% of conversion cost is envisaged after year one. Please mind that it is 10% of conversion cost and not just the maintenance cost. There will be a number of equipment developing into lower levels of breakdowns and minor stoppages or even zero breakdowns level.

Savings up to 15% of conversion cost after year two compared to year zero. Here the harvesting period starts. The manufacturing plant starts enjoying the returns for their effort. This continues year after year.

Up to 25% of conversion cost after year three compared to year zero. Just imagine it is going to continue forever and if the volume of production goes on increasing the amount of return also goes higher. However, just in case the volume goes down the savings will naturally come down. But the company will still survive due to the savings generated in the previous year and will give the endurance to face the dip in one particular year.

This saving goes directly to the bottom line. For a manufacturing company 25% of the conversion cost could be as high as 10% to 15% of sales turnover. This directly goes to the profit and is considered to be big saving.

First let us understand what are conversion costs?

Conversion costs are those costs required to convert raw materials into finished goods that are ready for sale. The concept is used in cost accounting to derive the value of ending inventory. It can also be used to determine the incremental cost of creating a product, which could be useful for price setting purposes.

Since conversion activities involve labor and manufacturing overhead, the calculation of conversion costs is:

Conversion costs = Direct labor + Manufacturing overhead

Thus, conversion costs are all manufacturing costs except for the cost of raw materials.

Examples of costs that may be considered conversion costs are:

- Direct labor and related benefits
- Equipment depreciation
- Equipment maintenance
- Factory rent
- Factory supplies
- Factory insurance

- Machining
- Inspection
- Production utilities
- Production supervision
- Small tools charged to expense

Example of Conversion Costs

ABC International incurs a total of Rs. 50000 during March in direct labor and related costs, as well as Rs. 86000 in factory overhead costs. ABC produced 20,000 units during March. Therefore, the conversion cost per unit for the month was Rs. 6.80 per unit.

These are ball park numbers and may vary a lot depending on the effort put in such as amount of restoration work undertaken, number of Kaizens implemented and amount of corrective maintenance done and compliance of preventive maintenance which are the key contributors to the savings generated. The savings are mainly coming from zero breakdowns, zero quality rejections, reducing other downtimes such as "set-up time" and minor stoppages.

2.5 WHERE SAVINGS COME FROM?

We are talking about huge savings here. But from where these kinds of savings come? This is achieved by eliminating several losses in the plant. The savings get accumulated by achieving zero breakdowns, zero quality rejections, improving availability and reliability. Let us briefly dwell upon a situation of a machine breakdown. So, let us enumerate what are the losses taking place in a manufacturing unit of a process industry. Just imagine there is a breakdown on a critical machine in the shop floor. So, let us see the losses.

2.5.1 Production Loss

The first and the foremost loss is the production loss for the duration of the breakdown. The equipment did not produce or make so many parts or the product. This is the generic production loss. However, in a "sold out company" enjoying a great demand for its products in the marketplace (a company enjoying a business situation where all the volumes produced by their manufacturing plant is sold immediately). It could be even sale loss and finally may come down to even franchise loss (customer goodwill loss).

2.5.2 Effort Loss

Effort loss of the maintenance technicians which is the effort taken to fix the breakdown. Effort costs money.

2.5.3 Loss Due to Spare Parts Consumed

To fix the breakdown the maintenance person has to change the damaged part with the spare part.

2.5.4 Damages Done to Other Parts and Equipment

Many a times it is not that just only one part needs replacement. There will also be a situation where even the surrounding parts around the broken parts of the equipment are also damaged and the loss could be much bigger. For example, when a ball bearing is seized, there will be scoring marks on the shaft and so even the shaft needs replacement. Similarly, when there is a flash in an electrical panel, there can be many components burnt out due to the flash. All these costs are considered to be costs emerging due to damages to the equipment.

2.5.5 Speed Loss Due to "Ramp up and Ramp Downs"

For every breakdown there is a time loss before the actual maintenance work starts. This time gap to close down production, clearing up the place and cleaning by housekeeping and making it suitable to start the maintenance work is called "ramp-down-time". Similarly, after the maintenance work is over, the equipment is started back again and the time taken to bring it up to the full running speed is called "ramp-up" time. Generally, the maintenance time gets recorded in the plant log book, but in some plants the "ramp-down" time and ramp-up time do not get recorded accurately. In process industries depending on the product spillage, etc., the ramp-down time and ramp-up time could be larger than the actual time taken for maintenance.

2.5.6 Spillages, Wastages, and Clean Outs

In process industries these losses are quite common during the breakdowns. This will also yield losses or the material losses.

2.5.7 Energies Consumed Even when Machine is Stopped

Energies are consumed when equipment repairs are going on. Even though the equipment is not running the ventilation, lighting and even the power to the equipment are switched on. This may create energy losses up to about 25% of the full load running.

2.5.8 Extra Hours of Work or Overtime Work

Especially in continuous process industries there is a need to immediately put the equipment in working order and so overtime work is also approved to be carried out. This is done in order to put the plant and equipment back into service as early as possible.

2.5.9 Items Consumed Like Gaskets, Lubricants

These are typically present during any breakdown. For normal maintenance work consumables and lubricants are needed to be replenished or changed.

2.5.10 Emergency Purchases

Since the time is precious in continuous process industries, sometimes the purchase of spare parts and consumables are bought at premium price or even shipped to the point of use paying premium freight is quite a common phenomena.

These are the losses which happen during a breakdown and many more situations. We can go on forever with this list. The point here is we fail to see all these losses at our manufacturing site and we treat losses due to breakdown as simple. However, you now tend to see a hierarchy of losses. Each loss is creating another loss or family of losses. This is an interesting phenomena and due to this chain reaction generally, the losses occurring in a plant are huge in nature and often we do not get a complete idea of how big they are.

2.5.11 Reliability Incident Effects

Figure 2.1 shows the ideal spending or ideal cost of manufacturing in case there are no reliability incidents or breakdowns. There are three major sets of losses taking place as shown. In Fig. 2.1 you see a box representing ideal spending situation when there are no breakdowns. The equipment is running at ideal rate and producing products without any stoppage.

Let us first take the box showing direct effects of breakdown incidents. This includes cost due to maintenance spare parts, cost of maintenance effort, cost of on going energy, cost due to overtime work, cost of additional start-up energy and chemicals usage, cost of consumables, etc.

Let us now take the second box showing wastes due to unexpected incidents. This includes cost of excess staff to deal with unplanned incidents, excess materials for unplanned maintenance and the cost of damage to the other parts due to breakdowns.

Let us now take the third box showing raw material spills due to this breakdown incident. This includes product clean outs, on going yield losses, start-up yield losses, material usage variance and start-up scrap and rework loss.

Due to these losses spending becomes several times higher than the ideal spending which is represented by the big box. This is the source of all the cost saving envisaged in world class maintenance. There may be

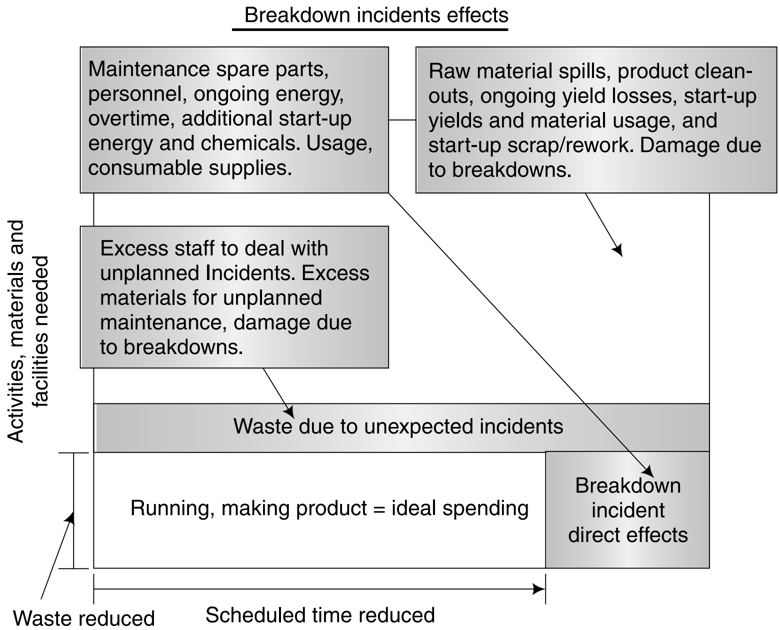


Fig. 2.1

many more such losses pertaining to each industry and it is for them to identify and eliminate breakdowns.

2.6 WHAT ARE KEY ELEMENTS OF MAINTENANCE COST?

Let us now get down to the various costs covered under maintenance budget. Usually, every year the maintenance budget is slashed as a result of cost cutting at the end of the year and maintenance people often get down to reducing spending suddenly at the end of the fiscal year.

We need to understand the various components of the maintenance cost before we embark on our journey on reducing maintenance cost. As we discussed earlier the first year the maintenance cost goes up after you start implementing world class maintenance. In all plants there is a particular measure of performance (MOP) called maintenance cost and there is a tracking system. But, however, you hardly see a downward trend unless and otherwise you start some activities of the kind of continuous improvement in maintenance. The answer is world class maintenance and as we have seen before the maintenance cost goes higher by at least 20%-25%. We can only envisage savings after the first year and the years to come. The game of reducing maintenance cost is discussed in detail in later chapters. This does not mean that maintenance cost reduction is not important, but just to mention that there is a process and it will take at least one year before we start observing any savings.

2.6.1 Cost of Spare Parts Consumed

This generally does not include spare parts inventory and the inventory carrying costs. The inventory carrying costs are covered under manufacturing costs.

This includes the cost of spare parts consumed during the year. For this there needs to be a good accounting system in place. Generally, at the end of the fiscal year there shall be an audit by the chartered accountants and all discrepancies in stores accounting system come to light at that time. In order to have a good accounting system for issues of spare parts every person in the maintenance department needs to cooperate and make it successful. Also a good transparent system needs to be put in place. Cycle counting or perpetual inventory system will also help in this process.

The spare parts consumption in any plant goes higher due to rise in breakdowns, or implementing “restoration process”. It can also go higher if there are any small projects undertaken and by implementing “preventive maintenance”. However, the consumption of spare parts comes down over a period by implementing world class maintenance effort.

2.6.2 Cost of Consumables and Stores Items

Though these are considered to be “C” class items in a store they are sometimes very essential for the maintenance work. So this area cannot be neglected. All nuts, bolts, all kinds of belts, gaskets, rubber rings, rubber hoses and ball bearings, etc., are coming under this section. Even lubricating oils, greases and chemicals come under this section unless and otherwise accounted separately.

The consumption of these items has to be controlled. Accounting for these items is difficult and so there has to be a good accounting system in place to control.

2.6.3 Cost of Indirect Labor

The cost of salaries and benefits of maintenance technicians is covered under this section including overtime if any.

2.6.4 Cost of Tools and Tackles

Tools and tackles is a very important section of maintenance cost. This will help improving the maintenance efficiency and reducing the maintenance time. Consequently, it helps in reducing mean time to repair (MTTR).

Proper tools for the maintenance technicians and various tackles like lifting tackles, measuring instruments and analysis tools like balancing and vibration analysis (BAVA) tool and various other tools and tackles come under this section.

2.6.5 Cost of Replacement of Die Sets and Jigs, etc.

This is also another important area. These are generally not consumables, but however they have to be maintained well and replacement of these dies and jigs is also needed periodically. In some industries these costs are attached to production budget.

2.6.6 Cost of Annual Maintenance Contracts (AMCs)

There are many annual maintenance contracts and mostly these come under the maintenance budget. To name a few, boiler maintenance contract, air-conditioning maintenance contract, HT/LT electrical maintenance contract, DG set maintenance contract, building maintenance piece rate contract, etc. Though this item looks small the cost is quite high and one needs to have a good control over this aspect.

2.6.7 Cost of Training and Development

Needless to mention, training of maintenance technicians in maintenance and diagnostic skills is another important area. In the modern plants training programs for technicians are undertaken. Skill assessment and skill development take place on a continuous basis. Naturally, training cost gets highest importance in the budget.

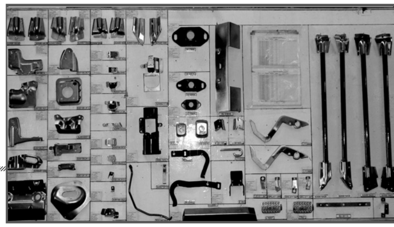
2.6.8 Energy Cost

This cost is generally not considered to be part of maintenance budget, but since the management of energy and verification of bills is done by the maintenance department it is in some places treated as part of maintenance budget.

This covers electricity bills, fuel oil bills, water bills, gas bills, etc. This is a major cost in some process industries and so great importance is given to savings in energy bills and energy conservation projects.

It is the responsibility of every employee in the organization to take care of energy conservation in his or her own area and together as it has the responsibility of reporting to the share holders about the energy conservation measures undertaken during the fiscal year and the savings there-off.

CHAPTER 3



Role of Maintenance Department

The maintenance department has a major role to play in implementing the world class maintenance and supporting the world class manufacturing effort. Here are a few key things which can help the maintenance function process.

3.1 SUPPORT TO JISHU HOZEN OR AUTONOMOUS MAINTENANCE

This is a major effort undertaken if the manufacturing unit implements Jishu Hozen (autonomous maintenance). In fact the speed at which Jishu Hozen can progress entirely depends on the resources deployed for this effort. This effort is called restoration. The Jishu Hozen team identifies the abnormalities in the equipment selected for Jishu Hozen. Depending on how old is the plant and whether or not preventive maintenance was implemented earlier it will emerge as a major amount of work for the maintenance team. There will be a big list of Red tags showing abnormalities, hard-to-reach areas and sources of contamination. In addition there will be White tags. White tags are handled by operator and the team. There will also be a list of chronic problems on which maintenance team will have to work. Then it becomes the responsibility of the maintenance department to analyze the defects or abnormalities and chronic problems to the root cause and take countermeasures. The maintenance department has to suddenly gear up and deploy resources for this most important work.

3.2 COACHING AND GUIDANCE TO PRODUCTION OPERATORS

During the Jishu Hozen work it will come to light that the production operator needs help in understanding his equipment to the component level. He needs to understand the function and setting needed on each component to deliver good quality product. At the same time he needs guidance on preparation of cleaning standard, inspection standard and lubrication standard. Similarly, he needs guidance in writing a one point lesson and documenting Kaizen. The maintenance technician is like a coach. By virtue of his or her higher skill level, he or she becomes a trainer, a coach and a facilitator in problem solving by analyzing using appropriate analyzing tools to root cause.

3.3 LEADING ROLE IN 5S ACTIVITY

The 5S program will be discussed later separately. However, the maintenance department takes the leading role in discarding the unwanted items, preparation of asset disposal request, keeping everything in identified place using “visual control”, and even teaching others the cleanliness and orderliness. One basic principle in 5S is that everything in the area identified for 5S implementation should work properly. That means all fans, ventilators, lighting, computers, lifting tackles, phones, instruments, gauges, fixtures, material handling equipment and everything that is installed should work properly. This is one area in 5S maintenance department can help in a big way.

3.4 ATTENDING BREAKDOWNS

Objective should be to achieve zero breakdowns in the plant and not have quick fixes. That means the breakdown should not recur. So the maintenance department has to achieve the mastery in analyzing the breakdown to the root cause using the “why-why analysis” or “fish bone analysis” and coming out with countermeasures. Then they will have to also fix breakdowns taking minimum time. This needs organizing the work of attending breakdowns by keeping everything (tools and tackles, spare parts, consumables, drawings, lubricants and people) ready to carry out the work. This helps in improving “availability and reliability” of the plant and equipment.

Breakdown maintenance is considered to be the minimum requirement in a manufacturing unit and in some cases the maintenance department just delivers that and neglects many other important roles and responsibilities. That means they may not be doing preventive maintenance (PM). This is due to lack of appreciation about the benefits of doing preventive maintenance. It does not mean that breakdown maintenance is not important. However, just breakdown maintenance may not be sufficient. This aspect has to be emphasized by the plant leadership and more education

<table>
<tr><td colspan="6">WHY-WHY ANALYSIS SHEET</td></tr>
<tr><td colspan="6">MACHINE NAME: Pump motor M/c.No.: 1456 Why-Why analysis No. 32
Date: 3/1/2014</td></tr>
<tr><td colspan="6">Breakdown/defect/Physical phenomenon Motor Bearing making sound</td></tr>
<tr><td colspan="6">What is your final action? Motor both end bearings are replaced Motor both end bearings. Lubrication checked</td></tr>
<tr><td>☑ In case of Spare-Part replacement</td><td colspan="5" rowspan="2">Describe Countermeasure On Inspection Motor bearing found making noise.</td></tr>
<tr><td>☐ In case of Spare-Part no replacement</td></tr>
<tr><td></td><td>Why did you take above action</td><td colspan="4">Due to</td></tr>
<tr><td>Why 1</td><td>Motor both bearings found making noise</td><td colspan="4">Lubrication failure</td></tr>
<tr><td>Why 2</td><td>Lubrication failed</td><td colspan="4">Grease filling not sufficient</td></tr>
<tr><td>Why 3</td><td>Lubrication not adequate</td><td colspan="4">Motor Preventive Maintenance not done for 3 years</td></tr>
<tr><td>Why 4</td><td>Preventive maintenance on the motor not done.</td><td colspan="4">The motor was not considered A or B category equipment</td></tr>
<tr><td>Why 5</td><td>The Motor not considered as Critical</td><td colspan="4">Equipment Ranking (ABC analysis) criteria not done in the plant.</td></tr>
<tr><td colspan="2">* Root cause is one of the following 5 items</td><td>AM</td><td>PM</td><td>Design</td><td>E&T Skill</td></tr>
<tr><td>1</td><td>() Poor Basic Condition</td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>() Poor Operating Condition</td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>(x) Deterioration</td><td></td><td>X</td><td></td><td></td></tr>
<tr><td>4</td><td>() Week Design</td><td></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>() Poor Skill</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">(Note: Please fill up this form in pencil immediately after M/c is started)</td></tr>
<tr><td colspan="6">Kaizen Idea & Schedule Periodicity for doing PM reduced to once a year.</td></tr>
</table>

towards world class maintenance system is needed to the maintenance department.

3.5 ANALYZING MAJOR BREAKDOWNS

This is another important function within maintenance function. The maintenance needs to set up a platform to analyze and go to the root cause on all major breakdowns in the plant. This is the way to achieve equipment reliability and achieve zero breakdowns ultimately. This is generally done by a team of engineers involving technicians and done regularly. The only way to do this is to create a platform and fix a time. It is recommended to carryout analysis immediately after the breakdown is fixed. Regularly, engineers shall also take up for analysis the past major breakdowns by using the tools like why-why analysis or fish bone analysis and then they come out with countermeasures. The criteria here is the same, i.e., breakdown should not repeat again. That means the analysis has to be perfect and the countermeasure should be the right one. This is the path to achieve zero breakdowns.

3.6 IMPLEMENTING PREVENTIVE MAINTENANCE

As the name indicates this is preventive in nature. That means it is a system to carry out maintenance work before the wear and tear goes up to the level of causing a breakdown. But how do we understand the level of wear and tear in equipment especially when the equipment is running continuously. This is very tricky and experience always counts. So fixing the "periodicity" to undertake PM is important. This is done using several inputs. Generally, equipment manufacturers give a maintenance manual or a service manual. This is very useful in identifying the periodicity.

However, the actual wear and tear depends much on the actual conditions in the plant. So as you gain experience and conduct inspection of the equipment you will have a clear picture of the wear and tear and then you may modify the periodicity which has been determined earlier using service manual. Here we are discussing the periodicity to carry out time based maintenance. There are two important aspects in time based maintenance; the inspection of the equipment by using checklist and replacement of worn out parts. So preparation of the checklist becomes very important. The person who prepares the checklist must have a comprehensive picture of the functioning of the equipment, the lubrication method and usage of the equipment. Another key factor is replacement of worn out parts. This list of parts to be replaced is also given by the service manual. Sometimes even if some life is left in the component the part is replaced so that no breakdown takes place. Here the service manual becomes the Bible and we do not ask any questions.

Preventive maintenance has two wings—time based maintenance (TBM) and the condition based maintenance (CBM). This is a major effort and the department has to first do preparation of TBM plan, deploying technicians to do it on a regular basis and also check the compliance rate compared to the preventive maintenance plan.

3.7 IMPLEMENTING CONDITION BASED MAINTENANCE (CBM)

Next do preparation for the condition based maintenance (CBM) and implement it. By this method the maintenance department shall be able to deliver savings in maintenance cost and improve availability and reliability. How is it different from TBM? In time based maintenance, the date to carry out the TBM work is determined by the plan. As per the periodicity mentioned in the plan the maintenance work is carried out. As per the plan the parts are also replaced as mentioned in the list. This is why it is called time based maintenance (TBM).

But however, in condition based maintenance, the periodicity is not determined before. The inspection is carried out on the equipment by using diagnostic tools to understand the wear and tear and then the maintenance work is planned. So, the life of the component is fully stretched and utilized. However, the diagnosis has to be proper and the maintenance work is carried out properly. Since the life of the component is stretched there can be savings in the maintenance cost. That is the reason it is called condition based maintenance. In process industries it is becoming more popular and the science of CBM is developing rapidly.

3.8 SPARE PARTS STORES MANAGEMENT

In order to achieve zero breakdowns the maintenance department should have an excellent storeroom. There should be adequate inventory but at the same time the inventory should not be excessive. All the parts in the storeroom are put under classification by conducting ABC analysis. The inventory levels in “A” category and also “B” category stores items are decided by properly planning the replenishment of parts. For this minimum, maximum and reordering quantities are decided for each item in “A” category and then “B” category. The “C” category items are generally consumable items and hence they are less important. Since “C” category items can be procured easily from the market, off the shelf, the extensive planning of quantities may not be needed.

The maintenance department has to organize the store. The first thing is to prepare a master list of all items with coding so that the stores inventory is computerized. Then there should be a layout plan of the stores at the entrance. The same should also be available in the computer. The person who needs to retrieve a spare part should be able to identify the location by using this layout. The racks in the store room should be marked with numbers or names so that retrieval becomes easy. All spares items should have identification tags. This helps in accounting the spare items. The most important work of the storekeeper is keeping everything in order with visual controls and achieving accountability of the spares consumption to see that there are no discrepancies in accounting. Keeping adequate inventory and also see that all non-moving and slow moving parts are reduced, is the key function of the storekeeper.

3.9 ENHANCING MTBF (MEAN-TIME-BETWEEN-FAILURES) AND REDUCING MTTR (MEAN TIME TO REPAIR)

These two are very important functions of the maintenance department. This is as important as measuring blood pressure and pulse rate for a human body. But this should not become a number game. These two measures have to make sense in the plant. This is key function and clearly shows the health of the maintenance organization.

MTBF is a measure showing how long a machine can run without having any breakdown or failure. So, by measuring MTBF for all important equipment the journey is started to enhance MTBF at least two to five times. Though this is the initiation, ultimately this effort shows a path to achieve zero breakdowns. One needs to know the theory of MTBF before embarking on the journey. This is discussed in detail in a later chapter.

MTTR clearly represents the efficiency of the maintenance department. This is a measure of mean time taken to repair when any breakdown takes place. That means every activity in carrying out repair work has to get attention and every activity will have to be done faster than before to reduce the time taken. The activities include clearing the site, getting tools and tackles, dismantling the machine for repair, identifying the countermeasures collecting the spare parts from store, fixing the parts with less effort or by simplified method and finally taking trials. This whole game should take less time in order to enhance the availability. Targets like half the amount of earlier MTTR and even lower levels are expected.

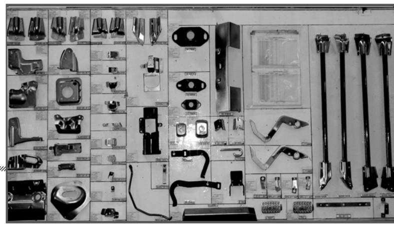
3.10 LEADING ROLE IN KAIZEN

This is continuous improvement and needs full support of the maintenance function. This does not mean that all the innovative ideas are generated by maintenance function only. All the people have to be involved in the plant. But, however, the maintenance function has to help the ideas to be developed and help the teams in fabrication and erection. Very essential thing in Kaizen methodology is making the idea successful. This is where the help is needed from the maintenance function. Similarly, training to be provided in documenting the Kaizen in the prescribed format is also done by the maintenance function.

3.11 IDENTIFY MEASURES OF PERFORMANCE AND TRACK THEM

The maintenance function needs to identify measures of performances (MOPs) and track them to show the progress it is making and the savings it is generating for the company.

CHAPTER 4



Objectives of World Class Maintenance Management

Let us now look at the prime objectives of implementing world class maintenance management. This is important since all the people concerned should be aligned on this objective. This being a major effort, maintenance department and production department should be very clear as to what they are going to sow and what they are going to reap.

4.1 IMPROVING AVAILABILITY

Availability is defined as the ratio of actual running time divided by the scheduled time. Or it can also be defined as

$$\text{Availability} = \frac{\text{Running time}}{\text{Running time + downtime}}$$

Let us try to understand what is the significance of this? Every entrepreneur who invests money in plant and equipment would like to have all the equipment running all the time and not have idle time or downtime. In order to have less idle time the machine should have been scheduled for production all the time. However, this particular aspect depends on the demand in the marketplace. In a sold out company the plant and equipment run all the time and whatever is produced gets sold. However, this kind of situation may not be prevailing in other companies.

The whole idea here is to reduce downtime. Downtime means the equipment is not running due to a breakdown or due to issues like material not available, people are absent and so nobody to run the equipment or even the power is not available. There could be many reasons for the downtime. There are two types of downtime:

4.1.1 Planned Downtime

Equipment shutdown for project work or modification, shutdown for preventive maintenance, shutdown for annual maintenance, holidays or shutdown due to no plan for production (no demand). Planned downtime can be reduced by reducing the time taken to do the project work, preventive maintenance and annual shutdown for maintenance. This can also be reduced by selling the products hard and creating more demand. In some plants there is a planned downtime for lunch and tea of the employees and in some cases planned shutdown for attending training. This type of planned shutdown is in the hands of the management and the employees. That means they can choose to reduce these types of planned downtime to increase the availability.

4.1.2 Unplanned Downtime

Equipment breakdown, material not available, people not available to work, power not available or some natural calamities, etc., are reasons for unplanned downtime. Proactively understanding the situation and preparing for such unplanned downtime can result in reducing such downtime. For example, for power outages have the supply from another installed feeder or have supply from diesel generators can be achieved. Similarly, unplanned downtime from other reasons too can be handled if you anticipate and are prepared for it.

Improving availability is all about eliminating breakdowns and eliminating all downtimes—planned or unplanned. Here we consider the ideal condition and compare the current situation with the ideal time.

One such example is the lunch-break. The people should have lunch but the machine should not have downtime for such reasons. So how do we keep the equipment running all the time and at maximum possible rate (ideal rate)? This is a challenge but it is possible to do it.

Another example could be the shutdown for major maintenance work. The maintenance department may take a shutdown which is properly planned. However, how to reduce this shutdown period is important. This is done by using modern methods, tools and tackles and also by reducing time taken to do the maintenance work by proper planning and by improving the skills of people who are working on this shutdown.

4.2 IMPROVING RELIABILITY

Reliability is defined as the probability of a plant to give satisfactory performance without any breakdowns or stoppages, when it is called upon for service. Reliability focuses more on equipment failures. In short, reliability is described as a study of failures. Analyzing the breakdown to the root cause and making design corrections. If you study about breakdowns some are caused due to overloading while some others could have taken place due to stress concentration or lack of lubrication and in some cases due to material failure itself. Reliability is all about studying the failures of equipment components to the root cause and making design corrections.

It is a unique situation here. Generally, equipment failures take place at the users end. Then how does the user get involved in the design corrections? If the users are capable to carry out the design corrections, then they can do it. However, this is a major effort starting from designing, making and installation and commissioning of the equipment.

The question is, how the end user of the equipment gets involved in designing, making of the equipment and then installation and commissioning. This is a joint effort and is explained in much detail in the following chapter.

There is a saying that good maintenance starts at the design stage. So, all the inputs from reliability study and customer feedback in the form of maintenance prevention data (MP data) could be considered in the subsequent design to improve equipment reliability.

4.3 CONCEPT OF BATH TUB CURVE

Figure 4.1 shows the bath tub curve. The name of the curve is obviously derived from its shape. This is in the shape of a bath tub and hence the name. In the X axis we have the time or "life of the equipment" and in the Y axis we have "mortality rate" or simply said "problems" or failures.

There are distinctly three main areas we need to concentrate on. The first phase is called "infancy". The second phase which is almost horizontal and uniform is the "youth" and the third phase which is again rising up is called "old age". Let us understand why these terminologies have been used in this picture.

The background is that somebody made a comparison of the behavior of equipment to that of a human being. Let us now get into details of this important feature.

4.3.1 The First Stage or Infancy Stage

As we see in this world the mortality rate for a new born baby is high in the beginning and goes on improving as it grows. Similarly, in an

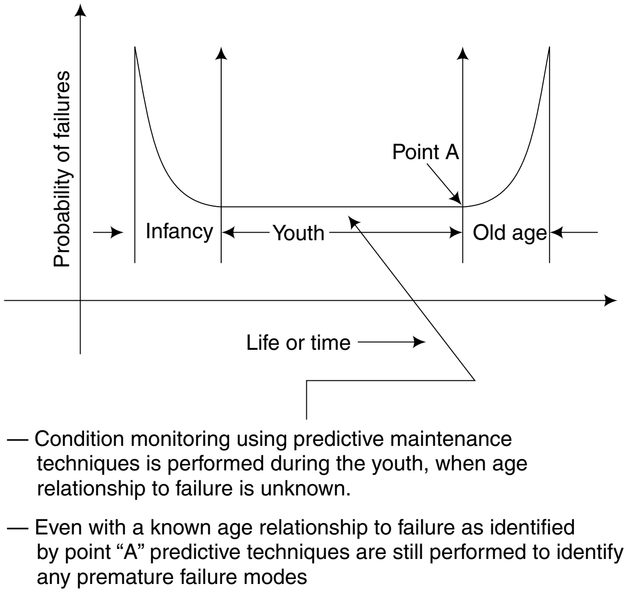


Fig. 4.1

equipment, the failure rate is high in the beginning and as the commissioning team of engineers keep a track of all the failures and coming out with remedial measures it goes on improving till it gets into youth. However, there are huge losses taking place due to these early failures.

4.3.1.1 Machine Time Loss Due to Failures

The equipment will lose production time due to failures. The failures are in the equipment, failures are in the process, and failures are in the method as people are not qualified to do the work as operator. Sometimes you will observe big breakdowns, process mess up and even accidents if the operator is not trained on the method.

4.3.1.2 Material Loss and Wastages

There will be considerable amount of wastages and scrap generated due to start and stops. Since the 4Ms are not qualified to start production you will see huge amount of wastages and scrap. Even the method of rework is also not understood at this point of time.

4.3.1.3 Quality Rejections

There will be quality rejections as the equipment is not set properly and the operators do not understand the settings. Since it is a launch of a new product the market is all eyes on the performance and quality of the product. This is the reason some companies get into market call back. This is highly undesired but happens sometimes.

4.3.1.4 Delay to Launch the New Product

It may also amount to delay in introducing a new product in the market-place and one cannot estimate the amount of loss which has taken place due this kind of delay. Delay in launching a new product is not considered to be simple. You may even lose customer franchise or goodwill. This is the reason we say that loss we may not be able to estimate.

4.3.1.5 Chronic Problem Loss

Finally, there will be permanent losses due to not attending all the problems such as "chronic problems" before handing over the equipment to operation department. Chronic problems are those problems which are not understood well. They have complex root cause (or causes) and so if you leave these chronic problems unattended, they will linger on forever.

So let us discuss about how to solve this issue. We need to have a good design of the equipment put in place. We need to have design reviews with operating teams. We also need to have a manufacturer who will make the machine with good manufacturing practices taking into consideration all the specifications and tolerances. And then we need to have inspection of the equipment carried out at various stages as planned. Finally, the project team has to install the equipment and commission it with good engineering practices. So, how do we manage to accomplish all these in a prescribed time frame?

4.4 FRONT END ENGINEERING

This is techno-commercial work to be done before we even start making the capital appropriation request to the company hierarchy. The front end engineering work includes the following.

4.4.1 Comparison of Technology

The first and foremost important thing we need to decide is what is the level of technology we are going to use and what is the level of automation or sophistication level? What are the benefits of going in for such technology levels? How this level of technology fits into the existing production line or production cell? What is the service set-up available in the vicinity of our plant? These are some of the main considerations.

4.4.2 Knowledge of Popular Suppliers or Makers of the Equipment

This is purely a commercial function. Knowledge about who are all the reputed suppliers of the equipment in India or internationally and what are the pros and cons of selecting a particular vendor or supplier. Of course, this part of responsibility needs a lot of work in terms of audits or visits to the supplier's place and understanding more details from such visits.

4.4.3 The Experience of Previous Users of Such Equipment if Any

This is an important feedback or piece of information needed before buying the equipment. We may even ask the vendors for a list of existing users of their equipment. Secondly, we may even ask the feedback from those users about the equipment. The vendor may even arrange visits to such users to understand in detail about the equipment from the users. In some rare cases confidentially getting all relevant information may be needed without the knowledge of the vendor.

4.4.4 Initial Cost and Recurring Costs of the Equipment

When we make the comparative statement of various vendors only tabulating initial cost or purchase price may be misleading. We need to take into consideration the recurring cost also. In some cases recurring costs are high and if you see long term we may lose. This is easier than done. It is a difficult task getting all the recurring costs. Only some actual users may be able to give you more accurate data. Recurring costs include cost of energy consumption, cost of repairs, price of annual maintenance contract and other operating costs.

4.4.5 Readiness of the Supplier(s) to Make Changes as Desired by the Customer

This is another key point. We are discussing about how the user of the equipment can give feedback to improve the design of the equipment, but practically when we go out and find that the supplier or the manufacturer of the equipment is not keen on taking up any design changes. He would not like to make any changes just for you. Some suppliers may even give an excuse of standardization work done by them which does not permit them to make changes.

4.4.6 Technical Capabilities of the Supplier in Terms of Credibility to Carry Out the Design and Deliver the Equipment on Time

This may look just a formality, but however this is an important work to be put in place before we make a comparative statement and make the final choice about the potential supplier. Hence, we need to conduct an audit of all the suppliers manufacturing facility and then decide.

4.5 LIFE CYCLE COSTING

Life cycle costing is an important factor here. When we make a comparative statement we need to have a system called “life cycle costing”. In some cases considering the technological change the initial cost of the new equipment might be more. However, if you consider the running cost over a period of the life cycle of the equipment one will see a big transition taking place. This is a key input in making the final choice of the supplier.

4.6 CUSTOMER FEEDBACK

This is another important factor to be considered. The buyer may ask for the list of key customers and may go and actually inspect the equipment at the users place or take feedback from the user. This is very important as sometimes there will be lack of information on some points or the sales people may not have the knowledge of all advantages and disadvantages of a particular equipment.

This front end engineering work then will slowly lead to making one final choice of the supplier of the equipment.

4.7 DESIGN INPUTS FROM THE USER OR MP DATA

At this stage all user inputs (design inputs) to be given to the supplier for all the changes needed. This is a very important stage because all the inputs for the improvements to be done in the design of the new equipment are given in such a way that the equipment supplier clearly understands the customer requirement for improving the performance of the equipment. The MP data should be given in prescribed format and supported by drawings, technical details, specifications so that the vendor understands them fully before they make any commitments.

Let us look at what are these inputs.

4.7.1 Standardization Requirements

This is to take care of standardization of various equipment components and sub-components at your end. If you have standardized your drive motors, V belts, gear boxes, electrical components, cables, programmable logic controllers (PLCs), ball bearings, etc., then at this point of time it is imperative to tell the supplier about your standardization program and give the supplier a list of all such components. It is done with good understanding from both sides that the new equipment will have these standardized components only.

4.7.2 Operability Requirements

Operability is ease of operation. These are requirements, suggestions or observations of the operating teams. During the operation of similar equipment or the same make equipment which was procured from the same supplier earlier the operating teams will have several suggestions for improvement. In a place where Kaizen is a way of life or the operating teams are practising Jishu Hozen they would have carried out a number of improvements on the similar machines. These improvements could be in the area of just operability, or on productivity improvement or even quality improvement. These are documented by the teams as operability improvements. These documents need to be very precise and supported by technical drawings and specifications.

4.7.3 Maintainability Requirements

Maintainability means ease of maintenance. This is coming out of requirements, suggestions or observations of maintenance team. During attending any breakdowns or while carrying out preventive maintenance work the maintenance team will normally come out with so many suggestions for improvement. These are important to reduce time taken to do maintenance work and reduce MTTR and thereby improve availability and reliability. These are captured by the maintenance teams and finally go into the maintainability data.

4.7.4 Reliability Requirements

These are coming out of reliability engineering studies done by the equipment user independently or jointly with the equipment supplier. These may include the studies done on some failures during the use of the equipment or some major changes done on the equipment in metallurgy or surface hardening or reduction of stress concentration, etc. These are generally documented by the reliability engineering team or by maintenance team if such reliability engineering team does not exist.

4.7.5 Maintenance Prevention Requirements

This is also known as MP data. MP data is very important in procurement of new equipment for a manufacturing plant.

Maintenance prevention concept helps reducing the maintenance work by coming out with new metallurgy, new methods or just new ideas. These are coming out of corrective maintenance work done in a plant on a similar equipment. These are documented by the maintenance teams in a prescribed format so that there is a good understanding between the end user of the equipment and the supplier of the equipment.

MP data is extensively used in the modern world in improving the time taken to do maintenance or eliminating the maintenance work. As a result so many maintenance free components are now coming into picture.

4.7.6 Visual Control Requirements

Recently visual controls are very prominent in equipment making and operating. Visual controls help in identifying the daily inspection points and that makes inspection easy. A number of standard visual controls are available in the marketplace, however, there are some very creative visual controls also coming into picture when there is Jishu Hozen activities going on in the plant. The buyer of the equipment has to make sure that there are extensive use of visual controls at making stage only so that the teams will not have to be worried. The visual controls help in identifying the inspection points, identifying tools and tackles, identifying operating conditions like flow direction, pressure, temperature and the like.

This improves the efficiency of the operator and the maintenance person.

4.7.7 Preliminary Discussions

These inputs are documented and then a preliminary discussion with the supplier is an essential part of equipment procurement. Since some major changes in the design are possible, the supplier may ask for revision in the quotation. It is the job of the procurement team to convince the supplier of the benefits the supplier is going to get by improving his design. If the supplier is convinced he or she may not ask for any revision in price.

4.7.8 Signing Agreement

There has to be a thorough understanding from the supplier side and an agreement has to be signed for all the changes to be incorporated in the design of the new machine. This is necessary as the supplier may not take it seriously if it is only a verbal agreement.

4.8 INSPECTION OF THE EQUIPMENT FABRICATION OR MANUFACTURING ACTIVITY

The next step is the inspection of the equipment at various stages. We need to inspect the quality of construction and assembly of the equipment. The inspection will have to be conducted by the user or by a competent third party. There are at least two stages in which inspection is carried out.

4.8.1 Static Check

This inspection is carried out when the equipment is not in running condition, but the components can be inspected. This is done with mutual agreement between the supplier and the user. Since the user has asked for many changes to be incorporated including metallurgy in some cases, a thorough inspection to be carried out with the help of a checklist specifically made for the purpose.

All items which have been the part of changes requested by the buyer by way of MP data sheet, operability requirements, maintainability requirements, reliability requirements and visual control requirements to be checked specifically during this static check.

4.8.2 Dynamic Check

This inspection is carried out when the equipment becomes ready to run, at least for a short time for trial purposes. Here the inspection is carried out on running parts if there is any abnormal sound, smell and heat. All the running parameters like rpm, pressure, temperature, electrical load while idling and while running (no load current and full load current) are checked at this stage. In some cases even functional characteristics are checked. If the equipment permits to take trial with raw materials actual running trial can be taken at this juncture. This again is done with the help of a checklist.

4.9 INSTALLATION AND COMMISSIONING

A three-step methodology for the installation and commissioning is generally followed. We commonly call it is installation and commissioning. But here we have a three step methodology. This is introduced mainly to achieve a smooth transition of the equipment from the manufacturer to the user's plant. There are chances that some things have not been inspected or discussed and that finally shows up at the commissioning stage. This three-step methodology is called commissioning, qualification and verification (CQV).

4.9.1 Commissioning

This is a generic term for the work done to get the equipment inspected at the supplier's end and make sure all the changes needed as per the order are met. But there are three distinct steps in inspecting, installation and commissioning of the equipment. This is the reason the three step methodology has been put in place.

4.9.2 Qualification

This is to qualify the four Ms (machine, material, man and method) and in some cases even environment is also included. For this purpose a specific step called technology transfer and training (TT and T) has been included. The four Ms have to be qualified before we hand over the equipment to the operating teams. A thorough plan is prepared well in advance to do this part and conducted methodically.

The person who is going to operate the equipment is important and has to be trained and qualified. This is done by giving proper training and taking a test at the end to see the effectiveness of the training. All adjustments and settings have to be learned by the operator in order to produce good quality product on a continuous basis. Similarly, the equipment will also be qualified by the static check, dynamic check and then the final check after installation with all piping, ducting and cabling, etc. Since the new equipment is expected to make a big difference after commissioning, even the material will have to be qualified. If there are any changes in the materials or a new supplier has been introduced or there is an import substitution of the material activity going on, the qualification process for the material has to be conducted. Finally, there will be a standard operating procedure (SOP) to be put in place and the operator will have to be trained on the SOP.

Once this part is over actual trials will start. The team shall decide the criteria for the vertical start-up. The equipment is expected to run without any major or minor issues. The definition of vertical start up is all the criteria of the vertical start up defined by the team should be met.

The equipment should operate at rated capacity and produce products without any rejects and continuously for the period stipulated by the team. This is called vertical start-up. In some batch processes it could be three consecutive batches. In some other equipment or assembly lines it may be eight hours production or a full day's production as decided by the commissioning team. There will be signing off and handing over taking place at the end of the qualification process.

4.9.3 Verification

It is also known as validation. This is done to take care of any problems taking place immediately after the project team hands over to the operating teams. If the commissioning is done meticulously there will be no chance that some such issues will come to surface. But, however, a detailed verification checklist is prepared in advance and a thorough inspection carried out to see equipment related, process related and human skill related issues are identified and resolved. The validation period is generally a bigger duration like a week or may be one to three months in some cases.

This much is about the "infant stage of equipment" and we now proceed further to the youth stage.

4.10 THE SECOND STAGE OR YOUTH STAGE

This is the real harvesting time and the benefits of all the work done in the infant stage will give dividends in this stage. Like in a human being the youth works, plays and takes part in all social activities for enjoyment in life, the equipment also runs normally if taken care of by implementing some important aspects mentioned below.

4.10.1 Elimination of Forced Deterioration

What is forced deterioration? The answer is deterioration taking place on the equipment due to factors which are external. Deterioration taking place due to dust, dirt and grime. Then the dust is causing rust and reducing the effect of lubrication. Forced deterioration is not just happening due to dust, it also happens due to improper operation, improper maintenance or misuse of the equipment. It can also happen due to electrical power fluctuation or by contamination. This contamination can be also due to oil, water and coolant leakages.

Now the question is who has to take care of forced deterioration? It is obvious that the person who is operating the machine and is all the time available near the machine, is the right person. This is why the autonomous maintenance or Jishu Hozen came into being.

4.10.2 Cleaning, Inspection, Lubrication and Tightening

If the operators are taking care of by cleaning the equipment and rendering it absolutely clean without any dust, dirt and grime, inspecting the equipment for normal functioning of all important components and also carrying out proper lubrication then there will be no chance for any forced deterioration. Furthermore, if the operator also understands the functioning of all the components of the equipment and knows all the settings and adjustments needed then there are no chances of any breakdowns. This is the origin of Jishu Hozen.

4.10.3 Good Operating Practices

All operators have to be trained to operate the equipment with complete knowledge of the equipment settings and adjustments and inspect the equipment with proper care. The operators who operate the equipment in the right way and produce good quality product have job satisfaction.

4.11 ELIMINATION OF NATURAL DETERIORATION

What is natural deterioration? In the plant and equipment there is an amount of deterioration taking place always. This may be due to ageing or material getting back to the original form; (like iron getting rusted and going back to the original iron ore form). Discussing further, even if a ball bearing is well lubricated the bearing has a small amount of wear and so will need replacement after some time.

Similarly, an electronic component during operation runs for several million cycles and then it fails. This is due to natural deterioration.

Now who has knowledge about this natural deterioration? Obviously, the maintenance department has knowledge about this aspect. So, it becomes the responsibility of maintenance people to take care of natural deterioration. That means understand the pace at which natural deterioration takes place and how often the part has to be replaced. This is the basis of preventive maintenance.

4.11.1 Preventive Maintenance

In the youth stage or second stage another important aspect is maintenance department carrying out preventive maintenance on all identified equipment. We shall discuss in detail about preventive maintenance later, but in order to have the curve (bath tub curve) in a horizontal level for a long duration of time, preventive maintenance becomes of utmost importance. In fact the life of the equipment depends upon the practice of elimination of forced deterioration and efficiency in reducing natural deterioration. In preventive maintenance as we have discussed earlier TBM and CBM both have to be carried out effectively.

Jishu Hozen followed by good preventive maintenance can give wonderful results. In fact the life of the equipment increases to such an extent that the third stage of equipment shall get eliminated. That means there is no old age for the equipment. Only in case of technological changes the superiority of the technology may come into picture and may demand replacement of equipment, not because of old age, but due to technological changes.

4.11.2 Condition Monitoring

This, as the name indicates, is maintenance activity carried out based on the condition of the equipment. However, assessing the condition of the equipment needs necessary skills. The condition monitoring is done at two different levels; firstly, the operators doing inspection thoroughly and assessing the condition of the important components on a regular basis. Secondly, the maintenance department or in some cases the inspection department carrying out the equipment diagnostics. If the condition monitoring is taking place simultaneously in the plant, the breakdowns will come down drastically and even the minor stoppages will also decline. This will slowly lead to resorting to condition based maintenance (CBM) instead of time based maintenance (TBM).

If this is done in a planned way, the plant can switch over from TBM to CBM in phased out manner and reduce maintenance costs.

4.11.3 Enhancing the Life of the Equipment

Generally, when we study the failures of the equipment we come across a few components of the equipment which are also failing. These components then become important for our study. Enhancing the life of the equipment means enhancing the life of these components. For this we need to go to the root cause of the failures and take corrective action. In this way enhancing the life of each critical component will lead to enhancing the life of the equipment. For this we need to establish a forum. This forum is a few engineers putting their heads together and solving problems by analyzing and going to the root cause. This may also be called enhancing mean-time-between-failures (MTBF).

4.11.4 Lubrication Management

Daily lubrication is different from lubrication management. The lubrication management is the responsibility of the maintenance function. Standardization of lubricating oils, storing them with good visual controls, providing proper oils for the operators to do the daily lubrication and training the operators on the lubrication system of the equipment are the key responsibilities of the maintenance function. This is to make sure that the proper lubrication system is put in place and daily lubrication without any mistakes happening in the plant.

We have now understood that in the youth stage or second stage of bath tub curve can be enhanced or enlarged by the above-mentioned practices; elimination of forced deterioration, taking care of natural deterioration by TBM and CBM, enhancing the life of the failing components by special diagnosis and Kaizens and also instituting a good lubrication management system. This sounds theoretical but has great merit to have reliable plant for a long duration.

4.12 THE THIRD STAGE OR OLD-AGE STAGE

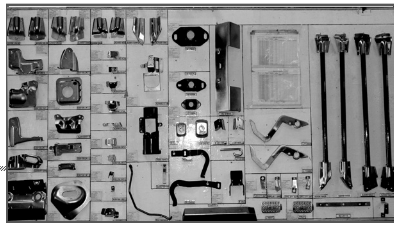
4.12.1 Replacement of Old Equipment

If the plant and equipment are taken care of during infant stage and youth stage then equipment deterioration can be minimized in the plant. However, technological changes in the equipment may demand replacement of the old equipment. On one hand these are assets and one has to take care of the equipment and enhance life of the equipment and on the other we need to replace some worn out equipment and are inferior in technology. The maintenance function should be able to do this with proper logic. The life cycle costing methodology will be useful here and the maintenance function should be able to present the case to the management with cost data.

4.12.2 Reconditioning or Refurbishing

This is another main aspect in maintenance. There are some instances where old equipment can be refurbished by using outside contract or in-house. This may be needed if found economical to do it. Again the responsibility is of the maintenance function to justify such equipment. There are some advantages of this methodology as the old equipment is completely overhauled and it will become as good as the new equipment.

CHAPTER 5



Six Steps of Progressive Maintenance

5.1 HOW DO WE START (SIX STEPS OF PM)

After we saw the initial justification of why World Class Maintenance (WCM) is important we now need to understand as to how do you make a beginning. Depending on where you are in your WCM journey we need to pick up from the current status and start. Let us now look at the step-by-step methodology for starting the journey and developing it to a fully-fledged maintenance function.

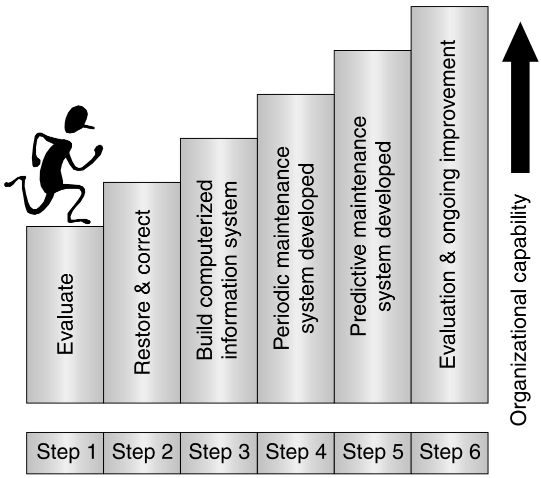


Fig. 5.1 Steps of Progressive Maintenance

5.2 STEP-BY-STEP DEVELOPMENT PROCESS OF PROGRESSIVE MAINTENANCE ACTIVITY

What is progressive maintenance activity? This has been named progressive maintenance because this is a much advanced and latest methodology compared to the planned maintenance activities generally carried out at the plants in our country. In a new plant you have a great advantage if you start progressive maintenance from the day one. It becomes beneficial to the organization if the maintenance manager starts using this methodology instead of starting it later. It is always good to start a culture from the very beginning. Similarly, if you join a new organization as maintenance manager, the author advices to start this six-step methodology as early as possible to achieve breakthrough results. This is not rocket science. This needs careful understanding of various steps and the activities mentioned here so that this will become a guideline.

This is a six-step process. If you are starting your journey in any plant or organization this six-step methodology becomes a very useful guide for developing your organization into a streamlined, efficient and effective organization. This is only a guideline and all users should first understand the situation and then start in any appropriate step as needed. However, this six-step methodology is proven and people have found it very useful.

5.2.1 Step 1. Evaluate Equipment and Understand the Situation

5.2.1.1 Prepare and Update Equipment Log

This is a very important step in developing a good maintenance system. For any further work in maintenance we need reliable and accurate data. The equipment log system has to be in place and also see if the data logging system is well understood by all people who are making entries into it. The major item in this is accounting for the equipment time. We need to be able to account for 100% of equipment time. Secondly, we need to be able to explain the minor stoppages in the equipment system. Many a times the equipment is not having any breakdown, however, due to minor stoppages or some small problems, loss of time is taking place in the equipment system. Our data system should give us all the data needed to identify all the losses taking place.

5.2.1.2 Evaluate Equipment: Establish Evaluation Criteria, Prioritize Equipment

Secondly, we need to get into prioritizing of our maintenance work. For this reason we need to understand as to which equipment we need to focus more than the others. This is called equipment ranking. This is also known as ABC analysis of the equipment. The criteria for equipment ranking is given below:

(A) Critical Equipment

- High level of criticality based on impact on PQCDSM (these are called plant level performance measures: productivity, quality, cost, delivery, safety and morale)
- Equipment with chronic problems.
- Equipment carrying out very essential function in the shop floor.
- Equipment which has major effects on product quality or market complaints.
- Equipment which is at the end of the line.
- Equipment which needs high level of monitoring and CBM.

(B) Medium Criticality

- Equipment which can have either Time Based Maintenance (TBM) or Condition Based Maintenance (CBM) system.
- Medium criticality as it is not a bottleneck machine or not running 24 hrs in a day and has free time for maintenance.

(C) Less or No Criticality

- Equipment is standby equipment or does not have much impact on production.
- Equipment which can have TBM maintenance system.
- The equipment is not on a regular production line.

5.2.1.3 Define Failure Ranks

Ranking of failures of equipment is important at this stage. Ranking failures can be done in the following manner. Rank failures as major, intermediate, or minor depending on their effect on equipment. For major and intermediate failures implement measures to prevent their recurrence and also to prevent similar failures from occurring in other equipment.

A failure data management system includes certain information, which shift operators must enter in the database. Such information includes data and time, failure rank (major, intermediate or minor), equipment model, failed component, nature of failure (vibration, abnormal noise, overheating, corrosion, wear and tear, etc.), then the root cause, action taken on the failure, effect on production and time.

The system should be able to generate reports with this information each morning for discussions at the morning meetings. The team can analyze minor failures at these meetings. However at weekly maintenance meetings they should reanalyze major and intermediate failures that were fixed by the team and consider measures to prevent their recurrence. This data should be analyzed and made available at regular intervals in the form of periodic failure summaries.

5.2.1.4 Set Maintenance Goals (Indicators, Methods of Measuring Results)

Setting maintenance goals at this juncture becomes the most important task. That is to establish breakdown time as a percentage of running time, breakdown frequency, breakdown compliance rate, preventive maintenance compliance rate, predictive maintenance compliance rate, maintenance cost saving, MTBF, MTTR, etc.

5.3 STEP 2. REVERSE DETERIORATION AND CORRECT WEAKNESSES

5.3.1 Establish Basic Conditions

This is a major step in developing world class maintenance. Reverse forced deterioration, and abolish environments causing accelerated deterioration by giving full support to Jishu Hozen or autonomous maintenance. This is known as restoration. In plants where the management is implementing Total Productive Maintenance (TPM), it becomes the part of TPM effort, but however in a plant where TPM is not yet considered to be a key strategy, the maintenance team will have to take lead and implement it. This is generally a team effort. Team members are selected from operation department plus resources from maintenance department and quality department. This multifunctional team will take charge and will carry out restoration work.

How this is conducted? Based on the equipment ranking the management shall take any particular equipment as a leadership model or management model. Here the most important decision is how to take this equipment out of service for at least 2 to 4 hrs at a stretch and then carry out restoration. All tools and tackles shall be kept ready so that no time is wasted after taking the shutdown for the restoration work.

There is a designated team leader and a technical resource attached to each team. The whole team shall meet at the site with the team leader and the technical resource. Roles and responsibilities are then identified for the team members, including data collection and documenting the abnormalities identified by the team. The team then starts the work of restoration.

5.3.2 Jishu Hozen Step 1: Initial Cleaning

The first and the foremost work is initial cleaning. All team members, irrespective of the roles and responsibilities, shall engage in initial cleaning. The machine should be thoroughly cleaned of all the dirt, dust, grime and oil, and rust marks. In order to facilitate good cleaning the machine can be dismantled if needed. All the connecting pipes, cables, conduits and all parts of the equipment are thoroughly cleaned by using rags, brushes, chemicals, kerosene or diesel, and in some rare cases scraping for getting rid of all the dirt. This work goes on for several hours and then the equipment is given for production back again. One needs to be careful while dismantling the machine and surely be mindful that the equipment has to be given back for production the same day. This way the initial cleaning goes on for several rounds with several sessions of cleaning work until it comes to a satisfactory level.

The cleaning work also includes 5S activities. That means all the tools and tackles belonging to the equipment are kept in an organized manner and the retrieving system is discussed among the team members. They are then identified with proper naming, numbering and color coding and kept near the workplace for the convenience of the operator. Yellow line marking is also done around the equipment in order to identify the boundary of the work happening right now.

Then the team will engage with the work of preparing a "Cleaning Standard". After cleaning the equipment several times, the team develops sufficient skill in cleaning and rendering the equipment in an absolutely spic and span condition. This skill is used to prepare the cleaning standard. This is developed in order to teach the operators to clean the equipment in a short span of time and very effectively.

Identify abnormalities: After several rounds of initial cleaning work conducted on the equipment, the whole team shall get engaged in identifying the abnormalities and putting red tags on the abnormalities. This is another major work. The team shall later engage in attacking the abnormalities by analyzing the problem and arriving at a solution. This is again a comprehensive piece of work as the solution to the problem has to be the root cause and the same abnormality should never occur again. There are abnormalities of various kinds. This guideline is needed for the new members to be able to identify the abnormalities.

1. Abnormalities
2. Hard to Reach areas (HTRs)
3. Sources of contamination (SOCs)
4. Chronic problems.

Let us now look at each one of these in detail.

Types of abnormalities:

1. Minor flaws (cracks, thermometer broken, pressure gauge not working)

2. Unfulfilled basic conditions (grease nipple not provided)
3. Inaccessible places (hard to reach places)
4. Sources of contamination
5. Sources of quality defects
6. Unnecessary items
7. Unsafe places/conditions

In addition to the above seven items, just simply anything that is not appearing as per good engineering practices is an abnormality.

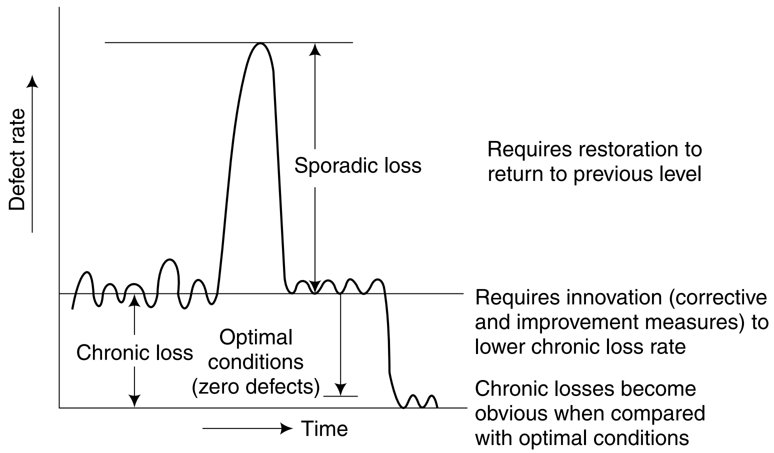


Fig. 5.2

Let us now briefly discuss the chronic problems. There are *sporadic problems* and there are *chronic problems*. Sporadic problems are repetitive in nature but generally they are simple to understand and to rectify. However, chronic problems are complex in nature and are very difficult to analyze. However, at this point of time the team shall not get bogged down by any chronic problems and shall carefully analyze and come to the root cause to solve them permanently. That means once having gone to the root cause and solved the problem the same problem shall not appear again. The chronic problems have sometimes multiple causes and so it takes some complex tools to analyze. The simpler tools like "why-why" analysis is good enough for simple problems. However, the team may need to use, fishbone analysis, work point analysis or PM analysis to finally solve the problem. Mastery over these tools is also needed to be achieved by the team.

5.3.3 Jishu Hozen Step 2: Fix All Abnormalities

Once the team has a list of all the abnormalities and the chronic problems, it is time to make an action plan or a milestone map. In step

2 the team gets enthused to solve all the problems by analyzing and finding the root cause. Then they shall fix all the abnormalities with the help of maintenance department. The white tags, however, can be fixed by the operating personnel. This work needs a lot of resources in terms of money and people. The team may choose to take outside help. The time has now come to prepare an *inspection standard*. This is used by the operator to inspect his own machine and find any abnormalities which are cropping up or left over from the list. The inspection of the equipment is needed to sustain the condition achieved by the team.

5.3.4 Jishu Hozen Step 3: Study of Lubrication System

This is the third step in restoration work. The work involves conducting a thorough study of the lubrication system and correcting all the flaws in the lubrication system. We do not get an opportunity like this anytime during the life of the equipment and we should not miss such opportunity. Adequate and appropriate lubrication is important to achieve zero breakdowns.

In some cases all the issues of lubrication system are eliminated by changing the system to motorized system. In some other cases the inadequacy of lubrication is resolved by changing the system. At this juncture it is also important to use all the visuals so that the inspection becomes enjoyable and also gives a sense of creativity. Visual control is dealt with in a separate chapter.

Figure 5.3 shows restoration work.

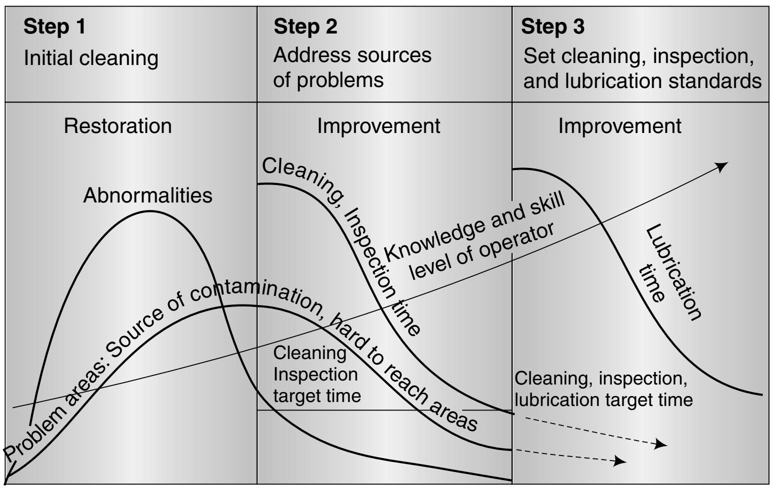


Fig. 5.3

This restoration work contains steps 1, 2 and 3 of Jishu Hozen pillar. Jishu Hozen pillar has totally seven steps. We shall see activities in steps 4, 5, 6 and 7 in later chapters.

Figure 5.3 shows the activities involved in steps 1, 2 and 3 of Autonomous Maintenance Pillar or also known as Jishu Hozen pillar. The main objective of these steps is to carry out restoration and render the equipment absolutely defect-free in all respects. All the abnormalities are now corrected and even chronic problems are now addressed and so the equipment has no breakdowns and minor stoppages. Even quality defect sources are now addressed and so the operator finds it much easier to operate the equipment and to do set up of the equipment.

You can see in the first column (step 1) in Fig. 5.3: The most essential thing is to carry out initial cleaning. Then you can see a curve which is rising up and comes to a saturation level. This curve represents the activity of finding abnormalities. That means abnormalities of all nature, hard to reach areas and sources of contamination. That also includes chronic problems which were lingering on with the equipment for long. A cleaning standard is then prepared putting together experience of all the team members. The team will use more of visuals, pictures in the cleaning standard so that the operator finds it much easier to understand. The cleaning standard also shows clearly without leaving out any particular area as neglected area. Negligence of any area means inviting abnormalities in that area. All the tools, tackles, chemicals used to clean are clearly shown in the cleaning standard. A clear and comprehensive action plan or a milestone map to complete the restoration work is then prepared for completing all the work.

You can see in second column (step 2) of Fig. 5.3: This is about fixing the abnormalities. In step 2 there are a few things the team has to give attention to. Obviously the main thing here is to fix all the abnormalities. You have seen earlier there are red tags and there are white tags. Red tags are put in places where the team will need maintenance department help. White tags are put in a place where the whole team including the operators fix abnormalities. This is very important as the operators needs to learn some maintenance activities so that they take ownership.

Now as per the action plan fixing all the abnormalities is done in step 2. In case a particular abnormality takes a long time to fix or it needs outside help to fix, such abnormalities are taken up separately as it needs a bigger shutdown and scheduling it is needed. The production manager shall give his or her consent to such work.

Another major activity which is done in the step 2 is the reduction of cleaning time. This will come about by eliminating all the sources of contamination and also by implementing a few Kaizens to contain or get rid of such sources of contamination. All improvements and corrective maintenance work shall take place in step 2.

You can see the third column (step 3) in Fig. 5.3: This step puts a lot of emphasis on the study of the lubrication system. As you have already understood that the lubrication system is the most important factor for improving the life of the equipment and also reduce breakdowns drastically. The equipment manufacturers generally design a lubrication system suitable for that equipment and for the given job. However, the system could go bad over the years and deteriorate to such an extent that wear and tear increases tremendously. In some cases the lubrication system delivers excess lubrication. Excess lubrication is equally bad compared to inadequate lubrication. So it is necessary to revisit the lubrication system and conduct a thorough study at this point of time. Checking for all the points needing lubrication, type of lubrication (grease lubrication or oil lubrication) and adequacy of the lubrication is a must. There are a few key points which are difficult to conduct inspection. These points are to be given special attention. Some kind of tell-tale indicators may be necessary in these situations. Tell-tale indicators would mean something to indicate that the lubrication is going on properly or if there are some blockades.

In some cases it may be necessary to change the entire lubrication system as the existing system is not working due to wear and tear or the system is wrongly designed for the given job of the machine. Just to give an example the author had come across a problem in a manufacturing plant on particular equipment. The type of the bearing used in the equipment (in this case it was a mill grinding the silica powder into a fine powder) was wrong. So the team found out that the bearing type will have to be changed to a thrust bearing. Luckily enough a bearing was identified which goes into the same place as the dimensions were same. However soon it was identified that the lubrication system needed a change as it was given in the SKF bearing manufacturers catalogue. The lubrication system was then changed to the new type.

Finally, it is necessary to reduce the time taken to inspect the lubrication system and replenish oils wherever necessary. General rule of thumb is that the operator should be able to conduct CILT (Cleaning, Inspection, Lubrication and Tightening) activities within ten minutes. This is needed to increase the availability of the machine.

Similarly, in the step 3 it is very important to implement visual control system. Visual control system is becoming more and more popular recently. Visual controls help conduct the inspection work fast. This includes keeping all the things in order with identification marks, names, numbering, color coding, using symbols, pictures, tell-tale indicators, level gauges, adjustment notches, etc.

5.3.5 Conduct Focused Improvement Activities

Conduct focused improvement activities to correct design weaknesses and extend life of the equipment and its components. This area needs thorough knowledge about the strength of materials, wear pattern, stress concentration in the equipment and lubrication methods. To correct design weaknesses you may even need the help of the equipment manufacturer. This is not an easy task. This again may not be a part of the company's core business. However, if you want zero breakdown it is absolutely necessary to enter this field and develop a team to handle this important aspect.

In the first place we need to develop a team with very enthusiastic members from various fields like design, maintenance and operation departments. There has to be a high level of technical knowledge and flair to get into details and investigate. This again requires high level of problem solving skills. So the team needs to first learn the problem solving tools; like "why-why" analysis, fish bone or cause and effect analysis, work point analysis and finally Phenomena-Mechanism Analysis (PM Analysis). Once this is done, the team will start developing the time schedule to start work on the analysis of major breakdowns.

The team shall be named focused improvement team. This is a specialized task and needs active participation. Generally, in a plant such teams are appointed as task forces. However, this task force is specialized in correcting design weaknesses and improving the life of the equipment and the specific components.

This is a typical phenomenon. The equipment breaks down often due to failure of certain components. This happens mostly with the failure of only a few components. That means if the equipment has fifty components, the failure may be happening due to two or three components. This you will realize as you get deeper into the topic. So, if you want to increase the life span of the equipment then you need to focus on failures of these two or three components. How to do this? The team needs to focus on the details of those components which are failing. This could be due to metallurgical defects, case hardening defects, overloading issues, stress concentration issues, or lack of adequate lubrication and many more defects. Once the team does the thorough analysis of the causes of failures, they will be able to plan and do the improvement activity. This way focus on each cause of failure and work on them to eliminate the root cause. This is called *Focused Improvement* activity. At the same time this information on analysis can also be shared with the manufacturer of the equipment through Maintenance Prevention Data Sheet (MP Data Sheet) so that the manufacturer can do improvements in future models of the equipment.

This is an ongoing or continuous activity. So, mainly the maintenance department shall develop this team using members from various sections and enable them to conduct this important task of focused improvement. I would rather recommend that they should create a platform where the team meets on a fixed day in a week and a fixed time in the day. Keep the self esteem high and continue.

5.3.6 Horizontal Deployment or Reapplication Management

This means taking measures to prevent identical or similar major failures occurring on the similar equipment. After having worked hard on the analysis of equipment failures or its components, we would not like to neglect the advantages of using the learning in other similar equipment or similar components. So how do we manage horizontal deployment or reapplication management? We would not like to overdo anything, but at the same time we would not like to throw away the learning which is very useful on similar equipment or similar components.

This again requires a thorough understanding of the plant and equipment and so the maintenance team comes into picture here. So, in order to know where such learning can be deployed with advantage we need to have plant data system support. We need to collect and store such information for all the equipment and all accessories. This is done from the very inception of the plant and equipment. In cases if it is not done before, it can be started at any given time in future.

The plant data system should collect information on make name, type of equipment, voltage, capacity, list of standard components and non-standard components and all relevant technical details. Only when we create such data bank we will be able to identify which equipment and which component comes under reapplication. So, if in one place a failure has taken place, we will be able to say which other equipment with similar components can also develop such issue and where we can effectively use this learning. So, in order to do effective and complete reapplication, collecting all plant data in a systematic way becomes very essential.

The horizontal deployment needs a thorough planning so that the re-application can be completed on the scheduled time. This is needed as it is necessary to complete all such reapplication work on schedule. In some plants, a specialized team is assigned with such responsibility. I would rather recommend that this is the best approach instead of completing the horizontal deployment work whenever you get time.

5.3.7 Introduce Continuous Improvement (Kaizen)

Introduce continuous improvement to reduce equipment failures or process failures.

In Japanese language "Kai" means change and "Zen" means better (improvement). So Kaizen simply means "continuous improvement'. Kaizen system is implemented to create Kaizen culture. That means the people in an organization spend sufficient time on solving their problems themselves. Solving problems is developed as a culture. They identify the root cause of the problem and come out with solutions to those problems. Then implementing them with entire satisfaction of the whole team is called Kaizen. Once the management takes lead and inculcates "Kaizen Culture" that becomes a foundation for any continuous improvement work like Six Sigma, Total Quality Management and Total Productive Maintenance.

So how does one create Kaizen culture in the maintenance function? Kaizen addresses the inefficient working in any organization. It is a systematic approach to change the culture of the organization.

5.3.7.1 How to Start Kaizen Activities?

Take any problem as challenge. Create a project around that problem. Analyze the problem to the root cause. Then come out with zero investment solutions. Challenge status quo, on methods and systems by using 5W/1H, 5-Why problem solving tools. Identify waste in an area. Just eliminate NVAs. Think out of the box solutions. Complete the implementation of the root cause solutions and check for effectiveness. The test is that the same problem should not recur.

Normally, in a manufacturing organization, maintenance people help in Kaizen activities by developing the idea, helping in fabrication work and finally helping erection and commissioning of the root cause solution. If that is so, what about some Kaizens in the maintenance function? Kaizen brings in creativity. So we need to be able to solve problems in maintenance. That means it does not have to be in the maintenance shop only. It can be used for reducing the breakdowns. It can be used to save energy bills. It could also be used to improve the maintenance functional activities and reduce non-value added activities. Problems could be in the method, materials or machines. They can come out with innovative ideas. They have a great opportunity to implement their own ideas with their own hands. This also leads to great job satisfaction.

5.3.7.2 How do we Start Kaizen in Maintenance Function?

First of all form teams from all people working in maintenance. Then identify problem areas with the help of the team members. Have a meeting of all concerned. Depute each team on problems identified and selected to work on. Establish a method of collecting ideas and the approval process. The supervisors and managers to be coaches and they need to be carefully guiding them. Carefulness is needed while analyzing and coming out with the root cause solutions. The ideas implemented should be effective. Implement those ideas. Check the effectiveness over a period. Give credit to all, but also give reward and recognition to the deserving ones. Go for non-monetary rewards. Reward system has to be established and implemented in such a way that it is not a one-time kind of thing. A system has to be developed for the reward system to be implemented throughout the year after year.

5.4 STEP 3. BUILD AN INFORMATION MANAGEMENT SYSTEM

This is the key strength of the maintenance function. We need to build accurate data system on failures, history cards, spare parts, breakdown maintenance, preventive maintenance and budget management.

5.4.1 Build a Failure Data Management System

This is about the equipment failures which have taken place in the past. Instead of keeping this complete data in the memory of people it has to be captured and should be stored for analysis at any given time. After attending each major breakdown (you need to define the minor breakdowns and the major breakdowns) the breakdown data will have to be captured in the computer. That means identifying the equipment and the component which had suffered the breakdown, the complete analysis of that breakdown using appropriate tool and then arriving at the root cause. The root cause solution will have to be implemented and trials taken. This will now indicate whether that is the correct root cause or not. Once having confirmed the root cause solution and taking trials for several days it is time to document the whole data on the breakdowns. This will be very useful for reporting the statistics of breakdowns and also to do reapplication in similar equipment. This also helps in calculating the cost of such breakdown. The major benefit of collecting this data and capturing it is that the root cause analysis has been already carried out and is now available in the system for reapplication. Secondly, it is also used to create MP data and used as input to the manufacturer of such equipment as design improvement data. This helps in creating improved design of the equipment and ultimately the design of the equipment can become defect free.

5.4.2 Build Equipment History Data

This includes any modifications done on the equipment, major repairs done, equipment shifting or transfer data. This is another major aspect in the maintenance technology. You may remember in the olden days the equipment had a history card hanging by the equipment and all relevant history data used to be written in that. Now it is all available in the system. In order to make it available in the system the data will have to be captured in a systematic and meaningful way. This takes a big effort. However, once the team members are given the roles and responsibilities, it will be carried out on a regular basis. All modifications done in the equipment on the mechanical side, electrical controls and in the instrumentation area will have to be captured by way of specifications, drawings, electrical wiring drawings and layout drawings. In some cases it will even have the shifting data from one line to another line or department. This will also facilitate planning preventive maintenance and also keeping a track of such equipment in asset management.

5.4.3 Build System for Controlling Spare Parts

Build a system for drawings, technical data, as built drawings, supplier data, etc. This is called maintenance controls. There has to be a link established in the system to check all the spare parts availability required to conduct preventive maintenance on any equipment. To get this a spare parts control system will have to be established. This is done by starting ABC analysis in the spare parts storeroom. In some cases there is another system called VED system. VED means Vital, Essential and Desirable. While ABC analysis is based on the cost of the spare part, VED analysis is based on the principle of importance of the spare part for completion of repairs. Both are equally important because ABC analysis helps controlling the cost whereas VED analysis helps undertaking the repairs effectively. A spare part may be costing less but at that situation is a very important part for completing the work and give the equipment back to service.

How do you create a list of spare parts to be kept in the store? We need to have less inventory in the store, but at the same time we need to have the particular spare part to be available while carrying out preventive maintenance or fixing a breakdown. Then how do we do this critical task of fixing the minimum, maximum and reordering quantities for the spare part. For each of the equipment, list of spare parts has to be prepared and those spare parts to be procured and kept in the store. Depending on the consumption pattern of the spare part and lead time for procurement the quantities to be kept in the store will have to be decided. Fixing minimum, maximum and reordering quantities is not an easy task. This will need input from the equipment manufacturer who will generally give a list of spare parts to be kept in store for the equipment they have supplied. But depending on your experience the list will have to be revised after getting sufficient experience. However, for old equipment, you will not have the input coming from the supplier. So in such cases, it is the responsibility of the maintenance team to make the list of spare parts with minimum, maximum and reordering quantities, so that there will not be any stoppage of equipment due to want of spares or delay in supplying spares. Here the maintenance team will have to gather experienced people from maintenance technicians and prepare the list. This methodology will have to be applied to all equipment in the plant and also in the utilities section too.

In case your plant has similar equipment you may choose to pool in the spares. This is a distinct advantage when you have standardized on make or type and capacity of the equipment. Sometimes standardization goes to the level of components of the equipment. That means components such as the motors, gearboxes, PLCs, cables, V belts, etc., are standardized and this helps very much in maintaining the quantities due to standardization in the components.

The next important aspect is storing the spare parts in a way that helps in identifying and retrieving without spending much time. In such cases, if you would like to have a good and efficient store then you need to plan for it. From your vision what is the ideal method to store the spare parts. Here the cost of the spare parts as inventory is very high and so on one hand we need to keep the inventory to minimum and also 100% availability of the parts when needed. Also retrieving should be done with no search time.

Here the principle of 5S comes into picture. The principle is “there is a place for everything and everything is in its place”. To achieve this, a thorough planning work will have to be done to organize all spare parts in identified places. Here I would recommend you to prepare a plan for storage. How many storage racks are needed to contain the spares, where each storage rack is located and in each rack where and which spare part is available? How to retrieve and account for the spares? If the height of the storage racks is more, then how to retrieve the spares, from that height easily? These questions will have to be answered in the planning stage itself.

This is achieved by preparing a master plan for the entire storage room. This can be prepared in the computer or it may also be prepared by a layout drawing manually. This master plan for maintenance storeroom should contain position of each storage rack, the list of spares to be kept in each rack depending on the weight and size of the spare part. Each spare part should have an identification tag and all spares stored in planned way. This is necessary as each technician should be able to retrieve a spare part easily within a specified time say 30 seconds. A rack-wise storage of items should also be displayed at the entrance of the store. The visual controls will come very handy here. In some stores, they even lay marks on the floor to help to lead you to particular rack or have identification with numbers, names or color coding. The idea is that any new entrant also should be able to find and retrieve the spare part within prescribed time or in emergency cases.

Accounting for the spare part retrieved is also as important as retrieving the spare. For this, various methods are in practice. As we said earlier there has to be a tag on each spare part for the purpose of identification. This helps in retrieving easily. At the same time it helps in accounting too. The tag to be separated from the spare part and an entry is made into the computer system with the help of the identification mark on the tag. This is the simplest way to handle. However in plants the maintenance crew, often forget to enter or leave it due to negligence. This creates a problem in accounting. So in such cases it is better to collect all the tags through the day and one responsible person shall take the task of making entries for the day. This needs a separate person to come into picture. Another method prevailing in some industries is making issue notes for the spare parts received by the maintenance crew before any PM or breakdown work has started. This is not a foolproof method. There may be some parts remaining as not consumed and they will be lying in the maintenance workshop. So the author would not recommend this method. However, this method is practiced in some continuous process industries. This is mainly done to reduce the retrieving time especially in the night shift.

In the storeroom as we discussed earlier, there are spare parts as well as consumables stored. The consumables are generally "C" class items but they are also needed to be retrieved when required. These are small bearings, nuts and bolts, gaskets, O rings, greases, etc. We need to have a good retrieval and accounting system for these items also. Here for such items, making issue notes for some bigger quantities of these C class items may be more suitable than issuing in small quantities several times a day.

We have so far discussed the physical store for spare parts and consumables. We need to have proper storage of technical items like, service manuals, electrical controls and wiring drawings, as built drawings and various annual maintenance contracts. This can be captured and stored in the computer system as otherwise it will just deteriorate and perish in the physical storeroom.

Another important aspect is keeping the supplier data for the spare parts, repairs and supply of labor. Also this includes all information on equipment suppliers, service contracts and supply of consumables. This will help greatly when there is manpower turnover in the plant.

5.4.4 Build Maintenance Budget Management System

This should help getting cost data equipment-wise. Spare parts costs, labor costs, outside repair costs and cost of modification and restoration work, etc.

In order to get this cost, the equipment master has to be filled beforehand. In order to do this effectively the grouping of the equipment is needed. Grouping is done either by conducting ABC analysis of the equipment (as discussed in earlier chapter) or department-wise. This is done by grouping the equipment area by area or department by department. All the utilities equipment are also included in this list.

After entering the equipment master all the relevant data is then entered as per the requirement. If you want to have equipment-wise cost data, the planning has to be done that way. In some systems they will have production line-wise cost data. This is considered sufficient in some plants. Just in case you want to have the cost equipment-wise, then the codification will have to be done equipment-wise.

The computerized maintenance management system will be discussed in detail in a later chapter. However, we need to be discrete while designing the system. All data on maintenance cost, spare parts cost, labor costs, outside repair costs and cost of modification work, etc., to be available from the system. The data you are going to get from the system is as good as the data you have entered in the system. So, we need to be very careful about the accuracy of the data while entering it. This also needs to be carried out on regular basis. In some plants they accumulate a lot of work and then start entering the data. Since there was a big gap of time from the date the expense has occurred and the data entry date, the cost will be loaded on to the date when the entry was made. This can create problems while reporting the cost month-wise.

5.5 STEP 4: BUILD A PERIODIC MAINTENANCE SYSTEM

Prepare for Time Based Maintenance (TBM): Time Based Maintenance (TBM) as the name indicates, is done on the basis of time elapsed between the previous and successive maintenance activities.

5.5.1 Prioritization of Equipment for TBM

This is very important for managing the TBM work responsibility in the plant. There will be hundreds of equipment in the plant. Some are production equipment which are being used 24 hrs for production. There are also a few production equipment which are used for only one or two shifts a day. There are auxiliary equipment which are not used every day, but used only sometimes. There are some utilities equipment, which have standby equipment and so getting them released for TBM is not a concern. So, how to prioritize them for conducting TBM? This is an important step before you start any other activity.

One such method is to go by ABC analysis which we have discussed earlier. "A" category means the equipment have higher level of criticality. "B" category means medium criticality and "C" category means less or no criticality. Based on this, you shall make a list of equipment on priority basis and start our work. This is clear, but in practice you may have to make some adjustments in the way we perform TBM on the equipment. This is because the equipment in highest priority list may not be available on a particular day for TBM as it has a busy production schedule. Here in such situations some adjustment is needed, but that does not mean that those priority equipment shall go without TBM and that gets carried forward endlessly. All backlog if any, shall be cleared in the immediate next month and that will work. There has to be a clear understanding between the production department and the maintenance department as far as the compliance of the TBM plan is concerned. It is also the responsibility of the maintenance department to quickly complete the TBM activities and hand it over to the production department in the time frame agreed. The compliance rate of TBM should be maintained at 90% to 100% so that even if there is a backlog it is easily managed in the successive month. This becomes the joint responsibility of the production department and the maintenance department. The production department should endeavor to release equipment for TBM and the maintenance department should strive to complete the entire TBM work carefully.

Here the author would like to give a word of advice. This is to focus particularly on the prioritization of equipment for TBM work. You have done ABC analysis and priority setting has been completed. However, in practice there will be some difficulties as the equipment may not be available for TBM due to various reasons. In such a situation you shall look into the list of medium priority or low priority and try to accomplish as much TBM work as possible and improve TBM compliance rate. However, all the backlog work as per compliance report of the current month should be completed in the next month.

5.5.2 Fixing Frequency of TBM

Fixing a time period or frequency for conducting TBM is important. If you make it too frequently, the cost of maintenance goes higher. In case you make it less frequently there may be a chance that the equipment will breakdown before the TBM activity is done. So, how do we fix a frequency to carry out TBM on the equipment? Some of the equipment manufacturers give clear guidelines about this and we need to just carry it out as per the guidelines. In case of your car, the car manufacturer gives very clear guidelines in the maintenance service manual. There the number of kilometers run is important. This is done as wear and tear of the car depends on the distance it has run. This may not be entirely true, but the manufacturer is considered to have sufficient experience and research data.

In such an equipment where the frequency of conducting TBM is not given by the manufacturer, we need to fix it ourselves. In such cases the history data helps. That means the history data gives the history on frequency of breakdowns and the components on which such failures have taken place. Based on this data, we may be able to decide the frequency of conducting TBM. Just in case the history data is not available in the system, then we need to call the seniors in the maintenance department and get information from them regarding the frequency of breakdowns, type of breakdowns and the components failed. This data from the memory of the people shall be used to decide the frequency of TBM on that equipment. This is subjected to trial. After a period of one year or so, this frequency shall be reviewed and more accurate frequency shall be fixed. The principle is that we should avoid over-maintenance and at the same time avoid breakdowns.

5.5.3 TBM Planning and Scheduling

We have discussed prioritization of equipment for TBM work. We need to now get into planning and scheduling after the decision on the frequency of TBM work.

Planning: Planning takes into consideration undertaking of TBM activities on a timely basis as per the frequency decided. Some of the equipment may need TBM work in one year's time. Whereas some other equipment may need it once in six months. In the same equipment some parts may need frequency of one year and some other parts may need it in three months. Based on these requirements the planning work is completed for the entire year. That means all the equipment in the list shall get attention during that year. Once the planning is done for a year, the same planning will be continued for the next year. In some cases you may need to make changes in the plan if your experience in the last year demands that change. In rare cases there may be a few equipment which may need TBM work done only once in two years or more. So planning is to complete TBM work as per frequency decided and completion of all work planned in a specified time interval.

Scheduling: This is basically giving time frame to the planned activities and making them happen on the shop floor whether annually, monthly, weekly, daily and shift-wise. This needs good knowledge of the time required, to carry out such planned work and the resources needed to carry out those activities.

Generally, planning is done for the whole plant and reviewed annually or six monthly.

Scheduling is done and reviewed more frequently as the changes may be needed to the schedule depending on how the work is progressing and deputing more resources if there is urgent requirement of work or if there is backlog. Compliance of Time Based Maintenance Activities (TBM) and Condition Based Activities (CBM) are reported to the hierarchy and so it is important to do review of the schedule more frequently so that resources can be deputed accordingly.

5.5.4 Prepare Time Based Maintenance (TBM) Flow Diagram

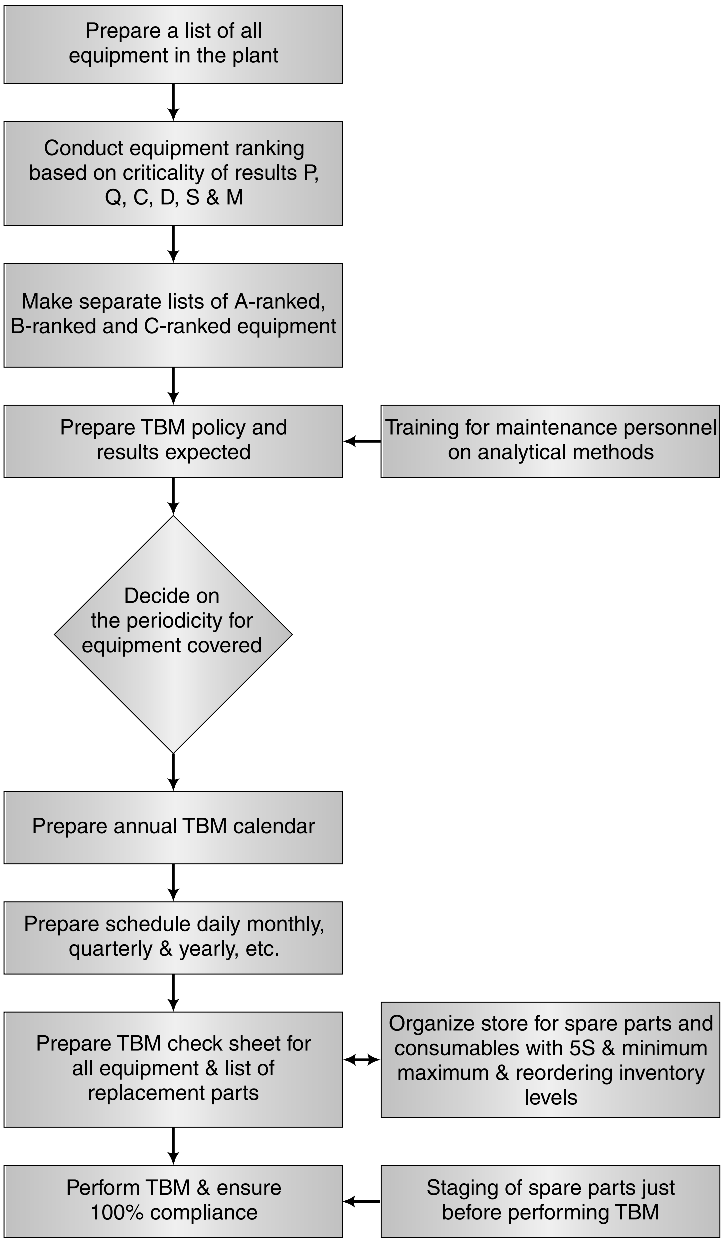


Fig. 5.4

5.5.5 Prepare Inspection Check-Sheets

Somebody should prepare inspection check-sheets and list of parts to be changed during TBM for all equipment. If there are similar equipment the check-sheet can be common, but otherwise each piece of equipment needs to have a check-sheet and list of parts to be changed. As we discussed earlier the technicians who are conducting TBM activities must have inspection checklist in their hand and they need to carry out the work as per the checklist and tick mark each and every item. This is what we call "checklist based inspection". For making this more meticulous, the checklist for inspection and also changing parts shall be available in the system. Each time the TBM work is done on the equipment, a printout is taken for the checklist for that equipment and given to the maintenance technician. After completing the work the tick marked checklist may be filed or the same information may be documented back into the computerized system. Preparation of this checklist however needs thorough knowledge of that equipment and so engineers and technicians doing this work shall do it meticulously. It may be an expensive proposition if any one of the check points is missing in the checklist or the maintenance technician has forgotten to check it.

5.5.6 Prepare or Update Standards

This is another piece of work, i.e., preparation of materials standards, work standards, inspection standards, acceptance standards and train maintenance technicians on these standards and procedures. Even better is that, technicians are involved in making these standards and training the relevant people who are going to handle the TBM work.

For example, a particular equipment needs bearing replacement. In some large equipment pulling out the bearing is done by hydraulic bearing extractor. But while inserting the new bearing it is heated in a pool of oil to a particular temperature and then slipped onto the shaft. If the technician is not aware of the procedure to do this he might even ruin the bearing and may even damage the shaft surface. This is why training the employees on the standard procedures is essential.

5.5.7 Performing TBM

Next important aspect of TBM is the activities to be conducted at the time of performing TBM. There are two things which predominantly happen during TBM. The first one is the inspection part and the second one is about replacement of worn out or defective parts. The inspection means a thorough checking of parts which are likely to be subjected to wear and tear. In plants where corrosion is very high due to the dust or environment, the inspection shall be carried out on parts which are not moving parts.

This needs real maintenance skills. Several diagnostic tools are used to carry out this inspection. We shall discuss in detail about these diagnostic tools in a separate chapter on Reliability Centered Maintenance. Here we shall discuss about the duties to be performed during TBM.

There are two important things to note here. Inspection of all the worn out parts by using diagnostic tools and visual inspection. But at the same time the inspection should not lead to opening up unnecessary parts and increasing the quantity of work. The TBM should be conducted with less and less time as we gain more and more experience. The second part of the work is called overhauling. Here we should as far as possible avoid concept of overhauling.

In order to contain this, we need to have a list of activities to be done prepared in advance and this is called the inspection as per the checklist. Once all relevant parts are inspected then the worn out or defective parts are considered for replacement. There may also be inspection of some filters or checking viscosity of oil which may be considered for replacement. These are also included into the list.

The second part is replacement of worn out parts and defective parts. In mechanical parts it is rather easier to identify and consider the worn out parts for replacement. However, some of the electronic parts need to have advanced tools for diagnostics or just replace them after a certain life. The life of the electronic parts is considered to be so many million cycles. But, however, there are no gadgets to measure accurately as to how much life is left within the electronic parts. In such cases, it is necessary to go by the number of hours the equipment has run after the last replacement.

In all cases of maintenance; either it is a breakdown maintenance or time based maintenance it is absolutely necessary to take trials of the equipment and then hand it over to the production.

5.5.8 Improve Shutdown Maintenance Efficiency

What is shutdown maintenance? This is unique in a way that most of the continuous process industries need to take annual or biannual shutdown for doing maintenance work on critical equipment. This is similar to TBM but done very aggressively and meticulously as time taken to complete is very important. We shall deal with shutdown maintenance in a later chapter. However, emphasis is on the time and quality of workmanship. All the work planned should happen strictly within the time frame and the start-up should be very smooth without any stoppages or rework later.

But this is not easy. A thorough planning is needed prior to the shutdown. It needs several months to do the planning work. First of all, a list of all the work to be carried out should be prepared. We need to be very careful not to include such work in the list which can be done without a shutdown. The list will have to be perfected over a period and all the activities to be planned properly. This planning can be done using the MS project software. This software is easy to use and a good planning tool for all the activities to be done in a serial way and also in a parallel way. Resource requirement can then be calculated by this software. The supervisory staff requirement can also be assessed to guide people and check for correctness. A thorough plan which includes all shutdown repair work can be then prepared and a critical path is established. If the critical path is taking shorter time than the available time it is then considered to be easy. But, however, if the critical time is longer than the available time, then we need to crash activities. This means how to shorten the critical path by using additional resources or in some cases look for some alternatives to complete all activities within time schedule.

5.5.9 Staging Spare Parts

Another important aspect is keeping all the spare parts ready before starting the shutdown. In very rare cases a particular spare may be arriving during the shutdown is allowed. But to be sure it is needed that all the parts should be available before the shutdown. The spare parts have to be kept in readiness after cleaning and inspecting them. This is needed so that there are no delays during the shutdown period.

One more area of importance is contract management. All the contractors have to be registered with the company and the company shall make sure that all the formalities are over before starting the work. All safety procedures are trained to the labor and the skilled labor availability should be checked thoroughly. Generally, any company undertakes prequalification of contractors and then only such contractors are allowed to work in the site for shutdown maintenance.

Last but not the least is the allocation of work by the contractors and supervising in such a way that the work listed for that day is completed on time.

A complete start-up procedure should be prepared so that there are no delays after the shutdown maintenance work is completed. All production staff and the maintenance staff should be available for the start-up.

5.6 STEP 5: BUILD A PREDICTIVE MAINTENANCE SYSTEM

We need to understand first as to why Predictive Maintenance is important. World over in process industries, Predictive Maintenance or (Condition Based Maintenance) is replacing Time Based Maintenance. Let us understand this in more details.

In process industries and also in some non-continuous engineering industries it is hard to find equipment time for carrying out TBM. As a result the time based maintenance work gets postponed. This gets on accumulating and you will find a big backlog of such work. If this happens it defeats the very purpose of TBM. So these days predictive maintenance is gaining ground and is becoming more popular. However, this is not a ready-made answer to the problem. Predictive maintenance has to be developed in such a way that it covers equipment diagnostics for the equipment and components which fail. That means there has to be a method for assessing the condition of the components and also be able to predict the remaining life of such components. This requires a lot of vigilance from the operating staff and a thorough inspection by inspection staff (or maintenance staff). So in brief this is the science of assessing the condition of the component or equipment and clearly predicting the remaining life. This requires inspection to be carried out by the operating staff in terms of Jishu Hozen (CILT) or by using the six senses (touch, smell, hear, see, taste and then imagination) of operating staff. But, however, this technology alone is not sufficient as these techniques are generally used to check abnormalities after it is deteriorated or about to fail. We need proper diagnostic tools which can measure wear and tear and also predict the remaining life. This field is ever developing and is extensively used in modern industrial set-up.

5.6.1 Introduce Equipment Diagnostics

This has to be done very carefully. First, keep the TBM ongoing on all equipment as it was happening earlier. Select just a few equipment as models for studying and developing predictive maintenance. Then identify in each machine the components which often fail. You will be surprised to see in each machine only a few components are normally failing. In some cases it may be just one or two components. This is the first step where you will start developing confidence. Identify the failure mode and then establish how the failure mode gets developed and how the deterioration (or wear down) can be measured on a regular basis. As mentioned earlier this can be done in two ways; one, daily inspection by operating staff and the second, by using the diagnostic tools. In the recent past the technology of developing these diagnostic tools is progressing tremendously. So, for a particular application which tool to be used and how to use it is the key aspect. These tools are generally very expensive or capital intensive. Once having identified a diagnostic tool for measuring a particular deterioration or failure, the tool has to be made available either by hiring the services from outside or by buying the tools and own it. But the responsibility of owning becomes more intensive. That means having decided to buy the diagnostic tool the responsibility of procuring it, storing it in a proper place, training the staff to use the tool and finally predicting the remaining life of the component under question becomes important.

Again, for the model equipment selected for predictive maintenance, whether all the deterioration or abnormality on the few failing components, are completely covered has to be assessed. If the deterioration or failure is accurately measured and predictive technology is working properly then the success of implementing the predictive maintenance is assured. This is the way progress is made by selecting more equipment as models and success has to be slowly achieved. Here in some cases you may come across a problem area. A particular deterioration or failure does not have a proper diagnostic tool to measure the deterioration and that particular failure measurement and prediction is very important for achieving zero breakdowns in the plant. In such situations expert opinion may be sought as early as possible to solve.

Furthermore training the technicians on how to use these diagnostic tools is very important. Otherwise it will turn into a dead investment. Last but not the least is calibration and maintenance of these tools. This is the way progress is made on Condition Based Maintenance (CBM) or Predictive Maintenance.

5.6.2 Prepare Predictive Maintenance System Flow Diagram

To make it more understandable, it is necessary to prepare a flow diagram of the predictive maintenance system. This is especially needed as the system has to be slowly developed and more and more equipment to be covered under predictive maintenance.

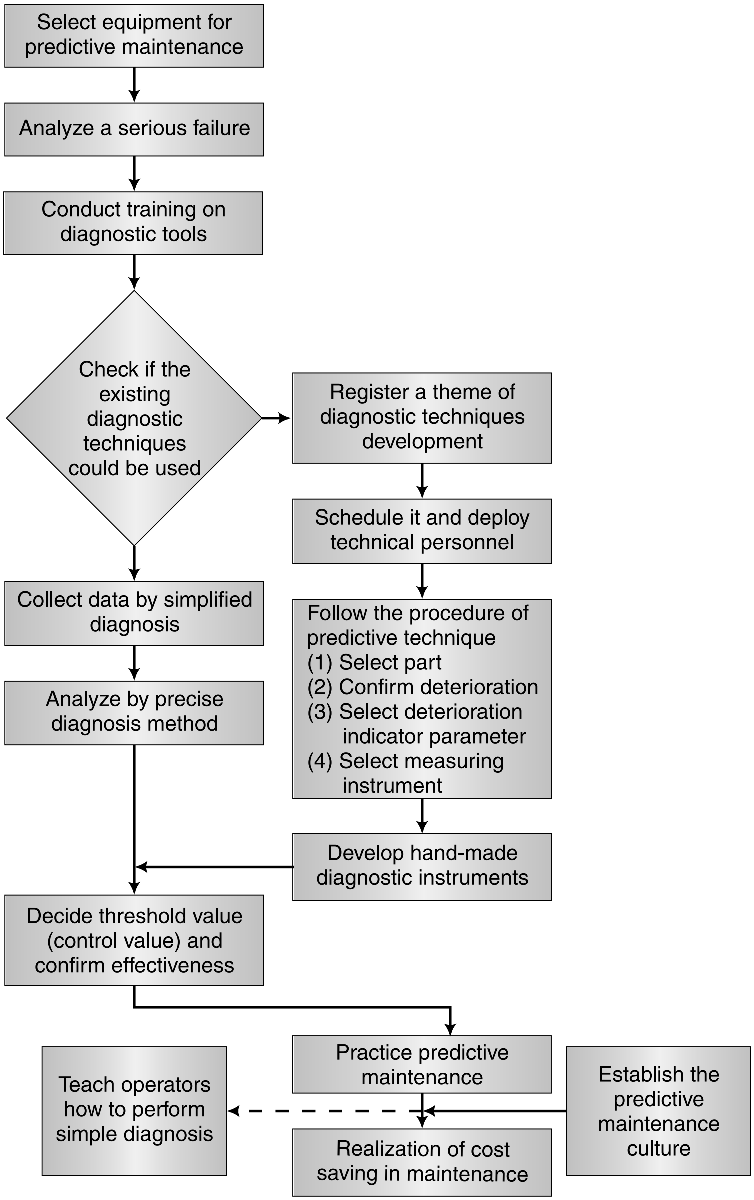


Fig. 5.5 Predictive maintenance flow diagram

5.6.3 Develop Diagnostic Equipment and Technology

Please refer to the chapter on Reliability Centered Maintenance for various diagnostic tools currently available and their use. However, since this technology is ever developing, it is necessary to establish one owner for this area. That means the owner needs to keep in touch with the latest developments in diagnostic tools and the diagnostic technology.

5.7 STEP 6: EVALUATE THE PROGRESSIVE MAINTENANCE SYSTEM

We have now come to the evaluation and renewal stage. This is the last point of evaluation and renewal of the system of progressive maintenance. Every system needs evaluation and renewal on periodic basis. So, it is time now to have discussions on the periodicity of assessment, how to conduct assessment and what kind of renewal and upgradation is needed. Simply said, it is necessary to prepare an audit sheet and the audit be conducted by the senior staff and identify which are some areas need course correction.

5.7.1 Evaluate the Progressive Maintenance System

In order to conduct assessment it is advised to prepare an elaborate Audit Sheet (see Fig. 5.6).

5.7.2 Evaluate Reliability Improvement

This is recommended to measure exactly the reliability improvement taken place during the implementation of world class maintenance. Reliability is nothing but taking into account the uptime. So what is needed is measurement of failures. So, the number of failures in a month or year, and frequency of failures and also measurement of Mean Time Between Failures (MTBF) is needed. At this point of time, a system to "Analysis Major Breakdowns" becomes very useful. Generally speaking, such a system does not exist in many companies. For any given breakdown, the maintenance department will depute a person or persons responsible for attending to the breakdown. Such responsible person will normally involve the technicians who attend to breakdowns on a regular basis and resolve. That means the focus is on giving the equipment back to production as soon as possible. In such a situation quick analysis is done and using spare parts to replace defective parts, the equipment is quickly fixed and handed over to production department as early as possible.

So, it is very necessary to create a forum for "Analysis of Major Breakdowns". A team with highly analytical mind is needed here. Once the forum is created, earmark a fixed time for such a work. That means fix a time on a particular day in a weak. Once you create a time schedule

World Class Maintenance Management System Audit Sheet

Sr. No.	*Company Name Main Function*	*Plant Name Sub-Function*		*Department Name Description*		*Rating*	*Comments*
A	**Self Managed Maintenance**	1.	Cleaning	(a)	Is cleaning done by equipment operators in each shift?		
				(b)	Is cleaning time optimized?		
				(c)	Is the cleaning process standardized?		
				(d)	How clean is the equipment when inspected?		
		2.	Inspection	(a)	Does the equipment operator carry out inspection in each shift?		
				(b)	Is the process of identification and rectification of defects formalized?		
				(c)	Is the process of inspection for defects standardized?		
				(d)	Is the work order system for major defects formalized?		
		3.	Lubrication	(a)	Is the lubrication inspection done by operator in each shift?		
				(b)	Is the lubrication oil or grease replenished by operator?		
				(c)	Are any leakages in lubricating system rectified by operator?		
B	**Breakdown Maintenance**	1.	Work order	(a)	Is work order system standardized?		
				(b)	How fast the work order is completed?		
				(c)	Are adequate resources deputed for breakdown maintenance?		
				(d)	What is the quality of the breakdown maintenance work?		
		2.	Analysis of Breakdowns	(a)	Is there a process for analysis of breakdowns existing?		
				(b)	Is equipment history for breakdowns maintained?		
				(c)	Are chronic problems identified?		
				(d)	Are MTBF and MTTR records maintained for critical equipment?		
				(e)	How fast can the technician get the spare parts and tools?		
C	**Corrective Maintenance**	1.	Operability	(a)	Are operator's difficulties identified and corrected by changes?		
				(b)	Are machine quality problems identified and corrected?		

Contd...

				(c)	Is there a documented process for collection of data existing?		
		2.	Maintain-ability	(a)	Are maintenance difficulties Identified and corrected?		
				(b)	Is there a documented process for collection of data existing?		
		3.	Reliability	(a)	Is there a documented process for calculating reliability?		
				(b)	Is reliability tracked for each shift/day?		
				(c)	Is there any methodology for improving reliability?		
D	**Preventive Maintenance**	1.	Equipment Ranking	(a)	Is there a process for equipment ranking established?.		
				(b)	Have all critical equipment been identified?		
		2.	History Records	(a)	Are history records for all equipment available?		
				(b)	Is the history updated timely?		
				(c)	Are the changes made and maintenance done recorded?		
				(d)	Are maintenance manuals and drawings maintained well?		
		3.	PM Master Schedule	(a)	Is there a PM master schedule prepared for all equipment?		
				(b)	Is there a PM schedule on daily, weekly and monthly basis?		
				(c)	Are all the jobs completed as per schedule?		
				(d)	Are all the resources identified in advance and provided?		
				(e)	Are all the spare parts checked for such work in advance?		
				(f)	What is the quality of PM work done?		
E	**Opportunistic Maintenance**	1.	Preparation	(a)	Is there a process for Identifying all jobs for opportunistic maintenance?		
				(b)	Are all parts and tools kept ready for such opportunity?		
				(c)	How is information sharing done on such opportunities?		
		2.	Implementation	(a)	Is there a good system for using the down time for jobs?.		
				(b)	What is the efficiency of completion of such jobs?		

Contd...

F	**Shutdown Maintenance**	1.	Planning	(a)	Are shutdowns identified and planned in advance?		
				(b)	Have shutdown jobs clear resources identified?		
				(c)	Are all the spares needed for shutdown organized before?		
		2.	Execution	(a)	Is completion of all jobs done on time?		
G	**Predictive Maintenance**	1.	Planning	(a)	Area of all equipment for predictive maintenance identified?		
				(b)	Have condition monitoring tools for equipment obtained?		
				(c)	Who will carry out the monitoring and prediction identified?		
				(d)	Has frequency at which it should be done identified?		
		2.	Execution	(a)	Are vibration analysis of critical equipment, ultrasonic thickness measurement, chemical analysis of oils and boiler water, infra-red scanning etc done?		
H	**Spare Parts Management**	1.	Inventory	(a)	Are max, min and reordering quantities for all A&B spares identified?		
				(b)	Are spares inventory stored with identification tags?		
				(c)	Is the spare parts accounting system working properly?		
				(d)	Is there a physical verification system of spares existing?		
				(e)	Are there proper visual controls in the stores?		
				(d)	Are slow-moving and non-moving items written off and sold?		
I	**Tool Room Management**	1.	Planning	(a)	Are jobs at tool room identified and planned?		
				(b)	Prioritizing for the jobs done?		
		2.	Execution	(a)	All the jobs at tool room done correctly and on time?		
				(b)	Tool room takes care of preparing in advance and keeping it as spares?		
J	**Computerized Maintenance Management system**	1.	Hardware & Software	(a)	Has there been good hardware and software installed		
				(b)	Is the software system user friendly?		

Contd...

				(c)	Does it have all capabilities to track down time, down time analysis, trouble-shooting module, history cards, MTBF and MTTR recording, etc?		
				(d)	Is there a direct link between preventive maintenance and spare parts inventory management?		
				(e)	Does this have master PM plan and separately daily, weekly and monthly PM plan.		
				(f)	Is this system capable of calculation of reliability, down time and doing pareto analysis and management reporting?		
K	**Cost of Maintenance**	1.	Cost tracking system	(a)	Is there a tracking system for maintenance cost?.		
				(b)	Are all costs captured properly for maintenance?		
				(c)	Is this system capable of making zero based budget?.		
				(d)	Can this system do analysis and reporting of costs?		
					Total Score		
	Rating system: 5 Excellent; 4 Good; 3 Satisfactory; 2 Needs improvement; 1 Major deficiency; 0 nothing done.						

Fig. 5.6 Sample audit sheet, for evaluation of the whole system of "World Class Maintenance"

to meet and also identify members depending on the type of breakdown, conduct that meeting every week for "Analysis of Major Breakdowns."

The members of the team will make a list of breakdowns in the last two to three years, which are not completely resolved to the root cause. Then pick up major breakdowns for analysis. The team members should be thorough in using analytical tools like, 5 WHY, Fish Bone Analysis, Pareto analysis, PM analysis, etc. If the team does not have hands-on experience then first the members should undergo a detailed training on analytical tools. Rather I would suggest that one system owner to be identified to take responsibility of training analytical tools.

Having done this much, start conducting the analysis and reach to the point of root cause. That means once the root cause is identified and countermeasure is implemented, the same breakdown should vanish and should not appear again. The test of the root cause is that the same breakdown should not come back again. For the team members it leaves a great taste and members shall get enthusiasm from the success of resolving an issue permanently. This will increase the “Mean Time Between Failures” for an equipment, or a given cell or a department. In some cases you will see an enhancement of MTBF to the tune of 5 to 10 times. This is a sure way to slowly achieve the goal of zero breakdowns.

At times, if there are design weaknesses in the equipment and it cannot be resolved at the user’s end you may have to take the help of design department of the manufacturers of the equipment. This particular system is called improving the design by using the inputs from the actual users of the equipment. In TPM there is a system called MP Data system. That means on a continuous basis the maintenance department of the users of the equipment collect data and suggest improvements through MP (Maintenance Prevention) Data Sheet. That means this data system shall reduce the breakdowns and finally reduce the maintenance work. So, you will see every year the maintenance effort needed for a given plant goes on reducing. This will obviously reduce drastically the “Mean Time to Repair”.

So, reliability is a probability of the equipment running without any breakdown when it is called upon for service. The probability number goes higher by deliberate effort of resolving equipment breakdowns and failures. This is done by analysis of major breakdowns by getting rid of them by going to the root cause.

5.7.3 Evaluate Maintenance Improvement Activities

Another key aspect of evaluation is measurement of TBM compliance rate, CBM or predictive maintenance rate, and Mean Time To Repair (MTTR), etc. This clearly speaks about the efficiency of the maintenance department. One important part of maintenance function is to carry out maintenance improvement activities on a continuous basis. That means to take into account how much time is spent on attending a particular breakdown. This includes analysis of the situation or failure, time taken to receive a spare part, fixing the breakdown and finally taking trial and handing over the equipment back to operation. This also includes proper documentation of the failure or breakdown so that the future failure if any can be fixed in less time.

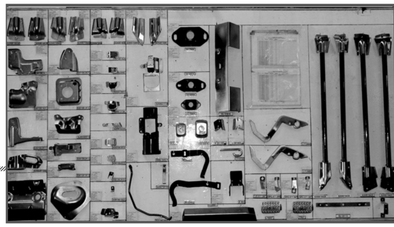
5.7.4 Evaluate Maintenance Cost Saving

We have seen in an earlier chapter that reduction of maintenance cost is a key deliverable by implementing WCM. Not only the maintenance cost, even the manufacturing cost comes down drastically by implementing the WCM. It is time now to assess how much of these two key result areas have been achieved. Our main objective is to achieve zero breakdowns. Furthermore by achieving zero breakdowns the maintenance cost as well as the manufacturing cost drops down tremendously. It is time now to establish a computerized system to measure and report it to the management. It is also time to establish if we have achieved the targeted cost saving.

5.7.5 Critique and Course Correction if Needed

A thorough critique is now conducted to identify a few steps to be implemented so that we continue to achieve the results and also to achieve higher results in the future. If there are changes in the system identified, it is advised to make corrections in the flow diagram so that all people understand it in the same way.

CHAPTER 6



Basic Concept of Progressive Maintenance Activities

6.1 BASIC CONCEPT OF PROGRESSIVE MAINTENANCE ACTIVITIES

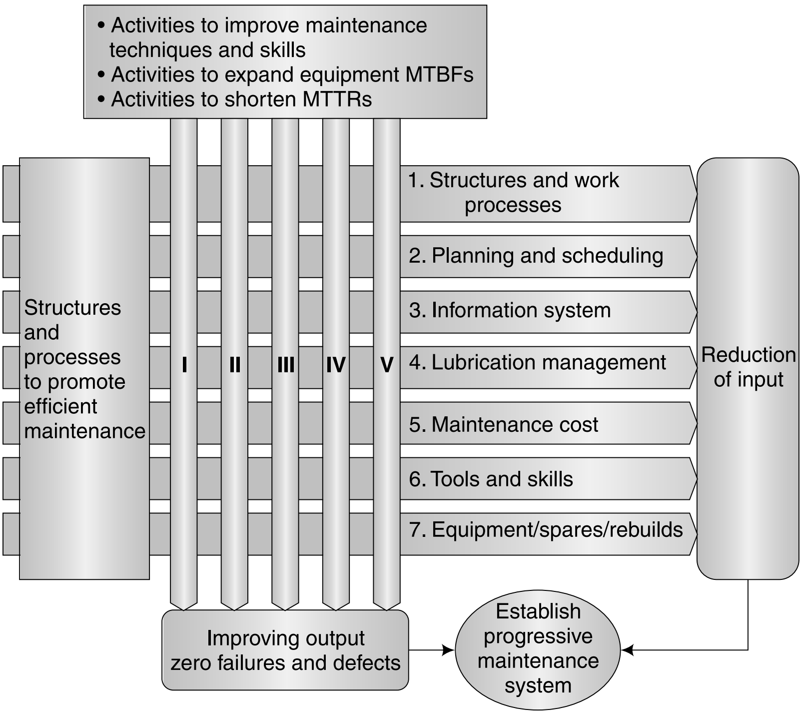
The basic idea here is how to improve the efficiency of the maintenance system. This is called "progressive maintenance methodology" mainly because we are looking at improving the efficiency of the maintenance system and making it a very progressive one. If you want to improve the efficiency of any function we need to understand the definition of efficiency first. Efficiency means OUTPUT divided by INPUT. So, if you want to improve the efficiency then either you increase the output or you decrease the input compared to the current condition or may do both.

There are two distinct sets of activities to be highlighted here. The first set of activities is for reducing the input. The second set of activities is about increasing the output. Let us now cover each area to understand how these two sets of activities are instituted in your organization and they are tracked to see if the progress is really taking place.

In Fig. 6.1, one can see seven activities in the horizontal field. These are very important activities to reduce inputs. That means use minimum resources. How to minimize resources is explained under each head of the seven heads shown. One may say immediately as a response, that everybody is doing these seven activities in general. Yes, you may be true. However, what is the efficiency of the system and how they are being carried out is important.

You may also see a little bit of repetition in some of the topics. The main idea of repetition is that nothing should be left behind and you must get a comprehensive idea about this.

In order to be able to name it progressive maintenance, we need to have the five activities mentioned in the vertical field. These five activities increase the output. The first seven activities in the horizontal field decrease the inputs. Together, the twelve activities increase the efficiency of the whole system. The author has first-hand knowledge of creating an integrated model of these 12 activities and get maximum efficiency. Of course it is a lot of work. But instead of firefighting all the time, it is better to have this integrated system established and get better efficiency for all the time to come.



I. Guidance and support activities for autonomous maintenance
II. Countermeasures to breakdowns
III. Maintenance improvement activities
IV. Maintenance prevention activities
V. Implementation of predictive maintenance

Fig. 6.1 Basic concept of progressive maintenance activities

The seven-key systems to reduce inputs are as follows:

(1) Structures and work processes; (2) Planning and scheduling; (3) Information system; (4) Lubrication management; (5) Maintenance cost; (6) Tools and skills; and (7) Equipment/spares/rebuilds.

6.2 STRUCTURES AND WORK PROCESSES

There has to be an organizational structure put in place to start the work of any function. Similarly, we need to have a maintenance organization structure. This will include the management hierarchy, roles and responsibilities of individuals. Generally, large manufacturing sites have three different functions within the maintenance function. They are mechanical maintenance, electrical maintenance and instrumentation maintenance. In middle and small size manufacturing sites generally, these are merged together and there is only one function that is maintenance. However, roles and responsibilities have to be very clear. We need specialized skills to carry out functions like instrumentation maintenance. That too specialized skills are needed in the electronic maintenance area. So we need to have trained and qualified people.

The structure depends on the size of the manufacturing site, various specialized skills needed to run the plant and also manning of three shifts if the plant is running three shifts. There are various activities in the maintenance function. Breakdown maintenance, preventive maintenance, breakdown analysis, documenting the history of the equipment and conducting specialized condition monitoring and predictive maintenance. The structure will now depend on these activities. In some manufacturing sites there is a concept of equipment owners who are responsible for certain identified areas for three shifts—means fully responsible for delivering results of certain identified areas. This particular system is called "process owner" concept.

6.3 PLANNING AND SCHEDULING

Let us first understand the difference between maintenance planning and maintenance scheduling.

Planning is taking into account various activities to be done by the maintenance function in a time like daily, weekly, monthly, quarterly and yearly. For this experience from various people, technicians, engineers, sometimes the machine vendor manuals and machine vendor's engineers will have to be put together. There are various activities like:

6.3.1 Breakdown Maintenance (Unplanned)

In any plant where major effort to reduce breakdowns like analysis of breakdowns, preventive maintenance, predictive maintenance or condition based maintenance are not carried out there will be breakdowns. As soon as there is a breakdown the production department sends a

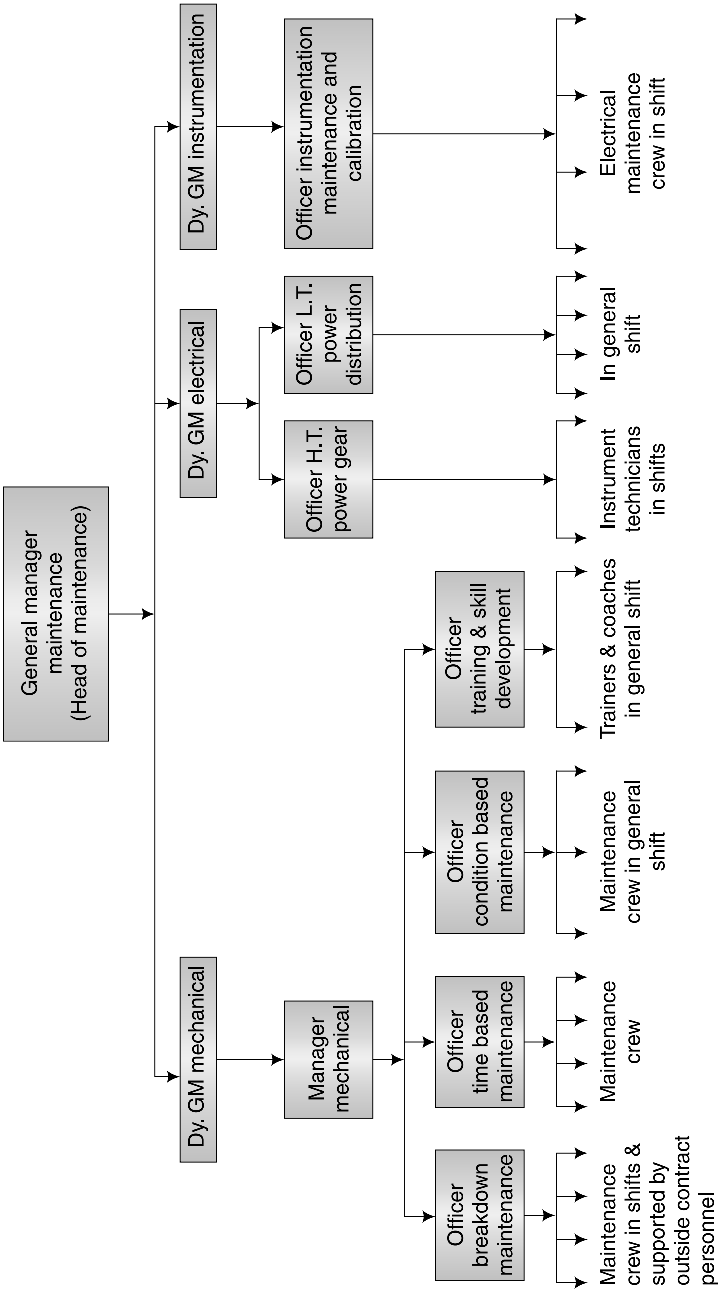


Fig. 6.2 A typical organization chart for a large process industry

request to maintenance department to attend to the breakdown by way of a job order or maintenance request sent through email. Then leaving aside all other priorities, the maintenance department shall send a maintenance person with adequate skills to attend to the breakdown. If the plant is running in three shifts this is done in all the three shifts. So, it is necessary to have personnel attending breakdowns in all the three shifts. Generally, all such maintenance requests are handled in the same shift and backlog if any is assessed on a daily basis. The next day priority is given to the previous backlog and importance is given to have no backlog on daily basis. The maintenance planning has to take care of these by having people attending breakdowns round the clock.

6.3.2 Planning Preventive Maintenance

A preventive maintenance plan is prepared as per the policy of the manufacturing site. This largely depends on the sophistication of the equipment, number of equipment and also on the ABC analysis of equipment done prior to the planning stage. Preventive maintenance requires a lot of planning to be done beforehand. That means, setting a goal to cover the equipment in the "A" category thoroughly. Then next level of priority is given to the "B" category equipment also if the TBM work is going on well and TBM compliance is 100%. In some plants the next level of priority is given to "C" category if the resources are available. Otherwise "C" category equipment will be covered by breakdown maintenance.

Once having done this, the work content of TBM to be carried out on all equipment to be studied thoroughly and manpower planning to be done accordingly. In TBM there is the work of checking (inspection) of the equipment components and also the work of replacement of some parts. So, it is necessary that for both activities, planning of all resources to be made accurately as per the TBM plan.

6.3.3 Planning Condition Monitoring and Predictive Maintenance

This is also called condition based maintenance (CBM). Condition monitoring is itself a specialized function and so there has to be an exercise identifying the equipment on which condition monitoring is done and then actually conducting condition monitoring and documenting the outcomes of that activity. Then as a next step predicting the condition and planning the maintenance activities based on the condition of the equipment are undertaken. So in the planning stage who will conduct the condition monitoring work and who will carry out the predictive maintenance has to be planned. In a given plant, all the equipment may not undergo CBM or PdM. So, planning has to take care of which equipment will be covered under TBM and which equipment will be covered by CBM.

6.3.4 Planning Support to Jishu Hozen (Autonomous Maintenance)

In plants where the Jishu Hozen activities are going on there is a major role played by the maintenance function. This is correcting abnormalities (identified with red tags by the teams). This also needs to get into the planning. Here the major concern is the list of abnormalities, hard to reach areas and sources of contamination is generally big and time consuming. This is because such an activity of restoration was not held in the plant any time earlier and for the first time such major activity is carried out. In addition to that sometimes the production department is unable to release the equipment for restoration work despite they themselves have identified those abnormalities and timeline to complete them is also laid down by them. Resolving sources of contamination takes longer duration and so these activities need planning so as to when the equipment will be freed up and when outside help for machining and implementing Kaizen is available. It is imperative to carry out restoration activities so that the plant can make progress in TPM.

6.3.5 Planning Small Projects

This is another set of activities carried out by the maintenance function. Installation of small equipment and replacement of some old worn out equipment are some examples of such work. Also, some developmental work like changing the electrical feeder system, installation of electrical panels with modern components like programmable logic controllers (PLC) come under this category. Here again thorough planning is needed to carry out these small projects, without much production interruption. Generally, these kinds of activities are carried out on weekly holiday, but sometime it may exceed the weekly holiday and extend into the working days too.

6.3.6 Scheduling

This is basically giving time frame to the planned activities and making them happen on the shop floor. Maintenance schedule schedules annually, monthly, weekly, daily and shift-wise. This needs good knowledge of the time required, to carry out such planned work and the resources needed to carry out those activities.

Generally, planning is done for the whole plant and reviewed annually or six monthly.

Scheduling is done and reviewed more frequently as the changes may be needed to the schedule depending on how the work is progressing and deputing more resources if there is urgent requirement of work or if there is backlog. Compliance of time based maintenance (TBM) activities and condition based maintenance (CBM) activities are reported to the hierarchy and so it is important to do review of the schedule more frequently so that resources can be deputed accordingly. At times there can be a backlog created due to some reason, so immediately course correction is needed to complete the backlog and priority is always given to these kinds of activities.

6.4 INFORMATION SYSTEM

Maintenance information systems need to accomplish three core functions.

6.4.1 Failure Management

This is about managing the failure of the equipment. Or in other words it is about reducing breakdowns by analyzing the breakdown to the root cause and coming out with solutions to breakdowns. Reducing forced deterioration of equipment and taking care of natural deterioration is done by time based maintenance and condition based maintenance.

Information needed to do this is equipment history cards and electrical drawings, service manuals and vendor circulars and as built drawings of changes done in the plant. Information starting from the date of purchase of the equipment till date is captured here. All information of major overhauls, major modifications, breakdowns and all relevant data is captured for future use here.

6.4.2 Equipment Improvement Management

This is about analyzing the breakdowns and other problems connected with the equipment and coming out with permanent solutions to those problems. This is an important section of the information system. All Kaizen work conducted on the plant and equipment and MP data also come under this section. All the improvements, capacity enhancement projects, changes made in mechanical, electrical and instrumentation areas to be captured here and is made available when needed and also when a similar equipment is procured. It is very useful.

6.4.3 Budget Management

First of all the maintenance department has to prepare a budget every year. So, this budget management module in the computer should be able to help prepare a zero based budget. In some plants even the energies budget is also prepared by the maintenance department. In such cases the module should be able to help prepare the energy budget.

In addition, the computerized module should be able to allocate cost of repairs, PM and modifications equipment-wise. Any time it is required to get the maintenance cost for any equipment in the plant it should be able to give the cost figures without leaving out any part. The cost of spares consumed from the spare parts store the system should be able capture that. The maintenance cost system consists of spare part costs, labor costs, cost of consumables and finally all the contract costs. There is a tracking system and budget control comes under this section. The system should also be able to give information on the cost saving projects and cost saving generated by implementing TPM in the plant.

6.5 LUBRICATION MANAGEMENT

6.5.1 Types of Lubricants

In olden days each manufacturing site used to have 20 to 25 different kinds of oils for various purposes. It was really difficult to keep a track of inventory of all these lubricating oils and prevent any mix up taking place at the use point. However, recently there have been lubricating oil surveys conducted by oil companies and there are only a few oils now in use in manufacturing sites. These are standardized and kept in inventory.

6.5.2 Color Coding of Storage Bins

Since visual controls are well recognized in the manufacturing sites, color coding of lubricating oils, has become quite common. The storage bins have color coding. Subsequently, the oil can is also color coded with the same color and finally the lubricating point on the equipment is also color coded with the same color so that there is no confusion to the operator for doing lubrication.

6.5.3 Lubrication Standard

It is important to understand the lubrication system in the equipment. In a plant there will be several equipment and so there will be several methods for lubrication. So in order to bring in seriousness in lubrication system the teams are now preparing lubrication standard and strictly doing lubrication and checking lubrication as per the standard. Care is taken to avoid over-lubrication as well as under-lubrication.

6.5.4 Standardization of Tools

It is also necessary to have standardization of tools like grease guns, oil cans, site glasses and lubrication cans helps in keeping inventories lower. Also it helps in saving time needed to carry out lubrication.

6.5.5 Standardization of Components

Another opportunity lies in the standardization of components in the plant in the area of lubrication. That is to standardize site glasses, gauge glasses, filters, FRLs, etc.

6.5.6 Storage Location of Oils

Storage location of oils is another important topic. The oils should be kept close to the user point, but at the same time proper accountability has to be maintained and misuse of oils to be prevented. In most of the plants correct accountability of the quantities of oils is a major issue. The maintenance store will issue a full drum of oil to the receiving person. However, part drum of oil is not accounted properly.

6.5.7 Lubrication Training

This is another important responsibility of the maintenance function. In the plant where Jishu Hozen is implemented, training the operators on the effective and economic lubrication method is important. The operator must learn to check the lubrication and so it is necessary that he or she understands the complete lubrication system for the equipment.

6.6 MAINTENANCE COSTS

We need to categorize maintenance costs so that they can be analyzed for improvement opportunities. Separately, targets are set in each category and then efforts are directed towards those areas where maximum opportunities to save costs are prevailing.

Examples of categories: Spare parts cost, consumables cost, cost of labor and cost of outside contracts.

This can also be categorized under different types of maintenance: breakdown maintenance, preventive maintenance, predictive maintenance, small projects and modifications and relocations, etc.

6.7 TOOLS AND SKILLS

Focus is on having the tools and skills to perform the activities you are focusing on.

6.7.1 Tools

First of all tools and tackles to carry out maintenance work should be provided. This helps in reducing the maintenance time. All the tools are properly inspected for correct functioning. Secondly, all the sophisticated tools for condition monitoring are to be maintained in proper order so that they can be used at any given moment and accuracy can be maintained.

6.7.2 Skills

The next important feature is the skills of maintenance personnel. Maintenance people are expected to be experts or at least having more skills than the operators in knowing the components and component functions. This is required to be developed or upgraded in some manufacturing sites. Analytical skills like why-why analysis, pareto analysis, fish bone analysis, PM skills (general inspection), FMEA, work point analysis are examples.

6.8 EQUIPMENT/SPARES/REBUILDS

This includes right parts in right place at right time and right value (inventory). Most important aspect is that there has to be adequate inventory of spare parts in the store, when you take up preventive maintenance or corrective maintenance. It is also needed for breakdown maintenance on daily basis. However, there should not be too much inventory. For this the slow moving and non-moving items in the storeroom should be reduced carefully. This is not an easy task. Also the manufacturing site should decide about the correct level of inventory. Minimum, maximum and re-ordering levels to be decided using the experience of maintenance personnel. Once decided those levels should be maintained both in the system as well as physical inventories.

Secondly, centralized store or decentralized store is another important decision to be taken by the maintenance department. This is not just the decision of the maintenance function. The finance department will also have a say in this. That is due to the accounting integrity needed of the people who are handling the spares. However, world over manufacturing sites have both models working.

Thirdly, the quality of locally developed spares and rebuilds is another important responsibility of the maintenance function. Development of local vendors for imported spare parts and vendors for other machining jobs, rewinding of motors and outside repairs is the responsibility of the maintenance department coordinating closely with the purchasing function.

The five key systems to increase output are as follows:

I Guidance and support activities for autonomous maintenance (Jishu Hozen);

II Countermeasures to breakdowns;

III Maintenance improvement activities;

IV Maintenance prevention activities; and

V Implementation of predictive maintenance.

These five key systems are implemented in progressive plants. Plants which are very keen on having zero breakdowns, zero quality rejections and zero accidents will surely need to implement these systems support them and sustain them.

6.9 GUIDANCE AND SUPPORT ACTIVITIES FOR AUTONOMOUS MAINTENANCE (JISHU HOZEN)

The role of maintenance function in a manufacturing plant where Jishu Hozen is implemented is immense and important. The role is illustrated in the following manner.

6.9.1 Restoration Work

Restoration means bringing the equipment back to the original condition. This entails fixing all the abnormalities listed by the Jishu Hozen teams, helping the operating teams to understand how they need to take care of the equipment by eliminating forced deterioration and operating them in the correct way. Finally, we all know that the development of Jishu Hozen work entirely depends on the pace at which the maintenance function is fixing abnormalities. This is a great responsibility shouldered by them.

6.9.2 Role of a Coach

By the virtue of having higher level skills than the operating teams, the maintenance person will have the role of a teacher and coach teaching them how to prepare cleaning, inspection, lubrication and tightening (CILT) standards. Furthermore, he or she will be teaching them how to use the analytical problem solving tools like why-why analysis, fish bone analysis, work point analysis, etc., and thirdly teaching the operators the functions of each component in the equipment and how to set them for proper functioning to get best quality.

6.9.3 Encourage Kaizen

Though we know that in a plant everyone gets involved in Kaizen, most of the time there has to be a trigger to break the barrier and come out with good improvement ideas. This role is generally played by the maintenance person attached to the team. Then giving them the help needed to fabricate and implement the idea generated by the team is also the main responsibility of the maintenance person.

6.10 COUNTERMEASURES TO BREAKDOWNS

"Countermeasures to breakdowns" is entirely the responsibility of the maintenance function. The maintenance department shall organize a platform in which key technical persons from operation, engineering and maintenance function are coming together and coming out with effective root cause solutions to breakdowns. The breakdowns may be occurring due to material failure, stress concentration, lack of lubrication, poor Jishu Hozen or poor quality of maintenance and or overloading. In such scenario one has to take the responsibility of bringing all these resources together and carrying out a good analysis and finally coming out with improved maintenance or design changes. The final result is that the number of breakdowns should reduce and that particular breakdowns should not recur again. This effort will continue until all the major breakdowns have got totally eliminated.

6.11 MAINTENANCE IMPROVEMENT ACTIVITIES

This is another interesting responsibility of the maintenance function. I would rather call this cleaning your own house or putting things in order in your own home. There needs to be some insight developed into how the maintenance work is going on and how the time and resources are utilized. This will include the tools and skills, condition in which the tools are maintained and how they are used. It also includes how the approach is done by a maintenance person conducting breakdown maintenance or preventive maintenance to be more effective. Analyzing the problem quickly and effectively, using modern methods to solve problems, coming out with good countermeasures with innovation is the key. Also giving feedback to the maintenance function as to how the work can be improved and making changes happen.

6.12 MAINTENANCE PREVENTION ACTIVITIES

Maintenance prevention is rather new to many manufacturing sites. This subject is gaining ground as in the developing countries maintenance prevention is going to play an important role. This originated from the saying “good maintenance starts at the design stage”.

How does the user of equipment get involved in the design of the same equipment? Does he or she have a role to play? Is it needed or the manufacturer of the equipment can take care of the improvement of design without outside help?

This is a very important aspect. After any modification for improvement is carried out on equipment immediately it is captured in the plant data system. This information should be communicated to the manufacturer of the equipment for further improvement or incorporating the Kaizen in the forthcoming design. The user may not have direct communication with the design department of the manufacturer of the equipment. This should happen especially the same user is planning to buy another equipment from the same supplier.

So, how to make this happen? It is the requirement that when the new equipment comes to the plant it should be defect free or trouble free. How do we get this result?

The maintenance department has a very important role of capturing all the changes, improvements and developments in the MP data system. The engineering department should take out this data and incorporate these into the design changes needed and convince the supplier to incorporate in the new equipment. The purchase department shall decide the commercial part and finalize the order. The maintenance department should be involved in the inspection of the equipment doing static check and dynamic check. This is how one gets best quality equipment into the manufacturing plant.

There are standard formats and prescribed method of collecting the MP data. This consists of engineering drawings and specifications so that the supplier of the equipment does not have any problem in understanding them.

6.13 IMPLEMENTATION OF PREDICTIVE MAINTENANCE

Finally, implementation of “predictive maintenance” helps in reducing costs and improves availability of plant and equipment.

Let us discuss as to how the predictive maintenance came into being. In continuous process industries many a times the maintenance department asks the operation department to release particular equipment for preventive maintenance. But often the operation department is unable to release it for maintenance work due to tight production schedule.

This is where the question started coming out. When should the maintenance department carry out the preventive maintenance? The maintenance department needs the equipment to be freed up. That means availability suffers.

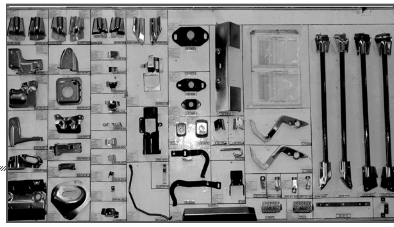
This is how the predictive technology came into use. Without disturbing the equipment, while the equipment is running the equipment is inspected, checked and deterioration measured. The results of inspection are then used to predict the health of the equipment and when any maintenance activities are to be planned. This is based on the condition and so it is called condition monitoring and subsequently carrying out predictive maintenance.

There are some sophisticated measuring devices available and these are used to measure the deterioration and also predict the future of the equipment.

Since predictive maintenance enhances the life of a component of the equipment compared to the preventive maintenance concept and reduces maintenance cost, it is becoming more popular. There is a need to achieve specialization in using the condition monitoring on equipment.

So you have seen the power of integrating the seven activities with these five new activities. First seven activities reduce the input and next five activities increase the output. Together these 12 activities have tremendous power and so it is the management strategy to focus and implement. Major part of the savings, we discussed in the earlier chapters are achieved by these 12 activities.

CHAPTER 7



Theory of Breakdowns

7.1 PHYSICAL ANALYSIS OF BREAKDOWNS

Why do breakdowns occur? This is best answered by comparing the stress applied to the equipment by various sources to the strength of the equipment. Breakdown occurs when the stress caused by various reasons exceeds equipment strength. All equipment are designed to withstand certain stress levels and equipment under operation are at certain level of stress. The equipment is subjected to stress under normal operating conditions. There is mechanical and electrical stress during operation. However, there are factors from external environment such as temperature, humidity, vibration, dust and contamination of lubricating oil by coolant or dirt.

7.2 FORCED DETERIORATION

The first aspect is the forced deterioration caused by negligence and improper care. This results in accelerated deterioration. Inadequate compliance of basic requirements of the equipment (cleaning, inspecting, oiling, and tightening), results in accelerated deterioration.

7.3 NATURAL DETERIORATION

This kind of deterioration occurs even when proper care of equipment is taken. This is a natural phenomenon and even with good care and working environment it will keep happening. If it is allowed to happen continuously, breakdown will occur. It can no longer endure the stress caused by the natural deterioration. Hence, there has to be some way of measuring the deterioration and when it reaches certain level, replacement of those deteriorated parts is essential.

7.4 UNCONTROLLED STRESS

Even if the equipment has not deteriorated and still retains design strength, breakdown can occur when the stress applied is more than anticipated at the design stage. This can happen intentionally or unintentionally and the stress caused is bigger than the design strength.

7.5 INSUFFICIENT DESIGN STRENGTH

This is caused by the designer's inadequate skills of design or mistake in design calculations. This is called weak design and the stress can exceed the strength of the equipment. This will also result in breakdown. Since the strength of the equipment is lower due to insufficient design strength right from the design stage, the equipment can break down at normal operating stress.

7.6 FACTOR ANALYSIS TO ACHIEVE ZERO BREAKDOWNS

We have analyzed the relation between stress and strength and three factors of breakdown from physical standpoint. We shall now further break them down into five factors so that production and maintenance can get involved in practical countermeasures.

7.7 INADEQUATE OR NO COMPLIANCE WITH BASIC REQUIREMENTS

The operating department does not perform the basic requirements such as cleaning, inspection, lubrication and tightening. This means the autonomous maintenance (Jishu Hozen) is not being carried out by the operating department. They are unable to even understand the deterioration taking place and also unable to understand the stress created by the accelerated deterioration. This is called inadequate compliance with the basic requirements.

7.8 NEGLECTED DETERIORATION

This is a situation when the equipment has not been taken up for restoration. The equipment is lying in a deteriorated state and the breakdown can take place or taking place very often. The operation department and the maintenance are incapable or not even aware that such thing needs to be done. They are incapable of conducting inspection of visible and invisible deterioration of the equipment.

7.9 NON-COMPLIANCE WITH USAGE REQUIREMENTS

This is a situation where operation and maintenance staff violate the operating conditions such as power current, voltage, RPM, velocity, temperature, etc. If the usage requirements are violated then the stress applied to the equipment will exceed the built-in stress limits. Non-compliance of the usage equipment can also occur when the operation department or the maintenance department takes up a work of modification of the equipment for a different application.

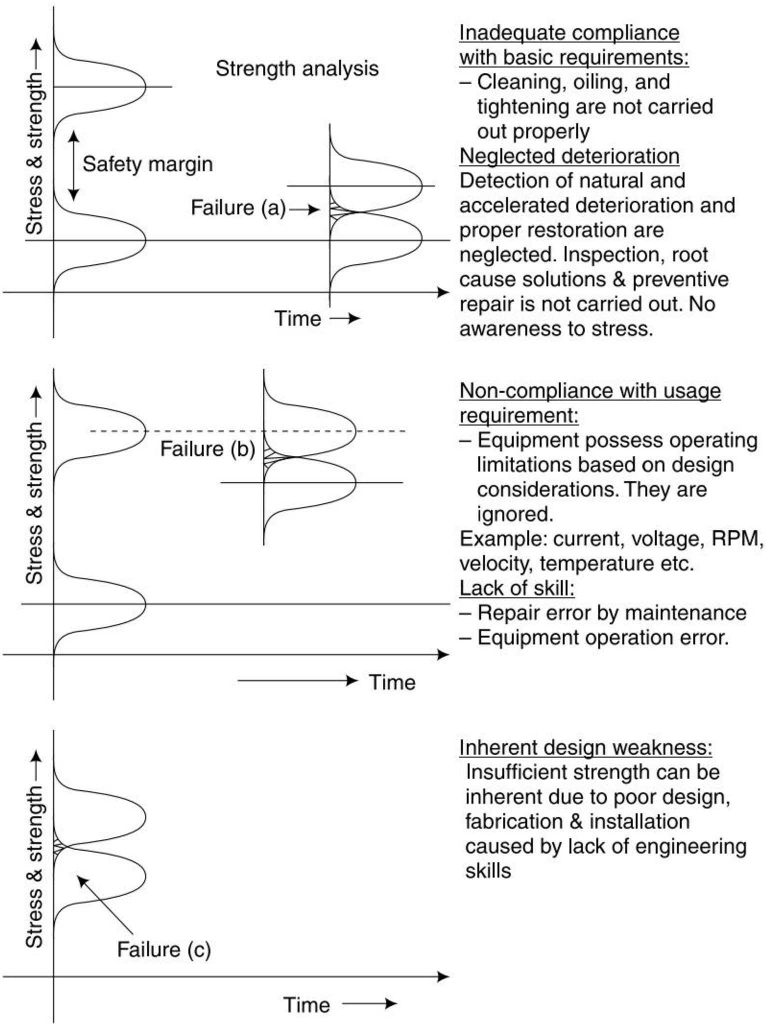


Fig. 7.1 Analysis of stress and strength

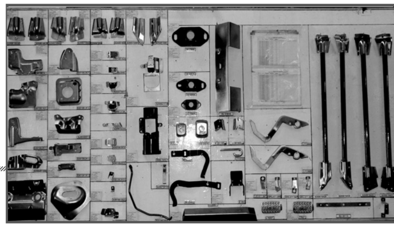
7.10 LACK OF SKILL

This is true for both operating and maintenance staff. Sometimes breakdown takes place due to improper repairs. Also operators may make mistakes as they are not adequately skilled. This results in extreme stress and breakdown occurs.

7.11 INHERENT DESIGN WEAKNESS

Lack of strength can happen due to design mistakes. This is possible due to designer's carelessness or lack of knowledge. It can also be due to lack of proper information.

CHAPTER 8



Nine Pillars of Maintenance Management

What are pillars of Maintenance Management? These are the main subjects under the head Maintenance Management. These are bodies of knowledge (faculty) in maintenance technology. Let us enumerate these and see the role of each one of them.

1. Breakdown Maintenance
2. Preventive Maintenance
3. Corrective Maintenance
4. Self Managed Maintenance (Jishu Hozen)
5. Opportunistic Maintenance or “If Down Do”
6. Predictive Maintenance (Condition Based Maintenance)
7. Reliability Centered Maintenance
8. Lubrication Management
9. Engineering Stores

8.1 BREAKDOWN MAINTENANCE

This is a situation where the equipment or a complete line of production comes to a grinding halt due to machine breakdown. That means some component or components have stopped working and so the equipment is not in a condition to continue with production.

Initially, when we begin our journey to achieve zero breakdowns, the major task is to achieve lower levels of breakdown first. So what we need to do is to assess where we are in breakdowns. This is achieved by instituting a good system to collect data for all the equipment in the plant and record the same. The starting point could be to take a three months average and take it as the starting point (current level). Then we shall establish a target to be achieved in the first year.

8.1.1 Performance Measures for Tracking Breakdown Maintenance

1. No. of breakdowns
2. Frequency of breakdowns
3. Time taken to fix breakdowns
4. Breakdown time as percentage of total working time
5. Mean Time Between Failures (MTBF)
6. Mean Time To Repair (MTTR)
7. Cost of breakdowns

The above measures are tracked on a monthly basis and team meetings are held to discuss the progress every month.

The maintenance department shall identify resources for attending breakdowns as soon as possible. In some plants there are dedicated technical personnel always waiting and ready to attend to breakdowns. However, in some other plants this sort of dedicated staff may not be there. In such cases it is the job of the maintenance supervisor to depute personnel with adequate skills to attend to the breakdowns as quickly and as efficiently as possible.

The maintenance personnel who are attending the breakdowns need to have good maintenance skills so that the diagnosis of the breakdown and fixing the breakdowns, taking care of all normal engineering practices is carried out efficiently. That means the maintenance technician needs to do the diagnosis accurately and quickly. Also he/she should have the skills to fix the parts with good spares, taking care of tolerances, lubrication methods, adjustments, etc. At the same time the time taken to fix the breakdown and handing over the equipment back to production department is most essential. That means, try and reduce the time taken to attend the breakdown. The time for attending the breakdown is recorded by the maintenance department in their records. There has to be an accurate recording system to see that the time recorded by production and maintenance departments is one and the same. In the organization of maintenance department the technicians to attend breakdowns every shift are allocated and this is treated on priority. The time taken for attending breakdown is from going to going. This includes the ramp up time unless and otherwise the ramp up time is separately tracked.

Furthermore, at times, the maintenance technician needs to carry out some temporary arrangements and hand over the equipment back to production. This is an exception and not a rule. But sometimes it is essential, so that the team can do thorough repairs later after organizing every resource and spares needed.

There are a few key things in the area of breakdown maintenance. These are important as we are now tracking the time taken to attend each breakdown. In a conventional factory many a times the communication between the management and the technicians attending the breakdowns is not as we desire it to be, the time taken shall be more.

Here it is imperative to record time taken for all activities while attending breakdown.

8.1.2 Time Recording System

1. The time taken to receive the "Work Order" or "Job Order" from the production department.
2. The time taken to clear the site to attend the breakdown. In some plants they will need the help of housekeeping personnel to do this work. This is where there is a chance that more time is needed to do the site clearance.
3. The time taken to understand the situation by inspecting at the site of breakdown.
4. The time taken to analyze the root cause of breakdown.
5. The time taken to organize the resources, tools and lifting tackles.
6. The time taken to bring the spares needed for repairs from the store room.
7. The time taken to finally execute the job.
8. The time taken to accept and start production.
9. Time taken to do ramp up.

This kind of analysis is needed for at least A category machines to begin with for sure. The question is how we can bring some level of accuracy in the time recording exercise. But anyhow this is needed if you want to achieve good results.

We have seen in the earlier chapters that the measure MTTR directly shows the efficiency of the maintenance department and we need to penetrate in this area much deeper in order to reduce MTTR.

Let us now get into how we can reduce the time taken for each of the above mentioned activities (Fig. 8.1).

These are a few guidelines to reduce time taken to attend a breakdown. This is important because now the breakdown occurrence has been in the focus. By carefully planning and handling the time taken for attending breakdowns can be brought to either one-fifth or in some cases one-tenth of the time taken earlier (MTTR reduction down to 20% or even 10% of the original).

Activity	Responsibility	Suggestions to improve
Time taken to receive the work order from production	Production	Switch over to electronic media. You can send the job order by Email.
Time taken to clear the site of breakdown	Production	This is not necessary if 5S is being implemented in the plant. No clearing is needed.
Time taken to understand the situation	Maintenance and production	The time taken to understand the situation will come down if the method of diagnostics is understood both by production as well as by maintenance.
Time taken to analyze the root cause of breakdown	Maintenance	This needs a platform where if the root cause of the breakdown is not known immediately call a small brain-storming session.
Time taken to organize the resources, tools and tackles	Maintenance	Often the maintenance is not in readiness to handle this. Please keep all tools and tackles in proper place. 5S in maintenance.
Time taken to bring the spare parts needed	Maintenance store	Physically all items to be identified and store should be organized for no search time. Decentralized store could be another solution.
Time taken to carry out the repairs	Maintenance	Explore the possibility of outside resources to augment the permanent staff. Plan the activities before starting the work.
Time taken to accept and start production	Maintenance and production	Maintenance to hand over quickly and production to start quickly.
Time taken to do ramp up	Production	First piece approval in engineering industries and qualification in the process industries to be streamlined.

Fig. 8.1 The methods to reduce the time taken for each activity

8.1.3 Pit-stop Methodology

Normally, in unplanned maintenance activities the maintenance crew will have to work round the clock. This is where the "Pit-stop" methodology can help. In the Pit-stop you will see a few things very clearly. The roles and responsibilities are very clearly laid out. The people handling the work are experts and focus on the work they are doing 100%. Proper tools and tackles are used without compromise. There is a great emphasis on quality of workmanship and at the same time importance is given to the time taken to complete the work. A video of the Pit-stop can help a great deal to train the technicians who are working on the unplanned maintenance activities.

8.1.4 Updating History Cards

As soon as the breakdown has been attended it is necessary to update the history cards to capture any findings or any changes done in the equipment by way of Kaizen etc. and as-built drawings of any modifications either in the mechanical or even electrical area to be prepared.

The modern trend is to capture MP (maintenance prevention) data. In fact, this is an investment for the future. The changes incorporated, however small, are all captured in MP data. The changes made could be in the areas of operability, maintainability, reliability or just helping in Jishu Hozen activities. A separate section in this book will go into detail of MP data system. However, it is mentioned here that updating history cards and capturing MP data are two things which are very important at this point of time.

8.1.5 Root Cause Analysis

We shall now discuss another important factor, that is, root cause analysis. Generally, in industries the breakdown is attended in a hurry so that the plant is brought back into operation with the least time. However, the breakdowns occur again and therefore the work content of handling breakdowns does not come down. This situation is called firefighting. So, the important factor here is how do we get out of this firefighting situation and come to a comfortable situation.

It is absolutely necessary to learn the analytical tools like why-why analysis, fish bone analysis, work point analysis and or even PM analysis if need be. At the lower levels at least why-why analysis and fish bone analysis should be taught and practiced. This has to be driven down to the technician level so that the analysis becomes more accurate and the root cause of the breakdown is identified and the countermeasures implemented. You may make a humble beginning and graduate slowly to put into practice the use of analytical tools to go to the root cause. In new plants it is easier as we recruit technicians we shall first take them through a few training programs and train them to handle the root cause analysis among a few other skills which are absolutely needed to run the plant.

8.1.5.1 WHY-WHY Analysis

This tool is a powerful tool for analyzing the problem to the root cause. So, it is expected that every single person in the company needs to understand how to use the tool to achieve root cause. This is not only pertaining to the plant situation, but can also be used for employees working in other departments in an organization.

Japanese people believe that if you ask WHY five times the real root cause will get revealed. So they have given it some shape to make it a powerful tool and also use it on a daily basis.

There are some principles we need to agree on before using WHY-WHY analysis.

1. It is not a paper exercise. We will document it once the analysis is complete, but it is not just a "form to be filled" kind of exercise.
2. WHY-WHY analysis needs more than one person. It is generally used by a team to solve problems. So, one person will ask WHY and there should be other persons to answer the question.
3. Going to Gemba is considered to be very important. Many a times the problem is not defined well enough or got distorted during the process. So it is necessary that we give a lot of importance to define the problem or state the problem correctly.
4. There are two different situations. One, the problem has been fixed by the maintenance person or operating person and now the team is doing re-analyzing to check what has been done earlier is correct. Second, the team is doing analysis for the first time. So the flow will be different in two cases.
5. The test of conducting the WHY-WHY analysis is in eliminating the problem totally. That means the same problem should not recur.

Let us now understand the method by using the format shown in Page 33.

1. First of all the identification of the machine or place or situation where the problem exists. Second comes the date of analysis. For example, the pump motor bearing machine number and WHY-WHY analysis identification number to be written.
2. Correct problem statement is needed: In this case it is motor bearing making unusual sound.
3. Description of countermeasures: In this case both end bearing replaced and fresh grease has been used for lubrication.
4. Now the WHY-WHY analysis will start. Please see principles mentioned earlier. Problem: Motor both end bearing making unusal sound.

WHY:	Bearing has run out	Due to: Lubrication failure
WHY:	Lubrication failure	Due to: Inadequate grease filling
WHY:	Inadequate grease filling	Due to: PM work not done for 3 years

WHY:	PM work not done for 3 years	Due to:	Motor was not A or B category
WHY:	Motor considered not A or B category	Due to:	Equipment not considered critical
WHY:	Motor not considered critical	Due to:	ABC analysis not done

Countermeasure: Both end bearings replaced and ABC analysis completed. PM frequency eatablished once every 12 months. Root cause: Deterioration (PM not done on time).

8.1.5.2 Cause and Effect Analysis

Cause and effect analysis can be used in any function or department. However, here we have taken the process of a factory floor. There are five major categories under which we have put the major bones. Man, Materials, Method, Machine and Tooling.

Why Use Cause and Effect Analysis?

This is to allow a team to identify, explore, and graphically displayed detail all the possible causes to discover its root cause.

What does it do?

Enable a team to focus on the content of the problem, not on the history of the problem and not on personal interests of the team members.

Focus the team on causes and not on symptoms. Create the snapshot of the collective knowledge and consensus of the team around a problem.

How do I do it?

Select the most appropriate cause and effect format. Generate the causes needed to build a cause and effect diagram.

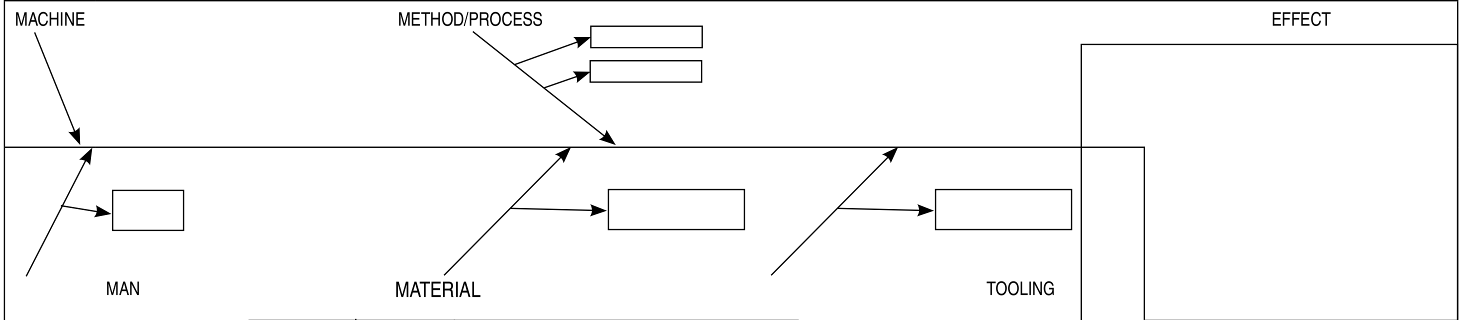
Construct the Cause and Effect/Fishbone Diagram

Place the problem statement in a box in the right hand side of the paper. Allow plenty of space in the paper. Paper is preferred as it can be moved as you need. Make sure everybody agrees to the problem statement. Include as much information as possible on the "what," "where," "when," and "how much" of the problem. That means use data and tangible data as much as possible.

Draw major cause categories in the production process. They are Machine, Man, Method and Materials and Tooling. Attach these to the backbone of the fishbone chart. Tooling has been chosen in place of "measurement" or "environment." This kind of flexibility is needed so that the team becomes comfortable.

CAUSE & EFFECT ANALYSIS FORMAT

	Plant Name:		
	Customer/M/C:		Other reference if any:
	Reference:		Date:
	Complaint/Non-Conformity Details:		
	Brainstorming points		



		Team members	7	Multivoting sheet									
Sr. No	Brainstorming Point (BP)	Point identified by	% contribution of the BP							Total	BP Validation/Verfication details	BP Validated/Verfied by	Date of BP Validation/ Verification

Remarks:	**Note: Carry out Why-Why analysis for the each significant causes i.e. the cause for which multi-voting rating is greater than 50%**		
Prepared by:		**Approved by:**	

WHY-WHY ANALYSIS SHEET						
MACHINE NAME:	M/c.No.: Why No.	Date:				
Breakdown/defect/Physical phenomenon						
What is your final action?						
In case of Spare-Part replacement ☐	Describe Countermeasure					
In case of Spare-Part no replacement ☐						
	Why did you take above action	Due to				
Why 1						
Why 2						
Why 3						
Why 4						
Why 5						
* Root cause is one of the following 5 items		AM	PM	Design	E&T Skill	
1	( ) Poor Basic Condition					
2	( ) Poor Operating Condition					
3	( ) Deterioration					
4	( ) Week Design					
5	( ) Poor Skill					
(**Note:** Please fill up this form in pencil immediately after M/c is started)						
Kaizen Idea and Schedule Periodicity for doing PM reduced to once a year.						

Place all the brainstormed data into the appropriate category. Again while brainstorming do not restrict much by the category instead do not bother so much on which category so that the flow of brainstorming continues. Fill in the format given to you. Here we have chosen brainstorming and so we need to record all those in order to have multi-voting.

Then the brainstorming point has to be validated and verified. Capture all the brain stormed points in the fishbone diagram.

Carry out "Why-Why" analysis for each significant cause, the cause for which multi-voting rating is greater than 50%.

8.1.6 Knowledge Sharing Meetings

This is another area a maintenance department can give attention to. In a manufacturing plant situation, there are no avenues for knowledge sharing in a maintenance department. This is because all people are very busy with the work allocated to them and there is no platform for knowledge sharing opportunity. A meeting is held of relevant members to discuss and share the knowledge of individuals including new ideas, new ways of doing things and also sharing difficulties and seeking solutions. Generally, this does not happen in many industries and so they find it difficult to come out of the firefighting mode. A bulletin board, or a fixed hour meeting and reward system can help greatly in this matter.

8.1.7 Why Cost Attached to Breakdown Maintenance is Generally High?

Please see the earlier chapter where we have dealt with the savings generated by zero breakdowns. This is mainly due to the hierarchy of losses taking place when there is an unplanned maintenance incident. It is not just that you lose only the production volume due to breakdown; there are a number of other losses which are taking place in series. There are material losses, there are damages to other parts when a component fails, there are quality rejections, and ramp up losses and energy loss etc. As a result the losses due to a breakdown are bigger in magnitude compared to other activities like preventive maintenance or predictive maintenance.

This is the reason breakdown maintenance should be by and large eliminated. This is how the belief that zero breakdown is the best policy came into picture.

8.1.8 Schedule for Completion of Work

Due to all these reasons there is naturally a great amount of urgency to attend the breakdowns. Therefore the maintenance department should be flexible enough to increase the resources in order to complete the tasks on time so that there is no backlog of breakdowns.

Therefore, the maintenance manager shall on a daily basis keep a check on the backlog if any and take corrective action to bring it back to the desired pace. The author's experience is such that if the breakdown compliance rate is 90% and above it can be managed by working hard to clear the backlog. However, if the compliance rate is less than 80%, then there are less chances that the backlog ever will get cleared.

8.2 PREVENTIVE MAINTENANCE

This is one of the most important responsibilities of the maintenance function. The maintenance work done in a planned way and with a predetermined time schedule is called the Time Based Maintenance (TBM) and the maintenance work done in a planned way but based on the condition of the equipment is called Condition Based Maintenance (CBM). It is also called Predictive Maintenance. The word "predictive" is used in some cases as modern equipment diagnostics help predict the time frame to undertake the maintenance work by planning it based on the condition and the scientific prediction. The prediction is based on the findings of the equipment diagnostics and a planned shutdown can be organized by keeping in mind how long can it run without failing.

Now, let us get into a little more detail of preventive maintenance. Since this is a major effort in maintenance and requires a lot of resources, let us now identify the three important points about preventive maintenance.

1. Prioritization
2. Methodology of conducting preventive maintenance.
3. Compliance rate for preventive maintenance.

8.2.1 Prioritization

This is an important planning process. In a medium scale to large scale plant it is necessary to take a decision to begin with. The decision is about whether you would like to take up all equipment under preventive maintenance from the very beginning. If the effort is huge it is better to prioritize a few equipment for preventive maintenance and keep on taking up more equipment as we go along. This is where the prioritizing tool is needed to be put in place.

The prioritizing tool is called the ABC analysis or also called equipment ranking. The idea here is to take up only highly prioritized equipment (A ranked) first and do a good job on preventive maintenance and later get into B category and C category if need be.

Let us now look at how this classification is done.

(A) Critical Equipment

- High level of criticality based on the impact on PQCDSM. (These are called plant level performance measures: productivity, quality, cost, delivery, safety and morale.)
- Equipment with chronic problems.
- Equipment carrying out very essential function in the shop floor.
- Equipment which has major effects on product quality or market complaints.
- Equipment which is at the end of the line.
- Equipment which needs high level of monitoring and CBM.

(B) Medium Criticality

- Equipment which can have either Time Based Maintenance (TBM) or Condition Based Maintenance (CBM) system.

(C) Less or No Criticality

- Equipment is standby equipment or does not have much impact on production.
- Equipment which can have TBM maintenance system.

This kind of classification is generally done by the maintenance function. However, in terms of criticality, it is better to even share it with the production department and take their input. There should not be two separate lists of equipment on ABC analysis; one belonging to maintenance and the other to production. To cut it short the ABC analysis or equipment ranking is an exercise to be carried out jointly by maintenance and production functions.

8.2.2 Methodology of Conducting Preventive Maintenance

The methodology of conducting preventive maintenance activities is equally important as equipment ranking or prioritization.

8.2.2.1 Periodicity to Carry Out Preventive Maintenance

What is preventive maintenance (PM)? It is the method of preventing breakdowns by taking up maintenance work before any breakdown occurs. Now, the question is how to estimate the time frame or periodicity to conduct PM. The periodicity is generally mentioned like; every month, every quarter or may be every six months. This looks simple but the important point here is that the PM work should be completed before any breakdown takes place. This should not be done too prematurely and at the same time it should not be delayed so much that the breakdown occurs before any PM work is done.

In a new plant the periodicity to conduct PM can be based on the equipment manufacturer's recommendations. The equipment manufacturers are well aware of this requirement from the actual users and so the service manual gives details of such periodicity to carry out the PM work. However, in older plants where such service manuals or such details are not available, we need to go by the experience of the maintenance crew. The maintenance crew normally carries out the inspection. Again these things are not etched in marble and so you may make changes in the periodicity if there is a necessity as you gain experience. The guideline here is that if you carry out PM work much prematurely the cost of maintenance goes higher as we are replacing a part too prematurely. At the same time if we delay too much the breakdown will occur and the cost will be much higher. We need to strike a balance between these two factors.

8.2.2.2 Checklist Based Inspection

In preventive maintenance activities there are two main activities to be carried out by the maintenance technicians. First is the inspection to be carried out on certain components of the equipment under PM; second is the replacement of parts as per the recommendations of the equipment manufacturer (or as decided by the maintenance team). Inspection is generally carried out visually by the technicians. In some cases it is even carried out from the memory of technicians. This is a pitfall. If you carry out the inspection by memory, there are chances that a few inspection points will be left out and the inspection which is done after several months is not complete. The PM activity is an intervention to assess the condition and such an opportunity should not be taken lightly. So, checklist based inspection has come into picture. Instead of leaving it to the memory of the technicians, a thorough checklist is prepared for all the equipment planned under PM program. Technicians while conducting PM activities shall pick up this checklist and carry out thorough inspection using the checklist and check all points. This documented checklist is very important for inspection and also as a documented record to be maintained by the maintenance.

Equipment Type or Category: A.C. Motor—10 h.p.

Equipment name and number	*Equipment component*	*Component to be checked*	*Checking parameter*	*Condition of the component (Wear & Tear)*	*Accepted or replaced*
Domestic water Pump No. 2	Ball Bearings	Both end bearings	Noise level Vibration Wear & tear	– Normal noise – Slight vibration – Small Wear & Tear	To be replaced
Stator	Windings	Insulation check by Megger	Insulation OK		Accepted
Armature	Armature	General condition	Clean surface & no visible marks		Accepted

Fig. 8.2 Preventive maintenance checklist example

8.2.2.3 Replacement of Worn Out Parts

Before undertaking the PM activities, the planning person will make sure that all those replacement parts are available in the spare parts storeroom and are kept in good condition. There should not be surprises later that the parts are not available, or it is not suitable for use. But however there could be some more parts needed to be replaced which are identified as a result of the checklist based inspection which was carried out. This could be due to some parts failed prematurely or some forced deterioration has been caused on those components. So, these parts should also be available in the storeroom. If those parts are not generally wear parts and by surprise it has happened that they are in a deteriorated condition they should be replaced at the earliest opportunity. This will need another intervention of PM.

8.2.2.4 Inspection of Hidden Areas

Since we get an opportunity to conduct thorough inspection while carrying out PM, the inspection of hidden areas is a key activity. This is needed to inspect the structural parts of the equipment, fasteners, and important areas such as insulation, damage due to corrosion, etc.

8.2.2.5 Updating the History Cards

The history cards will have to be updated as soon as the PM activities are carried out. Any observations or abnormalities will have to be documented. If there are any improvements carried out by way of Kaizen they shall be captured in the history cards.

8.2.2.6 Major Overhauls

This does not form a part of preventive maintenance. However, there are some industries who treat this under PM program. Major overhaul means dismantling the equipment completely and replacing all the worn out parts and totally refurbishing the entire equipment. The basic thing is that such a situation has arrived on this equipment means there was no preventive maintenance conducted on that equipment or the PM program was not good enough and so excessive wear of parts has taken place. Major overhaul is a separate activity where the equipment is identified for major overhaul and taken up as separate project. This will need longer period of shutdown and there can be surprises as many parts will be worn out and so sometimes those parts may not be available in the stores. If there is enough experience on similar equipment and an overhaul was carried out then the situation could be somewhat better.

8.2.2.7 Refurbishing

There is also another situation which is similar to the major overhaul. This is called refurbishing of equipment. These days some manufacturing plants are buying second hand equipment from Europe and such countries and conducting complete refurbishing here in India. This may be economical in some cases and so management is getting into such activities. However, as mentioned earlier this is not preventive maintenance, but treated as a separate project.

8.2.3 Compliance of PM Schedule

The PM activities are major activities in maintenance function. With all good intentions the maintenance does equipment ranking (ABC analysis) and mostly to begin with they would start PM planning and scheduling on only "A" category equipment. After gaining enough experience in handling PM activities they will include PM planning and scheduling for B category and then C category as per the need. The initial period of PM may take a year or more as we need to monitor on a daily basis how the PM activities are going on. Is production department releasing the equipment as needed by the PM plan? Is there a major deviation from the schedule? Is maintenance capable of handling the PM activities of check- list based inspection and replacement of parts on time as estimated in the schedule? Is there any issue on the availability of spare parts as needed by the PM activities? Is there any work which was planned and could not be completed on that day and is pending? All these are important factors to be checked before taking on bigger and bigger challenges. This is the reason the performance measure called PM compliance rate has been introduced. When you start the compliance rate every month could be as low as 60%. Immediately we need to understand why the compliance rate is so low. Because 60% rate means 40% of work is being carried forward to the next month. This way the PM program will come to a grinding halt within a few months. A compliance rate of more than 80% looks healthier to begin with. In case the planning and scheduling work has been done with too much care and the compliance rate is 100% to begin with it shows the schedule is easily achievable and so you can add some more activities in the schedule. From our experience a plant should be able to come to 100% compliance rate within three months time. In other case where the compliance rate is dwindling, then the PM program will need a review immediately to understand the situation.

PM compliance rate is a good way of measuring and tracking the progress of PM program. However, the quality of PM work is even more important than the compliance rate. Initially, by implementing PM program the maintenance is trying to achieve zero breakdowns on those machines. However, if the quality of PM work is not as per your expectations then the zero breakdown objective will not be achieved. The PM compliance rate may show very good, but the breakdowns have not come down to even closer to zero level. This is very important and a thorough analysis of the situation needs to be done at this point of time. Is the PM work being carried out just as a routine? Are the maintenance technicians trained on how to carry out PM activities? Is there any issue between production and maintenance? Or is it due to issue between maintenance and housekeeping? Is it due to company policy that the maintenance is not getting support? Is it the attitude of technicians?

These are a few points to be verified to improve the quality of PM work. One to one talk with the person or persons carrying out PM work may even help to improve the quality of work.

8.2.4 Locally Made Spare Parts and Quality of Reconditioning of Old Used Parts

This is an important topic typically for developing countries. On one hand they need to save money by developing locally made spares, but at the same time they need to give more attention to the quality of the spares developed locally. This is a challenge but it is imperative that we develop vendors for indigenously developed spare parts. This responsibility is big and so maintenance should dedicate certain resources for this kind of work. A machine development engineer who has complete knowledge of metallurgy, hardening and machining accuracies should be the resource for this kind of work.

Reconditioning of used parts which are taken out of the line is another set of activities. This is again similar to the locally developed spare parts, but however there is a subtle difference in that the old used part needs higher level of inspection to be done in order to make the part suitable for reuse in the equipment.

So, while we need to develop vendors for these kinds of work, it is most important to be very strict about the quality standards.

8.2.5 Storage of Rebuilt Spares

In some plants they store the locally developed parts, refurbished or repaired old parts and the new spare parts all in one bin or storage rack. I would rather give a warning here. They need to be stored separately and when we are using repaired old parts there is a kind of risk and one has to make a conscious decision and monitor on a daily basis. Otherwise the effort of developing locally of the spare parts and repaired parts can be big wash off.

Again caution has to be taken to see that these kinds of parts are not used on most critical equipment, as the consequence of failure could be very high.

Furthermore, the effort mentioned above is not worth using for insurance spare parts, as we will not come to know about how they are functioning immediately. The insurance spares are used sparingly or sometime they will be lying idle in the storeroom for many years. As a result we will not come to know the effect immediately and after many years they are used and they may fail.

So in other words, the policy of locally developed and repaired spares is a matter of risk and this decision should be taken by the higher authorities instead of maintenance department.

8.3 CORRECTIVE MAINTENANCE

Corrective maintenance is another important process in maintenance management. Making design corrections on the existing equipment is generally called corrective maintenance. In some books written by American authors corrective maintenance has a different meaning. Fixing a breakdown and bringing it back into service is called corrective maintenance. However, let us stay with the earlier concept.

Soon after commissioning a plant we notice certain deficiencies. These deficiencies could be some bottlenecks or may be design shortcomings. Due to these design deficiencies the plant cannot run with full capacity. Once we notice it we need to do something about it. The maintenance function has this responsibility to carry out design corrections. For this they may need the help of the machine manufacturer or in some cases it is handled totally in-house.

For example, the heat exchanger attached to the equipment is undersize and we are facing the bottleneck situation due to this. Since heat exchanger is a bought out item we need to work on the correct capacity needed and buy another one and fix it. This is rather simple. However, all situations are not as simple as this case. The current heat exchanger is of shell and tube type and we need to fix a plate type heat exchanger to improve the efficiency. Furthermore, the space provided is small to fix big size shell and tube type heat exchanger. In such a case this is entirely a different design. The maintenance function has to be careful in making the choice and undertaking the project for making the design correction. This is important as without it the whole plant cannot run with full capacity.

The design corrections could be in the mechanical area or even electrical or electronic control areas too. Introducing Programmable Logic Control (PLC) to the existing electrical control panel is corrective maintenance. In some cases it may need capital appropriation to be approved by the top management. In some other cases it may amount to small change. However, in all cases it will be corrective maintenance. Later in this book you will find how the corrective maintenance is important in the journey of achieving zero breakdown.

In a particular example an effluent treatment plant had a pump with cast iron impeller. This pump was installed only six months back and within six months the cast iron impeller got totally corroded and eroded. That shows that the material cast iron is not suitable for this type of application. This needs a design change and stainless steel 316 was recommended for this impeller. The correction was completed and the problem got over. This is where design corrections are required in some cases and the maintenance function is responsible to carry out such changes.

In some organizations they have a separate department called manufacturing engineering. The manufacturing engineering function is responsible for projects. Installation of plant and equipment is done by this department. In such cases the corrective maintenance is also done by the manufacturing engineering. But in most of the cases it is handled by the maintenance department.

In summary, corrective maintenance is needed in the following situations.

8.3.1 Design Faults

This situation could arise due to design fault, due to inadequate skill of the designer or lack of complete information.

8.3.2 Specification Not Adequate

Corrective maintenance has become a necessity due to specification given by the party ordering the equipment is not adequate or wrong information was given. In such cases it is necessary to do corrective maintenance.

8.3.3 Inferior Material or Workmanship

Corrective maintenance has become necessary due to inferior material of construction or poor workmanship of manufacturing the equipment. The tolerances are not as per specifications or negligence of the manufacturer as far as material and workmanship is concerned.

8.3.4 Utility of Equipment Changed

In some rare cases the corrective maintenance has become necessary as the utility of the equipment changed in the plant. The equipment was used to make a different type of product and now the product has changed and the equipment needs retrofitting in order to make the new product.

8.3.5 Unexpected Problem

Corrective maintenance has become necessary due to some unexpected problem has cropped up and it is necessary to resolve the issue.

8.3.6 Improvement Came Out of Suggestion Scheme

This situation has become necessary as in a Kaizen program or a suggestion scheme it has been brought out that there will be benefit by doing this Kaizen. Hence, the corrective maintenance is necessary.

8.3.7 Operability or Maintainability Issue

At the design stage the operability and maintainability issues are generally discussed. However, there could be some new issue that come to light and it is necessary to make a change.

8.4 AUTONOMOUS MAINTENANCE (JISHU HOZEN)

This is a methodology introduced to involve the operators in daily maintenance activities on their machines. This looks simple but the results are great and it makes a big difference to the maintenance function. The general tendency of the operators in the shop floor is "I run it and you fix it". But here autonomous maintenance is bringing in a different culture. Instead of you fix it, I run it and I fix it.

As the name indicates it is called autonomous maintenance or "Jishu Hozen" in Japanese language. Here operators are taught to clean their equipment, inspect their equipment and lubricate their equipment. This is the minimum requirement of Jishu Hozen. Then the involvement of the operators starts and there is no end. Operators come out with Kaizens to solve their problems on productivity, quality and safety aspects. They get into continuous improvement mode and they feel sense of achievement and sense of belonging. The operators may find these activities as extra work in the beginning, however they will find it interesting as they can show tremendous amount of ownership on their equipment and team. Autonomous maintenance demands team work and everything done in this area is all through team work.

Another important benefit which comes out of the autonomous maintenance is the early identification and diagnosis of abnormalities. These are the outcome of the inspection being carried out by the operators. This is the beginning of condition monitoring of equipment and as a result this leads to predictive maintenance. In the modern world this predictive maintenance technique has great value in continuous process industries.

Operators put themselves into learning mode and understand the functions, settings and centerlines of the equipment. They also learn to understand the machine at the component level and carry out autonomous inspection.

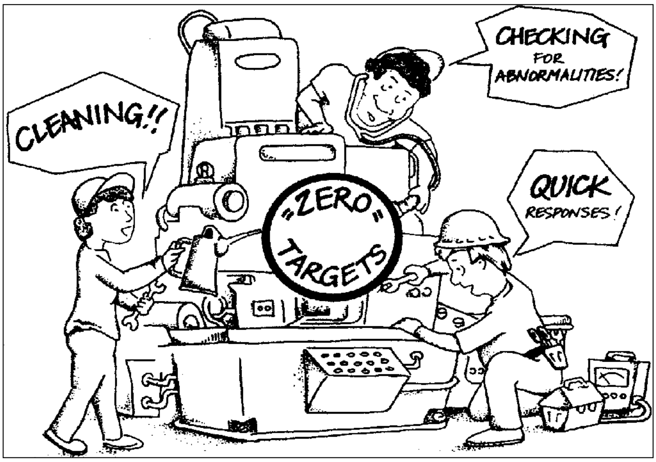


Fig. 8.3 Restoration activity

8.4.1 Aim of Autonomous Maintenance

The objective of autonomous maintenance or Jishu Hozen is to develop *highly skilled* production technicians and establish proper equipment conditions. This combination of equipment and people yields an orderly workplace that is: *effective* (zero losses/defects) and *efficient* (requires minimal effort).

Autonomous maintenance focuses on developing capability in people and equipment to last its design life by eliminating forced deterioration. This is done by the operating teams. Similarly and simultaneously, the maintenance team will look after the equipment by conducting preventive maintenance in order to reduce natural deterioration.

8.4.2 Theory of Deterioration Total Deterioration = Natural Deterioration + Forced Deterioration

While the natural deterioration part is looked after by the maintenance function, the operating teams will look after the equipment by eliminating forced deterioration and that enhances the life of the equipment. This is the key principle of autonomous maintenance (Jishu Hozen).

8.4.3 Seven Steps of Autonomous Maintenance

Step 1. Perform Initial Cleaning: Initial cleaning is different from just cleaning. The operating teams perform initial cleaning after many years and massive amount of cleaning is needed to render the equipment clean and orderly in all respects. At the same time they perform cleaning with meaning. That means they also identify all kinds of abnormalities in the equipment. These fall under different categories like normal abnormalities, sources of contamination and hard to reach areas. The abnormalities are identified by red tags and white tags and action plan is made to eliminate these abnormalities. They will also prepare tentative cleaning standards so that the team will just follow the standard method mentioned in the cleaning standard.

Step 2. Address Sources of Problems: In case you want to eliminate all the equipment abnormalities a list of all abnormalities like minor flaws, missing items, hard to reach areas, sources of contamination, unsafe conditions, sources of quality problems and unwanted items lying near the equipment should be put into a list. Then immediately the list has to be converted into an action plan so that enough resources are identified to complete the work on time. Normally, the correct step would be to start working on elimination of sources of contamination first since by adapting this method the machine will start appearing cleaner and then the other work becomes simple. This is done with seriousness as the objective is to eliminate all the abnormalities with permanent arrangements and not with temporary measures.

In order to do this the Jishu Hozen teams will need the help of maintenance function and the help of the manufacturing engineering or tool room. There will have to be so many Kaizens coming out and they need help actually to do fabrication and creation of these, to implement all those Kaizens. This is where an integration of various pillars of TPM come into picture.

Address all Chronic Problems: There are some problems coming up on a regular basis and mostly we are quite aware of such problems. These are simple in nature and action can be taken immediately. These type of problems are called "sporadic problems". However, there are some problems which have been there for a long period and some efforts must have been used to eliminate them. But they continue as the root cause is not so easy to find out. This is the time to address all the abnormalities including the chronic problems. The chronic problems do not allow the full capacity of the equipment to be utilized as there is some inherent problem.

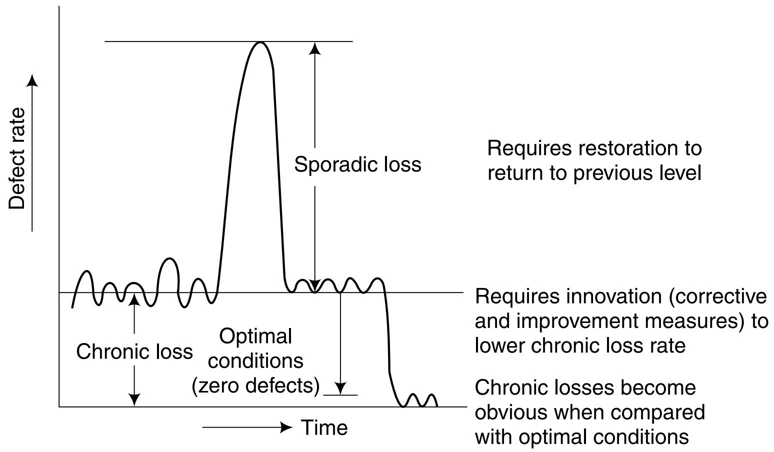


Fig. 8.4 Illustration of sporadic problem and chronic problem

There are various tools to analyze the chronic problems and go to the root cause. Just to name a few;

- Why-Why Analysis
- Fish Bone Analysis (Also known as Ishikawa analysis and cause and effect analysis)
- Work Point Analysis
- PM Analysis

How to use these tools to go to the root cause and how to eliminate these chronic problems shall be explained in detail in later chapters.

However, the chronic problems will have to be identified and analysis will have to be done by the team to eliminate it completely.

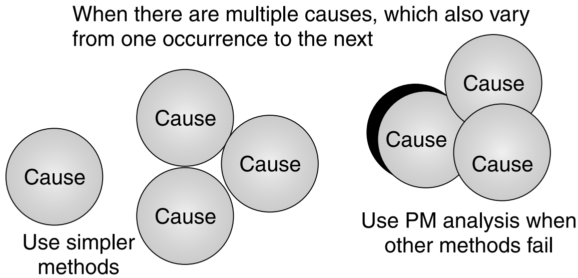


Fig. 8.5 When to use PM analysis

At the end of step 2 in Jishu Hozen a document called inspection standard shall be prepared by the team. This is a product expected at the end of step 2 after all the abnormalities are addressed.

There will be a training event at the end of the step 3 to the operators to understand and then carry out the Jishu Hozen activities.

Step 3. Establish Cleaning, Inspection and Lubrication Standards: The major activities in step 3 of autonomous maintenance (Jishu hozen) are a thorough study of the lubrication system of the particular equipment and preparing a lubrication standard. The lubrication standard is prepared in order to enable the operators to carry out inspection and replenishment if needed in the lubrication system.

As you are aware that the lubrication system is most important to reduce accelerated deterioration, in autonomous maintenance step 3 there is lot of emphasis given to the study of the lubrication system. This is done because most of the equipment have some deficiency in the lubrication system design or in actual lubrication implementation.

One important thing to be noted here is that the maintenance function is now handing over to the operating teams the responsibility of daily lubrication. However, the responsibility of the lubrication management will remain with the maintenance function. This means the responsibility of identifying the suitable lubricants for each application, organizing and storing the lubricants in proper conditions and in a easily identifiable manner. This would need the color coding and marking to identify the oils for each application.

Another most important thing the teams will do in the step 3 of autonomous maintenance is visual control. Visual control is playing a major role all over the world now and it has a major role to play here.

We believe in the philosophy that "every item in the shop floor has a particular place and it has to be in its place". In order to put this principle in practice we need to have identification to be carried out in the whole shop floor and of all equipment. Whenever teams are doing step 3 of autonomous maintenance, the teams will undertake this task in a meticulous way. All the inspection points to be highlighted and also to be identified by the type of inspection needed like look for vibrations, hearing abnormal sound, feel by the palm the heat and understand the parameters are within limits.

For this, we shall use color coding, attach stickers for visuals and identify each and every tool and gauge with identification number or name.

The examples of visuals generally used on the shop floor are shown in Figs. 8.6–8.15.

Fig. 8.6

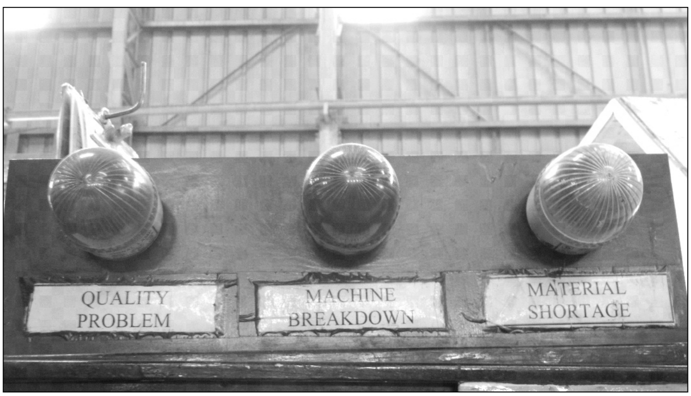


Fig. 8.7

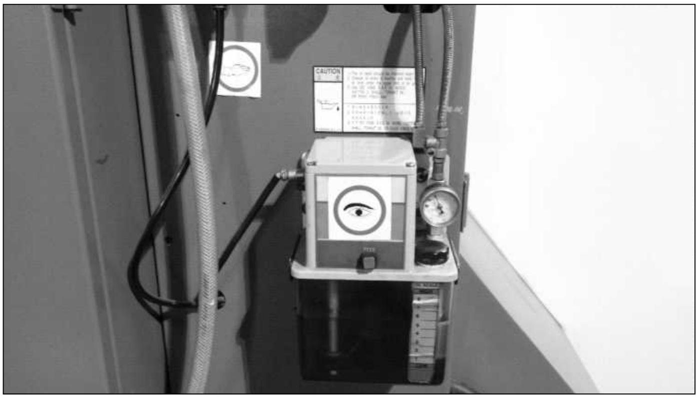


Fig. 8.8

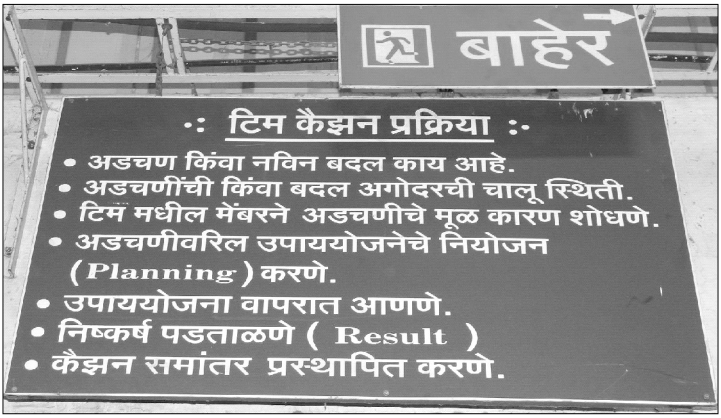


Fig. 8.9

Fig. 8.10

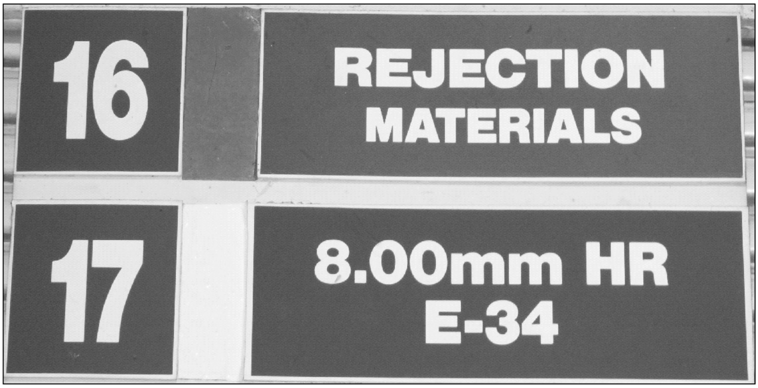


Fig. 8.11

Fig. 8.12

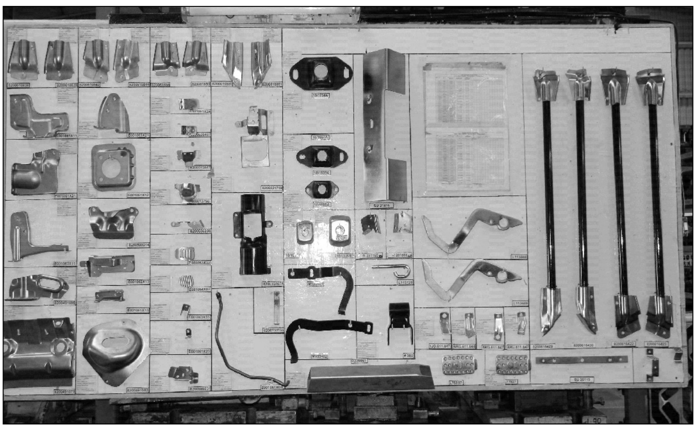


Fig. 8.13

Fig. 8.14

Fig. 8.15

At the end of step 3 here again a lubrication standard and tightening standard is expected as a product.

By then it is time for handing over the cleaning, inspection, lubrication and tightening standards to be implemented by the operators and so a training event will be conducted by the facilitators or with the help of maintenance personnel how to implement the standards. This activity is most important as sustenance of the achievements of autonomous maintenance entirely depends on how best these standards are being implemented. A sustenance audit could be a good idea to sustain the gains of Jishu Hozen. For this we need to create a "Jishu Hozen" sustenance audit sheet and conduct surprise audits periodically, but without announcement. This will put pressure on the operating teams and there are chances that they will maintain the equipment and surrounding as per standards all the time.

Jishu Hozen pillar has seven steps. We have now discussed about only steps 1, 2 and 3 here. We need a strong leadership support to take the Jishu Hozen to one level higher and take it to steps 4, 5, 6 and 7.

Step 4. Imparting technical training to operators: The step 4 in Jishu Hozen is a major effort and requires lot of resources. However, if done properly, this will give a major help to maintenance. This step is about improving technical knowledge of the operators so that they can inspect (condition monitoring) the equipment at component level and understand the condition of the component and predict failures. This will help a great deal in doing condition monitoring or measuring the deterioration so that action can be taken before the breakdown takes place.

This is capability building in operators and hence a thorough curriculum has to be drawn.

This curriculum will cover:

- Fasteners
- Power transmission from the power source to the work point
- Hydraulics and pneumatics.
- Electrical and electronic controls.

This effort takes two types of training approach.

1. *Generic Training:* A generic training is normally followed by a specific training. The generic training is given by a competent faculty on fasteners, power transmission, hydraulic and pneumatic circuits and then finally about electrical controls. This will bring theoretical knowledge on these topics. Then the practical training covering actually creating the hydraulic circuits, pneumatic circuits and electrical control circuits follows. This training is generally given to a small group of people who can potentially become trainers. There will be a qualifying test at the end to check the effectiveness of the training. Those who are qualified will be eligible to become potential trainers.

The potential trainers are then given the responsibility to train in one area each. So we will have at least five trainers from this group. You can always have a back-up person for one subject or area.

2. *Specific Training:* Then the specific training event will start. The specific training is given to the operators on their specific equipment. What the trainer has learned in the generic training will be very useful here. But the training module is not directly used here, since it is based on the technology used in that equipment and what components are important. So a specific training module is made for each type of equipment separately. The trainer shall take the operators through the important components, the theory behind each inspection activity needed and how

to set them correctly in order to get the best quality. However, when the operator gets this capability, he will need help to introduce more specific points into his earlier tentative inspection standard and make it more suitable for the present inspection capability level.

What do we get by doing all these activities? The workload on the maintenance gets reduced and it becomes more autonomous, in the sense the operator will start doing this inspection (condition monitoring) which is a big help to the maintenance. Furthermore, the operator gets the training on full inspection skill and will become capable to do that. Autonomous maintenance step 4 is a very important milestone in achieving zero breakdowns especially in continuous process industries where time is not available for doing maintenance.

Step 5. Systematize Autonomous Maintenance: The completion of the step 4 activities leads to the step 5. The inspection activity done by the operators goes to the component level and all the check points at component level are identified, included in the autonomous inspection standard and implemented meticulously. In petrochemical, fertilizer and some continuous process industries there is an inspection department which is very competent in carrying out the inspection while the equipment is running and using sophisticated diagnostic tools. This is needed as the plant cannot be stopped for maintenance very frequently. The shutdowns are taken to do maintenance, but that will have to be planned once a year or so. So this inspection department does the inspection so that the condition of the equipment is measured and this information can be used to plan the shutdown. Here in Jishu Hozen step 5, the inspection is carried out by the operators using their six senses and minimum diagnostic tools.

Step 6. Address Product Quality and Standardization: This step is about resolving any quality rejections on the equipment after all the effort from Jishu Hozen steps 1, 2 and 3 and also steps 4 and 5. These problems are generally chronic in nature and are very difficult to understand. Here the quality pillar shall intervene and using special tools like work point analysis and PM analysis the quality problems are totally eradicated. This also needs help from the maintenance. The quality pillar members are like specialist doctors and after they resolve the problems, some controls need to be put in place. The maintenance department and the operating department will be doing that kind of inspection to make sure that drift is not taking place in the contributing factors and standard values are maintained.

Step 7. Practice Full Autonomous Maintenance: The Jishu Hozen effort comes to maturity only at this step after taking the equipment to zero breakdown, zero quality rejection and zero accident situation. Now is the time to introduce some sustenance measures and conduct surprise audits. The operators are continuously doing CILT activities, conducting specialized inspection at component level and conducting inspection to see that the drift is not taking place in some of the control points. If this is implemented the Jishu Hozen will continue to deliver the results expected.

8.5 OPPORTUNISTIC MAINTENANCE OR "IF DOWN DO"

As the name indicates this is called "opportunistic maintenance" or in the US they call it "If Down Do". That means if there is a shutdown on the equipment, production line, the assembly line or a production cell then that opportunity is utilized to carry out certain maintenance activity. Generally, we do such a thing everywhere. Who would like to lose an opportunity as otherwise such a time is not available in the plant. However, the general situation is that we are not prepared for such an event and we waste a lot of time in getting ready. This is a very valuable time and if we are prepared by all means then we can use the time fully and get maximum benefit from this. That is the reason it is called opportunistic maintenance.

How do we get ready? In the anticipation of such an opportunity we prepare for a maintenance activity. Do you watch car racing? Have you seen a video on "Pit Stop"? What happens in a Pit Stop?

8.5.1 Roles and Responsibilities

There are persons to attend designated work and each person focuses on just his or her work. That means their roles and responsibility are clear.

There is team work. That means there is a team, there is a team leader and there are other members. Each member's role is clearly identified and then practiced.

8.5.2 Skill Training

They have been trained in the particular skill and they have demonstrated their skills many times earlier. They do not waste time looking at others or advising others. There is no need to do that as the team works in perfect synchronization. The time is of essence and everybody knows that.

8.5.3 Tools and Tackles

The tools and tackles used by them are the best tools and they have been using them and feel comfortable with them. Of course, the tools are designed to suit the vehicle and there has been a lot of design effort (research) on these tools. The tools are in perfect working condition.

8.5.4 Perfection

There is perfection in the work. That means there is no chance for any mistake or rework. They have practiced this many times earlier.

This is the philosophy of "Pit Stop". So what do we learn from here. In opportunistic maintenance we need to learn these principles.

8.5.5 Prepare a Time Chart

The preventive maintenance activities identified on the equipment shall be prepared with a time line. That means the PM activity shall be prepared with time line assuming that we will not get opportunity to do the complete work in one opportunity.

For example;

For half hour shutdown or opportunity: Make a list of the important PM work which is needed on the equipment.

For one hour shutdown or opportunity: Make a list of PM activities which can be completed in one hour.

For two hours shutdown or opportunity: Make a list of PM activities which can be completed in two hours.

This is the way, first the amount of work required and how can we accomplish the work depending on the time available to us. If we leave it to chance each person carrying out the PM work will do it differently and the time may not be best utilized or the important work may be left behind. This is the reason a very well planned list should be prepared and be available near the equipment all the time as we do not know exactly when such an opportunity comes. It may come in the general shift or for that matter in any other shift. Complete readiness is needed.

8.5.6 Identify the Work Required Now Clearly

We talked about PM activity in the earlier example. But sometimes a certain part to be replaced or opening a part and checking is needed. It may be different from the PM activities. In such cases, get the spare parts needed beforehand and keep it near the equipment. Leave instructions as to what work is to be accomplished. Identify for which shift the shutdown is planned and who is expected to do the work.

8.5.7 Identify the List of Work to be Done and which Time Chart to be Selected

There are different time charts—half hour chart, one hour chart, two hour chart, etc. At this point of time, select the time chart and identify work to be done. Since we need to use all the time available, discipline has to be exercised.

8.5.8 Identify the Resources Needed and Ask for Those Resources Beforehand

Also resources needed are required to be in place before starting the work. Any parallel activities to be carried out to save time, by using additional resources.

Sometimes the work cannot be accomplished by one person and so ask for resources needed in advance and get them at the correct time.

8.5.9 Completion of Planned Activity Before the Shutdown Time

Again complete all the work planned and hand over before the shutdown time is over.

If the opportunity is utilized by using these tips, then maximum amount of work can be done and it can be the best way to save the equipment time. In continuous process industries this method is extensively used as the shutdown for PM work may be an expensive way.

There are plants which are doing it much better than others. In such plants you will see a stainless steel trolley carrying instructions and all the spare parts and consumables are kept on the trolley. The person who is going to do such work is also identified. With this kind of method you can plan "If Down Do" and carry out such activities. The success rate is very high if you follow this method consciously.

8.6 PREDICTIVE MAINTENANCE (CONDITION BASED MAINTENANCE)

We have briefly discussed about this topic when we started with preventive maintenance. Preventive maintenance has two specific areas; Time Based Maintenance (TBM) and Condition Based Maintenance (CBM). In the earlier chapter we have discussed about time based maintenance. Let us now discuss about condition based maintenance in more detail. Condition based maintenance is also called predictive maintenance. In fact one leads to the other. If you have assessed the condition of the equipment, by your experience you may be able to predict the remaining life of the equipment or its components. In case you have very scientific method to measure the condition by using accurate instrumentation, then it is possible to predict the remaining life of the component more efficiently. This is the technology of predictive maintenance. In continuous process industries since the equipment cannot be stopped for time based maintenance, it is essential to inspect the condition-by-condition monitoring technology and decide how long it can run before the breakdown can occur. By this methodology, in many cases, you may be able to establish the life of a component accurately and the time period may be longer than established in time based maintenance.

There are two distinct advantages of condition based maintenance.

1. The condition monitoring technology allows us to assess the condition of the equipment or component while the equipment is running and so no downtime is needed.
2. We may be able to establish longer replacement period of spares depending on the condition and gain advantage of longer life to save maintenance costs.

Due to these advantages CBM is becoming more popular especially in continuous process industries, petrochemicals, fertilizers, etc.

Let us now discuss as to how the condition of the equipment or component can be assessed more timely and accurately.

8.6.1 Condition Monitoring Done by the Operator

We have seen in the autonomous maintenance (Jishu Hozen) that operator conducts inspection of equipment as a part of cleaning, inspection, lubrication and tightening (CILT). Furthermore, we have seen in step 4 he or she does general inspection by understanding the components, their function, their condition and settings. That is why the importance is given to general inspection so that the operator is capable of understanding the condition of the equipment at component level. This is the first level of condition monitoring. If trained well, the operator can also predict how long it can run before it fails or breaks down. This is used to carry out maintenance on time and avoid breakdown or stoppages.

8.6.2 Condition Monitoring Done Using Diagnostic Tools

This is normally done by experts in that area. That means the condition monitoring is done using sophisticated tools and by the people who have been trained or are experts. In some continuous process industries there is a department called inspection department which is specifically introduced in the organization for this purpose. These people are capable of using diagnostic tools and come out with exact or more accurate condition reporting and then naturally are capable of predicting the life of those components or equipment. This information is then used to plan the maintenance activities by taking a shutdown or if they can wait until next official shutdown. This not only brings the work content of maintenance function down but also reduces costs.

Let us now discuss some of the diagnostic tools and their applications.

8.6.2.1 Vibration Monitoring and Analysis

This technology or instrument is used to measure the bearing wear, an unbalanced condition, or other alignment problems in rotating machinery. Vibration sensors can detect loose or cracked support mounts, or support pads, bent or cracked shafts and problems in coupling if any. There is a particular software which detects vibrations and trending of vibration levels.

This instrument and the use of it can be learned, but however if you need a professional report you may even hire the experts who cannot only give a report about the trend but also predict the time frame how much can it run before it fails. This will give time for the people to plan the activities of shutdown. As mentioned earlier the vibration monitoring is needed to identify the areas from where the real vibrations are developed. It can be from the bearing wear, or it may be from the rotor where the tip of the blade might be chipped off or the dynamic balancing is disturbed. It could also be from the loose foundation bolts. It can also happen from the coupling. This tool pinpoints the reason, the magnitude and how long it can run before it fails.

8.6.2.2 Acoustic Monitoring

This application is used to detect internal and external leaks in all types of valves such as motor operated valves, air operated valves, manually operated valves and check valves. In butterfly valves the leaks take place by or through a butterfly. In diaphragm valves it can happen by or through the diaphragm, or other internal parts of the valves. This instrument detects leaks in all types of valves and it can also detect leaks through the tubes in heat exchangers due to cracks in the tubes.

8.6.2.3 Thermography or Infra-red Scanning

This is a very commonly used technique for detecting "hot spots" by using an infrared camera. Mainly in the electrical control or power panels where a particular component like a contactor or a lug in the termination, or any other part due to the connection has become loose or the contact is not proper. This can also detect any parameter that may be running hotter than it is expected to run like motor windings or relay coils.

An infrared torch which is carried to the places where you would like to do monitoring and when the torch is directed to the hidden hot spot it gives audio and visual indications. So the scanning is done by the torch.

8.6.2.4 Oil Sampling and Analysis

This is a very common technique to detect incipient bearing or internal gear failure. Generally, an oil sample is used to detect bearing wear or gear meshing problem. The metal particles normally go to the bottom of the oil sump and a small portion of the oil is drained from the bottom of the sump. Then the oil sample is subjected to laboratory test for any metal particles. This application is also known as ferrography. If there are metal particles it is obvious that there is some wear taking place.

8.6.2.5 X- Ray or Radiography Inspection

This application uses X-rays to detect subsurface flaws or defects in welds, welding joints or metallic parts such as castings or valve bodies. This is hard X-ray and so care must be taken to see that the operating personnel do not get harmed by it.

8.6.2.6 Magnetic Particle Inspection

This technology detects surface cracks in metallic parts by setting up a magnetic field around the part to be inspected. This is done for the parts which are subjected to heat treatment or castings.

8.6.2.7 Eddy Current Testing

Eddy current testing is also a similar technology. In this case it produces a magnetic field and an eddy current flow to detect surface flaws.

8.6.2.8 Ultrasonic Testing

This method also detects flaws in metallic parts. It uses sound waves to detect flaws. This technology is also used to measure the thickness of the metal bodies like boiler plates, pressure vessels, etc. This will show the flaw or the current level of thickness of an eroded part.

8.6.2.9 Liquid Penetrant Test

This technology uses a dye to detect surface cracks in pipes, welds, shafts and metal parts. The dye is applied to the part under inspection at the spot of inspection or in some cases all over the body of the part after thoroughly cleaning the surface of the part for dirt removal. The dye is viewed under ultraviolet light and the crack becomes visible where the dye is absorbed in the crack.

8.6.2.10 Motor Current Signature Analysis

This technique detects problems with motors such as cracked rotor bars and some motor winding problems. A clamp-on probe analyzes motor current traces.

8.6.2.11 Boroscope Inspection

This technique uses a boroscope to visually inspect internal parts of an equipment that cannot be normally inspected externally. There must be entry points for the boroscope to enter and then only it is possible to insert the boroscope and carry out internal inspection. This technology is largely used for big metallic parts like large valves and turbines.

8.6.2.12 Diagnostics for Motor Operated Valves

This is also called MOVATS. This tool or application normally has a set of equipment that recognizes a pattern signature of the valve to measure a number of readings. These include motor current, torque switch settings, stem thrust, switch actuation, and the electrical condition of the motor.

8.6.2.13 Diagnostics for Air Operated Valves

There is a test box which comes with it. This diagnostic test box is used to detect diaphragm leakage, air operated solenoid problems, and other internal problems that arise with air operated valves.

Many of the tools mentioned above are used in conjunction with other predictive maintenance tasks. For example, oil sampling and analysis, vibration monitoring, and thermography, may all be employed on the same component. This kind of combination of several predictive techniques will usually detect an incipient failure where using only one predictive maintenance technique mentioned herein may not be able to detect. New techniques are developed every day and are being used as a cutting edge technology. Instead of using these techniques only sometimes, it is advantageous to use them for continuous monitoring which has greater potential in detecting incipient problems.

8.7 RELIABILITY CENTERED MAINTENANCE (RCM)

8.7.1 Origin of RCM

We are right now learning about various pillars of maintenance technology and also which one is applied where and what are the pros and cons of applying each one of them. Even though there is no one answer to the issues, in some areas there were problems of a different kind; especially where the plant and equipment run 24 hrs per day and seven days a week. These are continuous process industries like fertilizer plants, petrochemical plants, atomic power generating units, etc. How do you find time to do preventive maintenance or even condition based maintenance? A time came when these issues became larger and there was a need to find a solution to this issue. So, annual maintenance shutdown came as the answer. But, in some of the processes the ramp-down time and the ramp-up time are so huge, several months would go in these ramping down and ramping up activities. Obviously, a better solution was required. That means without stopping the plant the maintenance has to be carried out. This includes assessing the condition of the equipment or components by using diagnostic tools while they are running. So, immediately a thought arose in the minds of engineers that all equipment in the plant are not treated as same, but a kind of classification is needed. This will allow us to apply different strategies to different equipment depending on the location and utilization for the process. At the same time safety of the plant and reliability of the plant became important.

This is the time reliability centered maintenance (RCM) came into being. Initially, the leaders in RCM themselves were not clear about some issues and a lot of confusion was prevailing. Slowly the confusion started reducing and a more clear picture started emerging.

An organization called airline maintenance steering group (MSG) was present right from 1960s. There were two engineers in USA named Stanley Nowlan and Howard Heap of United Airlines who introduced formal RCM. MSG was introduced in the commercial aviation industry in 1978. A book called *Reliability Centered Maintenance* was also published in 1978. In fact, this is the origin of reliability centered maintenance.

We all have heard about preventive maintenance. However, out of all the equipment which equipment need preventive maintenance? RCM is a logical way of identifying what equipment in your facility is required to be maintained on preventive maintenance basis rather than allow it to breakdown and then treat it like any breakdown and then fix it. This method is also called run-to-failure (RTF). A reliability centered maintenance approach to preventive maintenance is probably the best path to get closer to 100% reliability levels. The factor called economical way of doing RCM came into the picture.

So, what is reliability centered maintenance? A set of tasks generated on the basis of a systematic evaluation and that systematic evaluation is used to carry out a set of tasks to improve safety and reliability. This is to enrich the maintenance program and get safety and reliability. RCM incorporates decision logic to ascertain the safety and reliability. This includes decision logic to ensure operational consequences of failures and identify the factors responsible for those failures in detail.

8.7.2 Background of RCM

In the early years of commercial jet aviation a concept called overhauling did exist. The manufacturers of aircraft and individual airlines who are operating it, believed that if an aircraft was overhauled at a given time interval it is good enough. Overhauling would mean the aircraft shall be completely torn apart system by system, component by component and parts were replaced.

Even after doing that the expected levels of reliability were not being achieved. Then they thought of increasing the frequency or decreasing the periodicity and the aircraft will remain in the hangar for many days or even months. They found out that overhauling equipment actually did not help. In fact overhauling had reverse effect on reliability.

The probability of failure of newly replaced components increased due to premature failures and infant mortality. The truth came to light immediately after that. They also found out that about 11% of all components exhibited a wearout rate based on time; which means those components come under "time based preventive maintenance". That means that 89% of all the components failed randomly. This particular concept brought in a change in the field of maintenance and especially in the area of "time based overhauls". So, the scheduled overhauls did not solve the problem and were counterproductive for this problem.

They found out that a maintenance program cannot correct deficiencies in the inherent levels of safety and reliability (which is due to design). It can only prevent further deterioration of the inherent levels. A design modification may be necessary to obtain further improvement. This is the reason they came out with reliability centered maintenance and key thing is that this program shall be a "living program". Some new failure modes may become apparent and to make it dynamic the "periodicity of preventive maintenance" may have to be increased or decreased.

This is the time an effective RCM process emerged and that allowed the preventive maintenance program to evolve from a level based on the following:

- Recommendations given by equipment vendor
- Random selection
- More effective fundamentals like a component functional analysis.
- Any subsequent safety or operational consequences to the plant as a result of the component failure.

This will give a confidence that only those tasks that are specifically required for the safe, reliable and efficient operation of the plant are being carried out and unnecessary work is eliminated.

8.7.3 RCM as Asset Reliability Strategy

A good reliability centered maintenance program enhances bottomline (profit) from the business, improves reliability of the plant and equipment, minimizes unplanned production delays, maintains generation capacity, ensures personnel and plant safety and finally prevents any regulatory or environmental issues. RCM approach is the main thing for identifying equipment functions that must be preserved to protect plant assets and ensure uninterrupted working and revenues to flow continuously.

However, in some cases RCM has failed to deliver the results expected by the management on safety and reliability. But on the other hand, it increased the maintenance work content and the cost of maintenance.

So, why does RCM fail? Loss of in-house control takes place as the entire RCM analysis has been given to an outside agency or consultants. This aspect leads to the managers of the company taking it lightly. Also in many cases despite having internal RCM team, a correct mix of people with proper knowledge and background from different areas of the plant or discipline are not in the analysis team. Many a times the analysis has gone into such details and the planned maintenance tasks selected are unnecessary. It becomes an expensive program and half way through, many plants have given up the effort.

RCM is a very essential and interesting program. However, in some cases the consultants have not guided the people properly and so the fundamental RCM concepts not understood by the people in the plant. Similarly, there can be confusion in determining system functions and confusion concerning system boundaries and interfaces.

Furthermore, in the top management itself there were different expectations. This is detrimental to the healthy implementation of RCM. Similarly, there can be confusion regarding conventions used in RCM. In some cases even the consultants were confused or did not know about the hidden failures and redundancy and misunderstanding about run-to-failure. Despite having a competent team of people, the component classification was not done properly. And in some cases instruments were not included as part of RCM analysis. All these reasons and many more make the RCM program become a white elephant and a failure.

8.7.4 Three Phases of RCM

The first phase: This is to identify the equipment that is important to plant safety, generation (or production) and asset protection. These require RCM based preventive maintenance.

The second phase: This is to specify the different types of preventive maintenance activities and tasks including predictive maintenance techniques that need to be performed on the identified equipment.

The third phase: This is to ensure that the preventive maintenance tasks that were specified are properly executed in a timely manner.

8.7.5 Three Important Aspects in RCM

1. Know when a single-failure analysis is acceptable and when it is not.
2. Know how to identify hidden failures.
3. Know when a multiple-failure analysis is required.

8.7.5.1 Single Failure Analysis

RCM is basically a single failure analysis. When the single failure is hidden, RCM becomes a multiple failure analysis.

8.7.5.2 Hidden Failures

When a component is required to perform its function and the occurrence of the failure is not evident to the operating personnel (means the immediate overall operation of the system remains unaffected in either normal or demand mode of the operation) then the failure is defined as hidden failure. Addressing hidden failures is one of the key aspects for attaining plant reliability.

8.7.5.3 Multiple Failure Analysis

A multiple failure analysis is required when the occurrence of a single failure is hidden.

8.7.5.4 Single Failure Analysis

See Fig. 8.16.

If the pump P1 fails, the loss of that function will be evident in two ways. One, it indicates in the control room as the instrumentation has been provided and then the diesel will not be available to run the DG set when the power fails. This is a very significant consequence. Appropriate PM task would be required to ensure the reliability of the pump.

This is a typical single failure where the failure is evident and causes an immediate unwanted consequence. The component would therefore be classified as *critical component*.

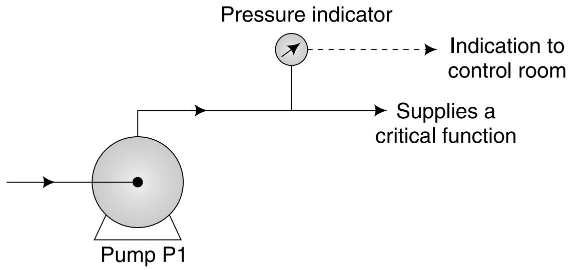


Fig. 8.16

8.7.5.5 Multiple Failure Analysis

In addition to the pump P1, another pump P2 was installed to provide 100% capacity so that either one had capability to start the DG set as shown in Fig. 8.17.

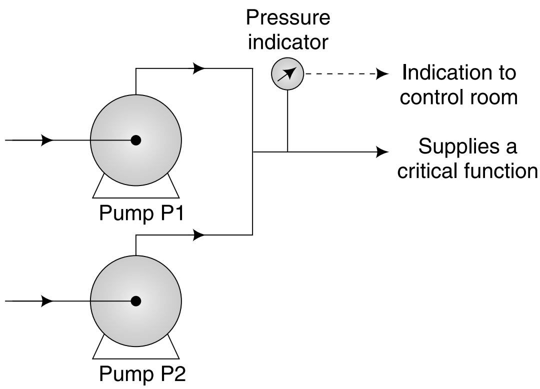


Fig. 8.17

Refer Fig. 8.17. Both pumps are operating and either pump can supply the function by itself. Downstream on the diesel pipe line a pressure indicator mechanism to give alarm in the control room was installed.

If one pump fails it is hidden since the control room indication is down below on common pipeline.

This is an example of multiple failure analysis. If pump P1 (or pump P2) fails it will not be evident, and will not have an immediate unwanted consequence of failure.

If pump P1 fails, is the failure is noticed by the operator or becomes evident by any means? No. Since both pumps are running, there is no indication of any one pump failing. Pump P2 is pumping the diesel to DG set and the failure of pump P1 remains hidden until pump P2 fails.

There are two redundant pumps. The redundancy feature has been included here by the designer of the layout plan but unfortunately it has been negated here in this situation. The DG set is now at the mercy of a single failure of pump P2 since pump P1 has failed earlier and not known.

Failure of pump P1 is a hidden failure! Therefore single failure analysis is not acceptable in this situation. A multiple failure analysis is required.

The failed pump is a potentially critical component. Here, both pumps are potentially critical components.

To analyze the consequence of hidden failure of pump P1 requires us to look at what additional failures together with the failure of pump P1 could result in an unwanted consequence to the plant. That is the reason it requires multiple failure analysis. Pump P1 remains in a "sleeper cell" mode.

Therefore, pump P1 is a potentially critical component.

Similarly, pump P2 is also a potentially critical component

Figure 8.18 shows a slight difference. Somebody has installed an indicator for each pump. Each pump has its own indication instrument monitored by the operator. If any pump fails, indication is given to the control room and immediately corrective maintenance attends the breakdown.

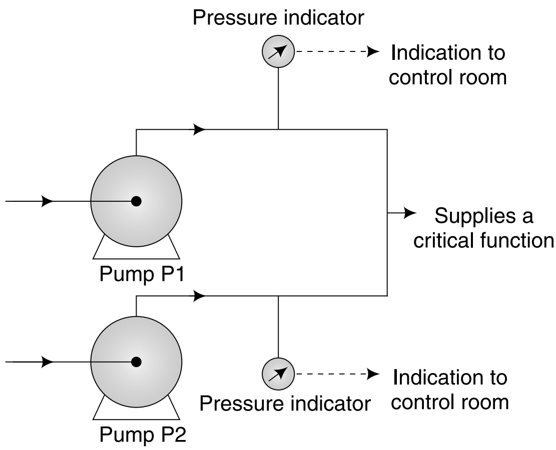


Fig. 8.18

8.7.5.6 Run-to-Failure

Both pumps are under a different classification called run-to-failure. They are not critical components.

8.7.5.7 Critical Component

Refer Fig. 8.19. Now you will see a different situation. Just watch the fun. See the pump P2 is a back-up pump for the pump P1. That means pump P2 will come into action only when the pump P1 fails. Now pump P2 becomes a critical component, because if it does not function when normally operated pump P1 fails, then there will be an unwanted consequence of failure. Since both pumps can be a back-up for each other both are critical components.

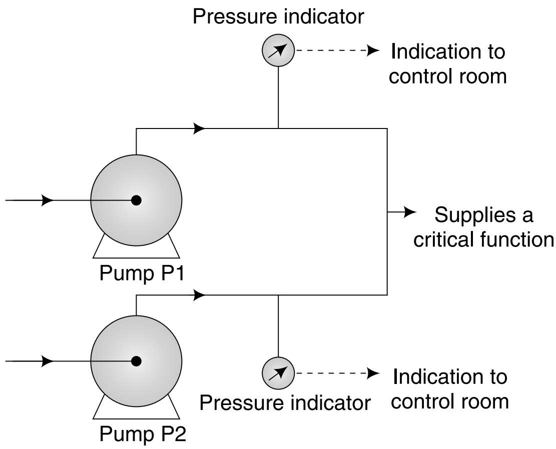


Fig. 8.19

8.7.5.8 Potentially Critical

Hidden failures are often failures of one or more components in a parallel design with no indication of failure for each individual component. In Fig. 8.20a, there is only one pressure indicator downstream of both the pumps. Since each pump is designed for 100% capacity the indication will not come. Even on a monthly checkup of DG set still it will not indicate as the second pump is available which pumps equally well and the failure of first pump remains hidden. That is the reason the pump P1 is potentially a critical component. Similarly, pump P2 is also a potentially critical component.

Therefore, addressing potentially critical failure mode is a key aspect in successfully achieving plant reliability. A PM task is required to address these potentially critical components to prevent the failures. What is the simple PM task in this situation? Just have rotation of the pumps every week. When you check each pump singularly you may then know if any one pump has failed.

Both pumps P1 and P2 are operating but only one pump is required to supply the function and the other pump fails, that failure is hidden.

Therefore, the failed pump is a "potentially critical" component. Since any one of them can fail first they both come under the classification of "potentially critical".

Refer Fig. 8.20b. If both pumps are operating but only one pump is required to supply the function, and the other pump fails that failure is not hidden. If there are no other considerations these pumps are "run-to-failure" components.

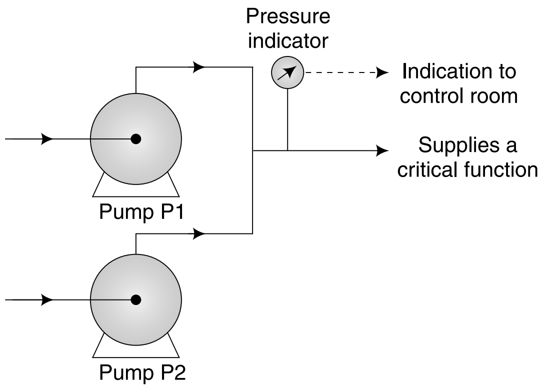


Fig. 8.20a

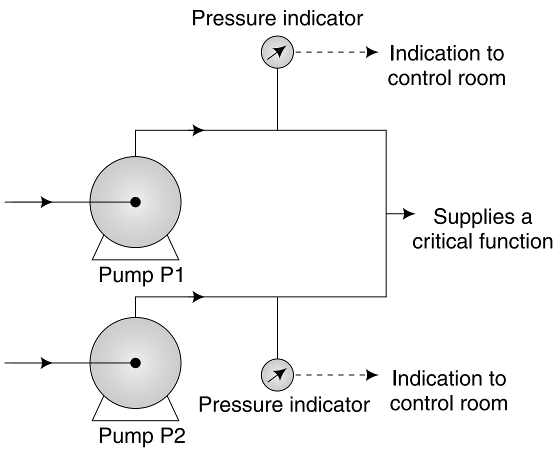


Fig. 8.20b

Refer Fig. 8.20c. If both pumps are required to be operating at a given time to supply the function and either one of them fails, that is "critical" component. Similarly, the other pump can also fail both are "critical".

Refer Fig. 8.20d. If only one pump is operating, and the other is functioning in a back-up capacity, if the operating pump fails, the back-up pump is a "critical" component. Same is true with the other pump, so both are considered "critical".

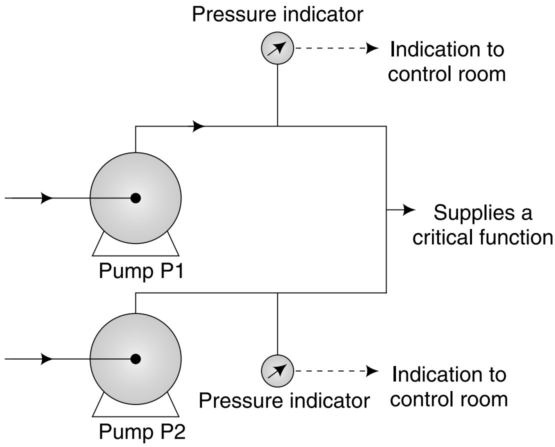


Fig. 8.20c

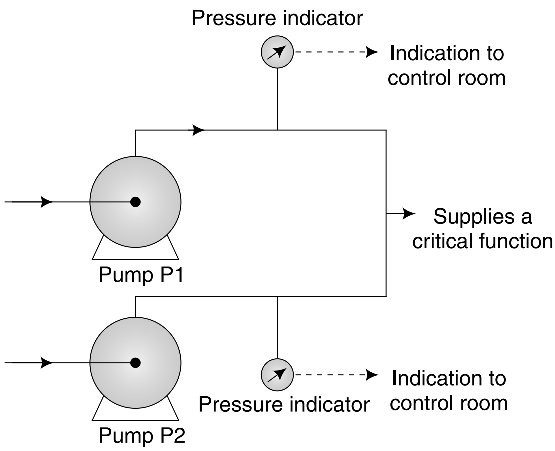


Fig. 8.20d

8.7.5.9 Failure Finding Task

You have seen earlier even though there were two redundant pumps, that in itself did not qualify for these two pumps to be non critical, run-to-failure components hence, any preventive maintenance strategy is not needed. A failure finding task at the component level (not at the system or subsystem level) would be required at a minimum. You can take care of this by adding one more task to the PM list to be done at the component level. If the operator goes near the pumps and listens to the sound for both pumps, it is good enough. The PM task can be that simple. Very high level of understanding and vigilance is needed. This has to be included in the PM list.

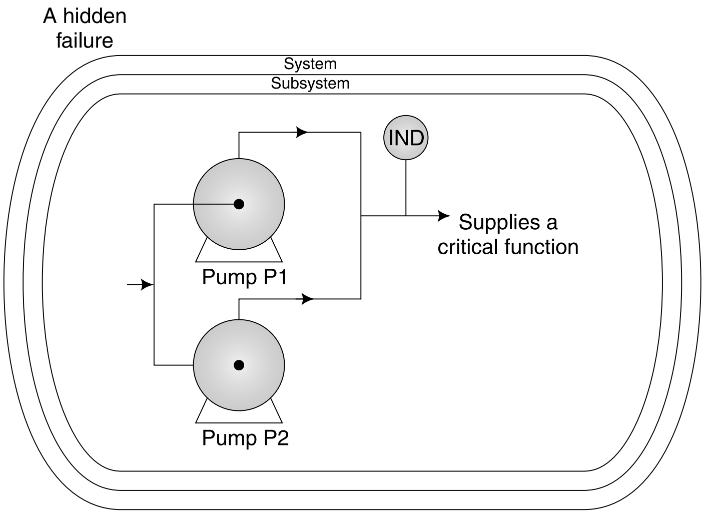


Fig. 8.21

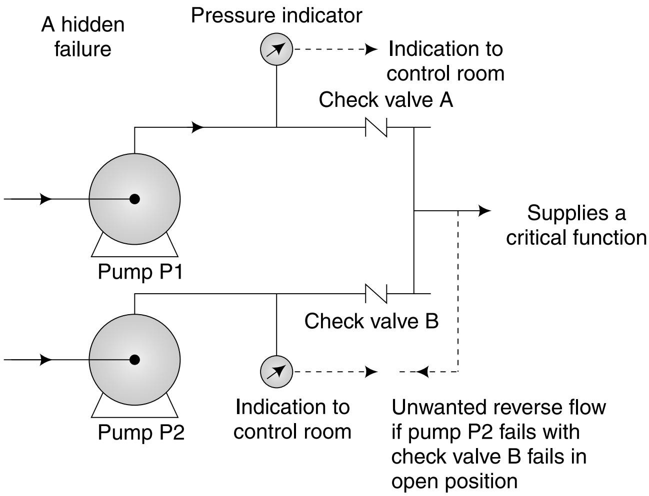


Fig. 8.22

During normal operation, pumps P1 and P2 are both running together and supplying a critical function (Fig. 8.22). Check valves A and B have been provided after each pump's pressure sensor. If the check valve B fails, open with both pumps running:

Nothing happens if the check valve is stuck in the open position. But it is not evident.

Therefore, a multiple-failure analysis is required to see what consequence could occur if some other component failed when the check valve B remains failed in open position.

If the pump P2 fails now what happens. Since the check valve B is stuck in open position a reverse flow will start. So check valve B is potentially critical and since either check valves can fail both are potentially critical.

What about the pumps P1 and P2. Since there is an indication of failure of any one of them and in the absence of any safety, operational or economic concern, both are run-to-failure components.

8.7.5.10 Testing Hidden Systems

In Fig. 8.22 you, actually, we see a hidden failure within a hidden subsystem within a hidden system. The entire system is the DG set, which is a hidden standby system. The subsystem is the fuel oil feed system which is a hidden subsystem of the DG set. The hidden failure mode within the subsystem is the fuel oil pump. In such a system one would normally say that the whole system is a hidden system and that is it.

Just look at the interesting part of analysis here. For making the analysis meaningful any normally non-operational system, such as fire protection, emergency or auxiliary power, emergency feed water, automatic shutdown features, or any other emergency standby systems that do not normally operate must be analyzed in its demand mode of operation, just as if it was running though that demand mode was its normal operating mode.

While testing a system like this by doing a PM task, for example, testing the system once in a month or quarterly is not enough. PM task to test each pump individually and verify its operability would be required. It is an accepted practice to test an entire hidden system once per month or per quarter and validate it as 100% reliable and ready for operation in the emergency demand everything perfectly. This is called failure finding task.

Failure finding task is a valid type of preventive maintenance strategy; but it should not be an alternative for internally analyzing the entire hidden system. The failure finding task alone will not reveal the potentially critical "sleeper cell" modes of failure at the component level.

8.7.5.11 Potentially Critical Component

A potentially critical component is one whose immediate failure is not evident and is not immediately critical, but has the potential to become critical, either with duration of time or with an additional failure at which time the consequence of failure may become quite evident. Potentially, a critical component can be thought of as sleeper cell waiting to bring havoc on your facility.

1. **When two or more components** (valves, pumps, motors etc.) operate to supply a function that each can fulfill individually, and there is no indication of failure individually then failure of one of the components remains hidden. However, should a second component fail or if some other failure takes place then a consequence will occur. Hence, the component is considered to be potentially critical.
2. **Potentially critical components as a result of time:** Like a filter screen in air-conditioning system which can get clogged over time. This does not need a second failure, but the clog slowly develops and a plant consequence can take place. This component is also called potentially critical.

A potentially critical component could become critical and so it must be avoided either by preventive maintenance strategy or redesign.

8.7.5.12 Commitment Components

Commitment component is a part of preventive maintenance strategy to ensure that nothing is overlooked in the analysis.

What are commitments? Commitments are obligations which need to be fulfilled and they are almost mandatory like:

- Safety requirements
- Health administration fulfillments
- Insurance requirements
- Regulatory requirements
- Environmental obligations
- Occupational requirements

It is a preventive maintenance strategy to prevent a component from failing and causing commitment to be missed. A commitment component can also be classified as either critical or potentially critical because of its importance. During the analysis however you can find out that many components that were earlier required to be maintained by PM because of commitments, but later classified as run-to-failure components. However, since they are commitment components, we need to check back with the authorities if they can be treated as RTF.

8.7.5.13 Economic Components

An economic component is one having an economic consequence only. Failures of economic components have no effects on plant safety or operability. Economic failures will result spending more money for labor or parts.

If a failure occurs to a component with an economic consequence but failure also results in effect on plant safety, operation or production, it will be then treated as critical or potentially critical component. If you are in a tight situation where you have to prioritize the PM work you may defer the one with economic consequence only.

8.7.5.14 Run-to-Failure

A run-to-failure component is designated as such because it is understood to have no safety, operational, commitment, or economic consequences as a result of a single failure. Also the failure must be evident to operations personnel**.** As a result there is no proactive preventive maintenance strategy to prevent failures. However, having once failed, an RTF designated component does have a proactive corrective maintenance strategy similar to all other components.

Here, corrective maintenance has a different connotation compared to what we have discussed in the 9 pillars of maintenance management. Here, corrective maintenance means breakdown maintenance or just a repair is needed and to be completed.

Traditionally, run-to-failure means PM is not required prior to failure. But corrective maintenance is required in a timely manner after failure. This does not mean that RTF component is not important. Only that PM program is not needed but corrective maintenance is surely needed on timely basis. So it is important. It is like if you have a punctured tire, replace it but if the flat tire is kept in the trunk without rectifying the defect, it can become important at any given time.

Another important assumption here is that only one component fails at a given time. Two component failures do not take place at the same time. If we made such an assumption that two or more components can fail simultaneously then everything would be critical.

8.7.5.15 Integration of Preventive and Corrective Maintenance

Preventive maintenance is a strategy to prevent component failure before the failure takes place. Corrective maintenance is a strategy to fix components once they have failed. After a component has failed whether the component was governed by PM or RTF, it is prioritized for corrective maintenance with an equivalent relative importance. This prioritizing is decision making at that time depending on the plant condition and availability of resources; but has to be fixed before another failure takes place.

8.7.6 Story of Three Over-speed Protection Devices

At a major power generating station there was a steam driven main turbine. There were many safety devices in the system. We are now talking about the three protective over-speed devices to ensure that triple redundancy was available. Despite such a situation the turbine went into an uncontrolled over-speed and caused a great damage.

The three over-speed devices (Fig. 8.23) were in parallel and the inspection was carried out regularly. That means checking was done only from points A to B. That means they are not installed serially but they were installed parallelly. One device had failed earlier and it was not noticed as individually they were not checked. The second one also had failed recently but again not noticed. The triple redundancy became single failure vulnerability. The third one finally failed and over-speed running took place. The PM did not have PM task to check the three over-speed devices individually. So they used to check the three in parallel from points A to B.

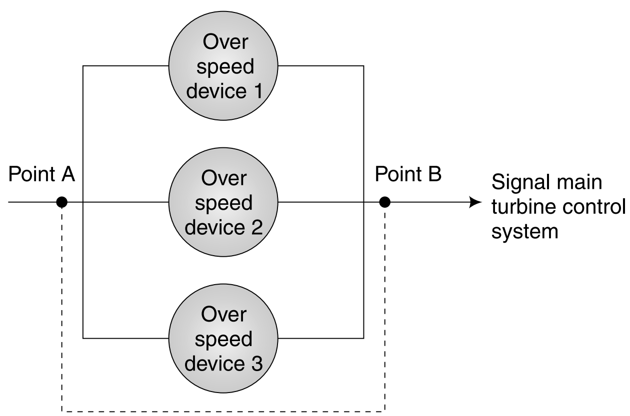


Fig. 8.23

8.7.7 Critical, Potentially Critical and Hidden Failures

If the failure mode is evident, then a preventive maintenance task can be specified to prevent failures. These are called "critical components". The occurrence of the failure mode could become evident either through continuous monitoring instruments or by the occurrence of the adverse effect itself.

A valve fails in a close position. An alarm will be initiated by the position indication. At the same time an unwanted event can also occur. This is also an indication if the occurrence of the failure mode is not evident, then PM task can still be specified to defend the facility against failure if its hidden failure effect has the potential to result in an adverse consequence.

Hidden failure mode exists when:

- The components function is normally "active" or "in use" when the system is in "service" but there is no indication to control room when the function is gone or it ceases to perform.
- The components function is normally "inactive" or "not in use" when the system is in "service" and there is no indication to the control room that the function will not be available when needed.

Failure modes: An individual component may have several different failure modes that result in different classifications. One failure mode may cause the component to be critical. Another failure mode may cause the component to be potentially critical. Another failure mode of the same component may be even classified as run-to-failure. However, the final classification of the component is decided by the default to the most important classification, i.e. the component would be classified as critical.

Hidden failure: To analyze the hidden failure modes occurring within hidden standby systems, the hidden system must be analyzed in its demand mode.

True hidden failure: When you identify a component failure mode that is not evident even upon demand then it is the true hidden failure.

Operator rounds: Is there a practice of operator taking rounds for vigilance or inspection in your plant. These kinds of formal operator rounds are an integral part of preventive maintenance.

Every facility is not a commercial jet aircraft where everything is monitored in the cockpit. Every facility is not a nuclear power plant where everything is monitored in the control room. The factories do not have such sophisticated monitoring facilities. There, these formal operator inspection rounds at discrete time intervals are very important.

This is coming closer to the Jishu Hozen concept of "inspection" by the operator.

8.7.8 Redundant, Standby, and Back-up Functions

When there are two pumps and the function of one pump is that it be used as a backup or standby mode. Thus, one is operating at a given time and the other is operating as a back-up should the first one fail.

Either pump can act as a back-up for the other. When a component is called upon to perform a standby or a back-up function it must be assumed that the normally operating component has failed. Thus, if the back-up should fail an unwanted consequence could occur. Therefore, standby or back-up components both are considered critical. There will be a PM task for these two components.

Redundant components or redundant systems usually operate simultaneously. If there is any individual indication that each one is operating and likewise there is any individual indication when each one should fail, the redundancy allows for run-to-failure classification.

Automatic back-up or automatic standby components do not operate simultaneously and will normally start on an automatic input signal.

Manual back-up or manual standby components also do not operate simultaneously and become operational only on manually noticing it and starting manually.

In either case should an unwanted consequence occur as a result of failure of the back-up or standby component, that component would be considered a critical component.

8.7.9 Three Important Strategies of a PM Program

1. **The first level of importance:** Protecting your plant against unplanned equipment failures consists of identifying critical components. When these components are called upon to function a single failure immediately results in a detrimental plant consequence.
2. **The second level of importance:** For protecting your plant is to identify potentially critical components. When these components are called upon to function their failure is hidden and does not result in an immediate consequence. However, either over a period or in combination with one or more additional failures a detrimental plant consequence will occur.

3. **The third level of importance:** For protecting your plant is to identify commitments and economic components. When these components are called upon to function, their failure is neither critical nor potentially critical, but they result in either a missed commitment or an economic concern.

8.7.10 Consequence of Failure

Identifying consequence of failure is the essence of RCM program. Every part of analysis is driven to obtain only one answer: what is the consequence of failure?

Once this is found out, next is how to prevent the unwanted failure via a prescriptive PM program that includes a vast selection of preventive maintenance (PM) tasks.

How to get there:

The sequence is as follows:

- Begin by identifying all the functions of the particular equipment.
- Identify the functional failures or different ways the function can fail.
- Identify the different failure modes or the different ways the equipment can fail.
- Identify the effects of the failure modes. This is normally done at plant level; however it is also done at system level.
- Identify what consequences to your plant or facility will take place as result of the failure effects. This is based on the asset reliability criteria you have established.

8.7.11 RCM Implementation

So far we have discussed the definitions and the method of classification of components. This part is important as RCM is different and understanding the definitions and classification is most important. Let us now try and understand the approach to implementation of RCM.

8.7.11.1 Preparation

1. Identification of a single point of contact (SPOC): Also called RCM champion or RCM coordinator. This person is fully involved in this program and a person who is a good program leader and having good technical knowledge is needed.
2. RCM coordinator should be capable of understanding RCM implementation and should be an enthusiastic leader.

3. RCM coordinator should also understand the consequence of failure analysis (COFA) logic.
4. Team leader and team members: Gather your RCM team members from maintenance, operations and engineering departments. Technicians should also be members of the team. These members may be rotated depending on the need.
5. When team formation and draft of mission statement are ready, then there are a few steps which will guide you through. Roles and responsibilities of the team members are to be understood so that there is no duplication of effort or members remaining idle.
6. RCM analysis should not take too much time. So two to three hours each day the team must devote for the COFA analysis. The timing should be fixed so that the members do not have to ask everyday about timing. In the fixed timing all members should just gather at that timing at a fixed place.
7. An off-site meeting for one or two weeks may be considered.

8.7.11.2 The Sequential Elements Needed for the Analysis

1. A simple but comprehensive alphanumeric equipment database must be established.
2. All identified resources with lot of information must be available.
3. A descriptive convention for specifying functions and functional failures must be specified.
4. An excel COFA spreadsheet (or a RCM software) must be available.
5. An excel PM task spreadsheet (or the same RCM software) must be available.
6. A excel based economic evaluation worksheet must be available.

8.7.11.3 Alphanumeric Equipment Database

1. All equipment in your plant should be included in the plant design drawings, piping and instrumentation drawings (P& IDs), facility schematics, electrical drawings, system operating manuals, training manuals and so on.
2. If you have the capability and if you prefer to sort your equipment IDs by system tag number that sort capability will be helpful.
3. RCM analysis requires at the component level and so we may have a simple system with IDs at component level.

4. No equipment ID to be overlooked. COFA will reveal a component to be significantly more important at times than you thought it to be.
5. Equipment database should include component only at the equipment level where a specific ID number has been assigned like valve, motor, pump, or compressor. Parts of the equipment are not included in the equipment database.

8.7.11.4 All Identified Resources with Information

Applicable maintenance, operations, and engineering procedures, training manuals, study guides, design basis documents, vendor manuals, technical bulletins, plant equipment drawings and schematics, electrical schematics, P& IDs, and so on. This is needed to ascertain the functions of the equipment and the ability to determine what the consequences of failure would be at the system and plant level. Knowledge and experience of your maintenance, operations and engineering personnel is most essential as they are the people who have been working in the plant for many years.

8.7.11.5 Establishing Convention

The COFA requires that you define the different failure modes for the functional failures. To simplify the phraseology of the failure modes, you establish your own convention. For example, if you choose "valve fails open" this phrase is understood to cover three conditions.

- The valve fails in open position.
- Valve fails to remain closed.
- Valve fails to close.

This is the reason why the convention to be very clear to you.

8.7.11.6 Specialized Workstations and Software

If you are a big industry and have a large number of equipment like a refinery, petrochemical, automobile assembly then you will get specialized workstations and CMMS systems commercially available.

There are also computer based RCM tools available that will store your data and monitor performance. These software programs schedule the work, personnel load required, PM tasks, monitor equipment performance criteria, etc.

Many industries have already available database. So they need not look for a specialized workstation for this purpose. They can use the same database. Some smaller plants may develop their own software if they have internal capability to develop.

This is an excel spread sheet.

	A	B	C	D	E	F	G	H
1								
2								
3	Which system being analyzed which subsystem being analyzed							
4								
5								
6–9	Define all subsystem functions	Define subsystem functional failures for each function	Define the dominant component failure modes for each functional failures	Identify the component identification numbers associated with dominant failure mode	Is the occurrence of the failure evident	Define the system effect for each failure mode	Define the plant effect	Define the component classification
10								
11								
12								
13								
14	Analysis performed by ____________							
15	DATE ____________							
16								
17								

Fig. 8.24 Failures modes and effects analysis (FMEA) sheet

Consequence of failure analysis (COFA) worksheet. This is an excel worksheet.

	A		B	D	E	F	G	H
1								
2								
3–8	Component ID and description	Describe all functions component	Describe the ways in which each function can fail	Describe the dominant component failure modes for each functional failure	Is the occurrence of the failure mode evident (determined by the COFA logic tree)	Describe the system effect for each failure mode	Describe the "consequence of failure" based on the asset reliability criteria you specified (determine the COFA logic tree and the PC and ES guidelines)	Define the component classification
9								
10								
11								
12								
13								
14	Analysis performed by ____________							
15	DATE ____________							
16								
17								

Fig. 8.25 COFA spreadsheet

8.7.12 COFA Spreadsheet

See the difference here. In the earlier method FMEA spreadsheet was used. In this new method COFA spreadsheet is used. It is rather very simple to implement and a lot of time is saved as it is easier to understand.

The COFA can be completed either in its simplest format which is an excel spreadsheet. The COFA worksheet will be one of the tools you will use when we commence the analysis.

Figure 8.24 gives an example of FMEA worksheet. Figure 8.25 gives an example of COFA worksheet.

In FMEA worksheet you have to start with the system and then define the functions for each individual subsystem. The systems must be compartmentalized and you are required to establish the process of identifying boundaries and hundreds of interfaces.

In COFA worksheet, identifying the systems and subsystem boundaries and interfaces not required because analysis is performed at the component level. This is a big benefit of implementing the analysis part with the new method.

8.7.13 PM Task Worksheet

1. PM task worksheet is where we enter the data for all the components that were classified as being critical, potentially critical, commitment or economic.
2. These components must have a preventive maintenance strategy with applicable and effective PM tasks specified. Some failure modes may have been stated but these are not credible in the sense they may be just imaginary. So only exceptions are those not credible failure modes.
3. Each failure mode has one or more preventive maintenance tasks. Therefore, a single component will often have a host of different types of PM activities associated with it.
4. The worksheet is where we introduce subassemblies of the components that are credible causes for failure such as bearing failure, heat exchanger tube failure, motor winding failure, check valve hinge pin failure, pump seal failure, impeller shaft failure etc.

8.7.14 Economic Evaluation Worksheet

Economic components have no safety or operational consequences resulting from their failure. They result only in a monetary cost of labor or

This is an excel worksheet.

	A	B	C	D	E	F	G
1	NOTE: The PM task worksheet is only applicable for those components which are either critical, potentially critical, commitment or economic						
2							
3–6	Component ID and description (from COFA)	What were the consequences of failure (from COFA)	Describe each dominant functional failure mode (from COFA)	Describe the credible failure "cause" for each dominant failure mode	Describe the appropriate PM task for each failure "cause" (from PM logic tree)	Define the frequency and interval for each PM task (from PM task tree)	Is design change recommended
7							
8							
9							
10							
11							
12							
13	Analysis performed by ____________						
14	DATE ____________						
15							
16							

Fig. 8.26 Preventive maintenance (PM) tasks worksheet

materials. Often the cost of a PM is rather more than letting an economic component fail. Then it is the decision up to what extent we should go. On an annualized basis the cost should be worked out and check the PM task will also cost the same or lower.

8.7.15 RCM Implementation Process

1. The first step in implementing your RCM program is to define precisely and accurately what asset management criteria your top management wishes to preserve.
2. Defining your asset reliability criteria basically means identifying all the unwanted consequences of failure that can occur in your facility and that must be prevented.
3. To define these criteria:
   - Ensuring personnel and plant safety.
   - Minimizing unplanned production delays.
   - Unplanned facility shutdowns.
   - Power reductions.
   - Production interruptions.
   - Loss of generation or production capacity.
   - Bad publicity and litigation.
   - Please write all these and then arrange for senior management sign off.

8.7.16 Establishing Asset Reliability Criteria

One can see in Fig. 8.27, a detailed asset reliability policy. This policy is written to give guidelines regarding safety and operability.

The asset reliability policy covers safety to personnel who are operating the plant and public safety. Similarly, it also covers concerns of safety on plant and equipment.

Further, it covers in detail the operability concerns like unplanned facility shutdown, power reductions, technical specification violations regulatory concerns, environmental concerns, etc.

8.7.17 Role of COFA Logic Tree in RCM

You need to have understanding of logic tree. Similarly, you need to know about the potentially critical guideline, and economically significant guidelines.

ASSET RELIABILITY POLICY

SAFETY

- No concerns whatsoever on personnel safety or public safety
- No concerns whatsoever on plant or facility safety

OPERABILITY

- No unplanned plant or facility shutdowns
- No power reductions or production interruptions
  - Greater than ……… percent
  - Longer than ……… minutes
- No technical specification violations
- No regulatory consequences
- No environmental impact, consequence or issues
- No litigation impact, consequences or issues
- No non-routine or abnormal control room violations
- No operator required work arounds
- No unplanned actuations emergency system
- No significant customer concerns or issues

PREPARED BY
DATE:

APPROVED BY
DATE:

Fig. 8.27 Typical asset reliability criteria

8.7.17.1 RCM COFA Logic Tree

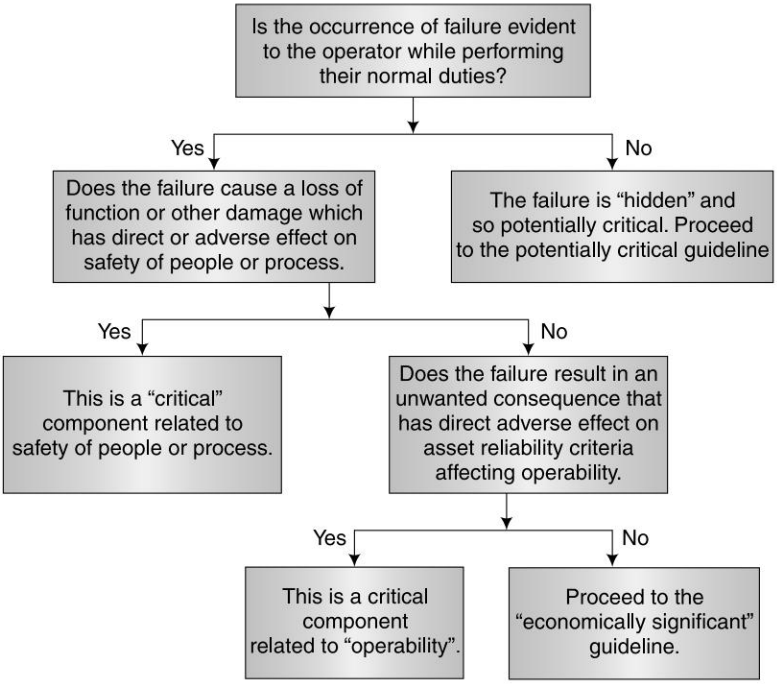


Fig. 8.28

POTENTIALLY CRITICAL GUIDELINE

Can the component failure, in combination with an additional failure or over a time period, result in an unwanted consequence that has a direct adverse effect on one or more of the asset reliability criteria.

IF YES This is a potentially critical component. It could be potentially critical for safety or operability concerns depending on its consequence of failure.

IF NO Is the component associated with a commitment? If yes, this is a commitment component, if no, proceed to the economically significant guideline.

ECONOMICALLY SIGNIFICANT GUIDELINE

- Will the component failure result in a high cost restoration work?
- Will the component failure result in significant downtime?
- Will the component failure result in high cost of corrective maintenance?
- Will the component failure result in long lead time for replacement parts?

If yes to any of the above: This is a economic component.

If no to all of the above: This is a run-to-failure component.

Fig. 8.29 Potentially critical guideline and economically significant guideline

8.7.18 COFA Worksheet

1. The entire analysis process begins at the component level.
2. Upfront you have already established your asset reliability criteria, which constitute your standard for determining safety and operability concerns.
3. The COFA logic tree then identifies critical components through the RCM decision process if it affects any of the asset reliability criteria you have established.
4. In case the component is not found critical by the COFA logic tree, the potentially critical guideline was enforced in the decision logic process to determine whether a hidden failure could affect your asset reliability criteria, which would make the component potentially critical.
5. If the potentially critical guideline decision logic did not find the component to be potentially critical or have a commitment associated with it, the economically significant guideline was enforced in the decision logic to determine whether the component failure could result in an economic concern.
6. Thus, the entire RCM decision logic has been integrated into one very simple process.

8.7.19

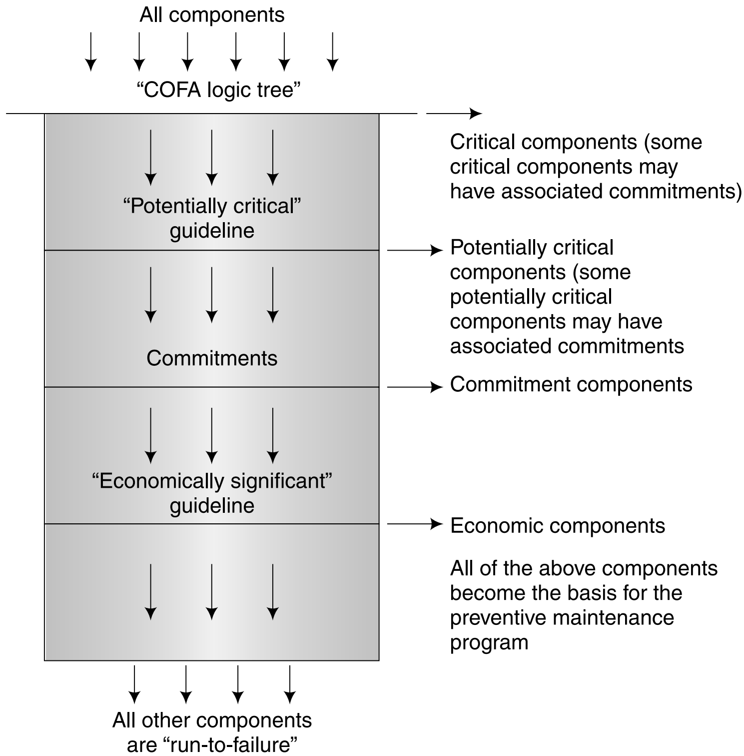


Fig. 8.30 Concept of a filter in RCM

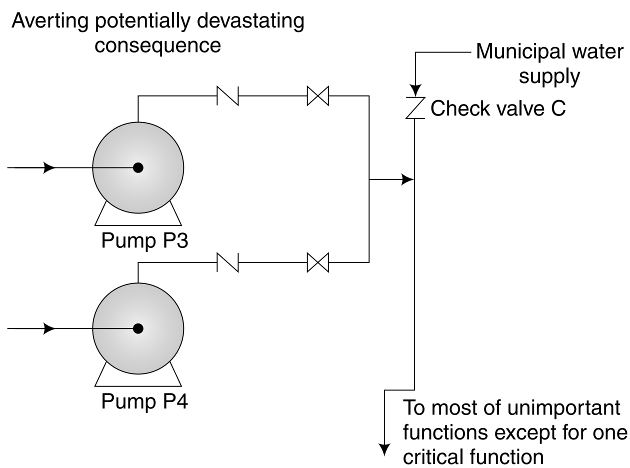


Fig. 8.31

The service water is supplied by the city water supply during normal operation. Check valve fails in open position.

Analysis: The failure of check valve C in open position is "hidden" since there is no indication of failure. If the service water is continuously supplied by the city, there is consequence of failure in the OPEN position. Even if the pumps P3 and P4 are periodically tested, the failed check valve will still be hidden.

However, by another additional failure such as pipeline of city water supply broke, there will be diversion of service water to a critical plant function.

The result of check valve C in the open position, during normal plant operation is considered to be "potentially critical" because its failure is hidden and plant consequence will not happen until another failure takes place.

8.7.20 How to Begin with COFA Worksheet

1. First start with the COFA worksheet.
2. Enter the component ID in column A of the COFA worksheet and in column B we describe all the functions of the component.
3. There will be several functions for each component. These include all of the normal operating functions and any emergency functions such as those design functions that come into being as the result of the loss of on-site power, flooding concerns, during heavy periods of rain or cloudburst, the loss of cooling capability, the occurrence of a fire, and the like.
4. The purpose for defining functions as part of the analysis is to enable the emergence of specific failure modes and their respective consequence of failure.

8.7.20.1 Describe Component Functions

In the column B enter all functions of the component. The function must be written such that there is a clear definition of the conditions that constitute functional failure. It should at the same time be written in a simple language. For example: "Provide the necessary flow needed to maintain tank inventory at its nominal level" unless there is any regulatory requirement that specifically defines the operational parameters that the function must meet.

8.7.20.2 Describe the Functional Failures

1. In column C of the worksheet, you describe the ways that each function can fail. The functional failures are exactly opposite of the function.

2. For example: Function is “provide a flow path…..” The functional failure will be “fails to provide a flow path”. This kind of functional failure does not add much value. However, it may help in some cases.

8.7.20.3 Component Failure Modes

In column D you describe the dominant component failure modes.

8.7.20.4 Describe the Dominant Functional Failure Modes for Each Functional Failure

1. The failure modes are different types of failures or different ways a component can fail so that it fails to provide the functions specified.
2. We include only plausible and realistic failure modes.
3. For example, for a functional failure: “Fails to provide a flow path for cooling heat exchanger X while pump Y is operating” , “Valve fails closed” is the failure mode.
4. Similarly, the failure mode for the functional failure of “ Fails to provide emergency cooling flow to back-up heat exchanger during a main condenser malfunction” would be “valve fails to transfer to its emergency position”

8.7.20.5 Is the Occurrence of Failure Mode Evident?

1. In column E you identify whether the failure mode is evident.
2. This question comes directly from question 1 of the COFA logic tree. It is the very first question asked determine to whether the failure is evident or hidden. If the answer is “yes” the failure mode must be evident when it occurs. It must be evident to operating personnel while they are performing their normal duties. It could include control room indication and monitoring or it could include operator rounds if the rounds are formally done with proper procedure. Due to this valve failure will be evident.
3. If the failure mode is not evident to the operating personnel, then it is a hidden failure mode.

8.7.20.6 Describe the System Effect for Each Failure Mode

1. In column F describe the system effects for each failure mode.
2. What are the failure effects at the system level?
3. This is really an intermediate form of information because our ultimate goal is to identify the consequence of failure at the plant or facility level.

4. However, system level effects are included as an informational element as they make identification of plant effects a bit clear.
5. Also all hidden failures have no system effect. This is because the failure is not evident to the operating personnel the overall operation of the system remains unaffected.

8.7.20.7 Describe the Consequence of Failure Based on the Asset Reliability Criteria

1. In column G we identify the consequences of failure that can result in an unwanted impact on one or more of the asset reliability criteria you selected.
2. The consequence of failure is determined directly from the COFA logic tree, the potentially critical guideline, and economically significant guideline.
3. All these unwanted consequences are at the plant or facility level and they are identified for each failure mode, so there may be more than one consequence.
   - Failure mode 1.a. the consequence is power reduction greater than 25% for more than 10 hrs.
   - Failure mode 1.b. there is no plant consequence.
   - Failure mode 1.c. the failure results in a plant shutdown.

If there is more than one consequence, you need to include all of them.

8.7.20.8 Define the Component Classification

1. The component classification for each consequence of failure must be identified in column H. Column H becomes quite important because any subsequent questions that arise in regard to what happens when the valve fails to open is documented.
2. You will have several different classifications for the same component ranging from critical to RTF. The final component classification always defaults to the highest level that means critical, potentially critical, commitment or economic.

8.7.20.9 Companion Equipment

1. An important check and balance for RCM logic is to ensure that any companion equipment as also carefully analyzed.
2. Companion equipment are those components associated with a critical and potentially critical component. Companion equipment

could include an inlet or discharge check valve, a component providing an input signal, or a component that supports one of the functions of the critical or potentially critical components. It could be as simple as a steam trap that drains the moisture of a critical or a potentially critical component.

8.7.21 The PM Work Selection Process

1. Preventive maintenance tasks consist of three general categories: condition-directed, time-directed and failure finding.
2. Condition directed and time directed preventive maintenance is specifically intended to prevent failures at the component level.
3. Failure finding preventive maintenance tasks do not prevent failures at the component level.
4. Failure finding is a strategy to ascertain at a periodic interval, whether or not a specific component or system has already failed so that the failed component or system can be detected before it results in a plant consequence upon the occurrence of an additional failure.
5. Therefore, failure finding tasks can be viewed as a preventive maintenance strategy to prevent failure consequences at the plant level.
6. Failure finding preventive maintenance is applicable to hidden failures and also performed on safety systems and components that are not normally operating.

8.7.21.1 Preventive Maintenance Tasks (Fig. 8.32)

Time directed tasks normally include replacements, overhauls, and restoration of components at given periodicities. For most part they require disassembly and removal.

Condition directed tasks normally include tasks that measure, monitor or analyze the condition of a component to determine whether it is operating acceptably or it is about to fail. Predictive maintenance tasks such as vibration monitoring, oil analysis and thermography are all types of tasks that fall into the condition directed category.

Condition directed or failure finding tasks must be scheduled at some given periodicity but they are not considered to be time directed.

Proactive preventive maintenance is really synonymous with predictive maintenance which is a subset of condition based maintenance.

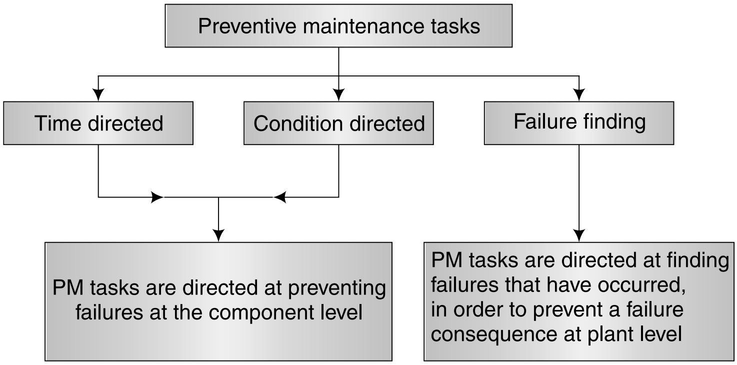


Fig. 8.32 Preventive maintenance tasks

There is a misconception that all PM is performed by maintenance department. In fact preventive maintenance is also performed by operations, engineering, chemistry, and other departments. When we get into PM task worksheet all applicable and effective tasks will be described and who should do what. But they have to be documented and follow a procedure.

The integrated preventive maintenance program is shown in Fig. 8.33.

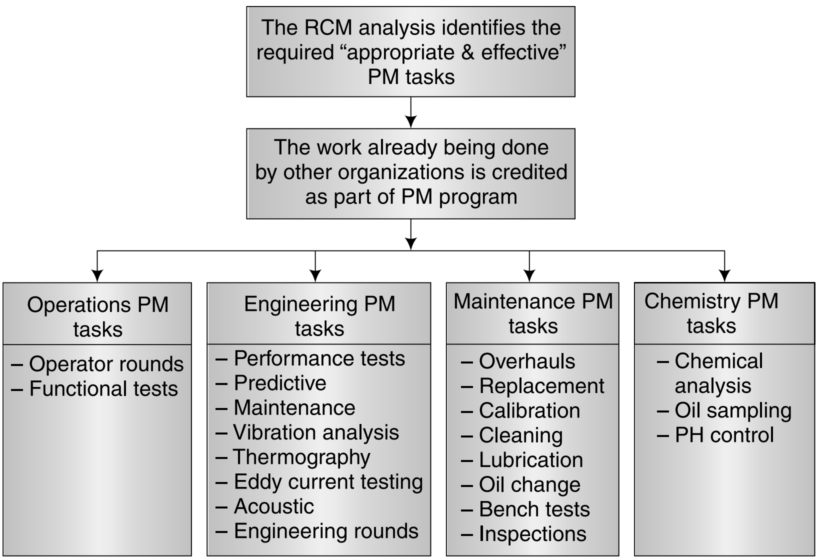


Fig. 8.33 Integrated preventive maintenance program

8.7.22 PM Task Worksheet

PM tasks are entered on the PM task worksheet which is one of the implementation tools shown in Fig. 8.26. The data for columns A through C of the PM task worksheet comes directly from the COFA worksheet. The component ID, and description, the consequences of failure and each dominant failure mode are entered from there.

In column D of the PM task worksheet the credible cause of failure must be identified for each component failure mode that resulted in an unwanted consequence for any of the asset reliability criteria regardless of whether it was critical, potentially critical, commitment, or economic. Invariably there will be several causes of failure for each failure mode.

There will be different causes for different failure modes which in turn require different PM tasks to address these. This is important and failure causes are determined by knowledgeable individuals with thorough understanding of the equipment. Generally, engineering and maintenance people are more knowledgeable than the operators to carry out this work.

8.7.22.1 Bathtub Curve (Fig. 8.35)

We have seen bathtub curve in earlier session. The significance remains same, but there are some additional information added here.

An interesting observation is about 11% of all the components universally exhibit an age relationship to failure. That means 89% of all components do not show age relationship but fail randomly. That is the reason time directed overhaul without regard to the condition of the equipment is not a good practice.

Why condition-directed task is preferred?

This question is very interesting. This part of knowledge is there in front of us, but sometimes we get carried away by the rules or stringent requirements and we just do it. But by doing it we get into more problems.

Whenever a component is removed from service for an overhaul or replacement, its time is zeroed. Means, one is premature failure and the other is infant mortality. Therefore, it is necessary to allow a component to operate until some predictive task shows that the component has impending failure mechanisms and is in need of overhaul or replacement.

Premature failures are very common. Quite often a piece of equipment which is operating satisfactorily will be removed from service to satisfy a vendor's recommendation for replacement at some given interval.

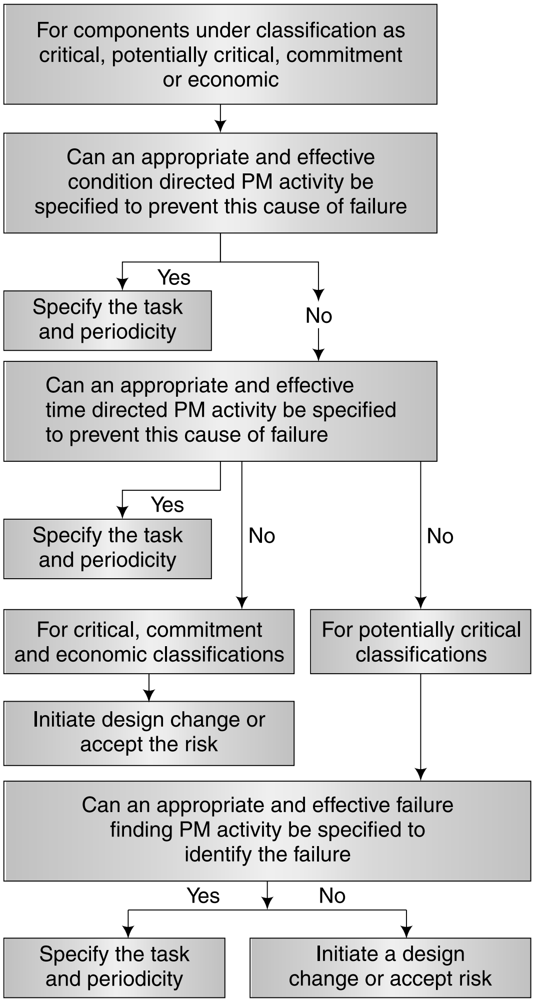


Fig. 8.34 PM task selection logic tree

Once the equipment is replaced there are a host of reasons for the newly overhauled unit to fail prematurely. There could be problems during reassembly especially if it is a complex component. There could be problems with the replacement parts or in re-installing.

Infant Mortality: Another source is infant mortality with new equipment during its "running in" period. This period is to allow the rubber rings, seals, wear rings and clearances to settle down in a relaxed state. If you replace a component before it becomes necessary you will lose all of the remaining time. Not only it is a waste of resources but it also diminishes the available critical work.

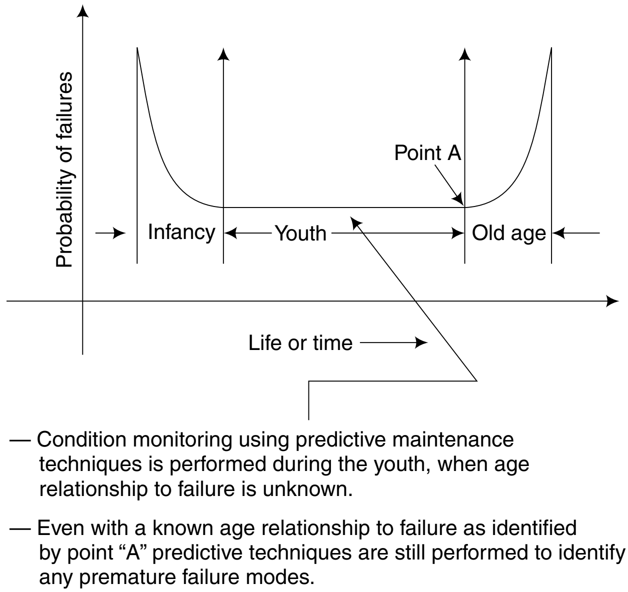


Fig. 8.35 Bathtub curve

Another interesting observation is about 11% of all the components universally exhibit an age relationship to failure. That means 89% of all components do not show age relationship but fail randomly. That is the reason time directed overhaul without regard to the condition of the equipment is not a good practice.

Often both condition directed and time directed tasks are specified for the component for different causes of failure. For example, vibration monitoring to ensure that an incipient bearing failure is not about to occur, while time directed overhaul may also be specified for the component if an age relationship to failure is known.

8.7.22.2 PM Task Frequency and Interval Considerations

There are several considerations for determining the frequency of PM task:

1. Failure history
2. Condition monitoring history
3. Industry history
4. Recommendations of the supplier
5. Planned outages
6. Regulator requirements
7. Design and operating conditions
8. Environment

8.7.22.3 Determining PM Task Frequency and Interval

How do we define the frequency and interval for the tasks?

The periodicity for the tasks selected, are entered in column F of the PM task worksheet. The frequency is daily, weekly, monthly, quarterly, annually, etc. This is entered in code like once every four months is entered a M4. Every four years will be Y4.

For PM task frequency and interval considerations; if you have a good failure history data that data should always be a primary consideration for establishing periodicities. It is more of an art than science and so experienced people sitting together and deciding the frequency with all other considerations is the best practice. It should always be directed to take optimum use of the component's life. This always works as a more economical way.

There are always some "opportunity areas" as some sections of the plant are having some outage or shutdown and such opportunities are fully utilized. This is called opportunistic maintenance as we have discussed in detail in the earlier chapters. Also any unplanned equipment breakdown, always has the chance to modify the schedule so that such unplanned events do not take place in future.

8.7.23 Optimum Time to Establish a Reliability Program

The optimum time to implement an RCM program is during the design stage of a new plant or facility. Later it is all adjustments.

1. One benefit of developing a reliability program as a part of the design stage is to plan all things like ways to replace certain equipment without having to schedule an outage for accomplishing the maintenance work.
2. Create accessibility to the equipment so that the PM work can be done without disturbing other equipment in the vicinity.
3. Provisions can be made to use predictive maintenance techniques.

8.7.24 Is Design Change Recommended?

Column G of PM worksheet, includes a recommendation for whether a design change is warranted. Design change is an exception rather than a rule.

However, most of the time, condition directed or time directed preventive maintenance to prevent failure or failure finding task to identify when a failure has occurred can be specified. But, there are occasions when this is not possible and a design change is mandatory or face the risk of failure.

8.7.25 Filling up a Typical PM Task Worksheet

The PM worksheet is shown in Fig. 8.26.

In column A, we enter the component ID.

In column B, we enter critical consequences of failure.

1. A power reduction
2. A plant shutdown

In column C we describe dominant component failure modes associated with the two consequences of failures. Each dominant failure mode that resulted in an unwanted consequence of failure must be analyzed. This is entered in column C.

1. Valve fails closed
2. Valve fails to transfer to the emergency position.

In column D of the worksheet we describe all the possible credible failure causes for each dominant component failure mode.

- Valve binds
- Bearing failure
- Motor failure
- Torque switch fails
- Limit switch fails
- "Others" depending on specific equipment type.

In columns E and F of the worksheet the applicable and effective PM tasks and the frequency and the interval of the task are defined for each failure. The task and their periodicities are ascertained from the PM task logic tree. Finally, in column G a design change is recommended.

8.7.26 A Sampling Strategy

In an old plant you have just completed RCM analysis and found that one of the most critical components you have is a major pump which is very large and quite complex. Similarly, you have many such pumps. Now you have realized that these pumps are all due for overhaul since they have not been overhauled for the last 15 years.

Would you rather go to the management and say that we need to overhaul all these pumps and cost would be huge? The management obviously will not approve such a budget.

So the idea here is to take a sample of worst case scenario and tell the management that we will open one pump and check everything as sample.

This is called sampling strategy. Once the sample is studied thoroughly then further action will be planned.

8.7.27 Common Mode Failures

Common mode failures are failures of a population of equipment all of which is subjected to the same failure mode. A sampling program will help in this case. Such a common mode failure can happen in your plant too, but the sampling method of investigation study helps.

8.7.28 Different Predictive Maintenance Techniques

This topic has been covered under condition based maintenance in Sec. 8.6.

8.7.29 The Corrective Maintenance Evaluation Element

If a critical, potentially critical, commitment or economic component continues to have history of failures and that needs corrective maintenance activity it could be an indicator that the following items to be taken care of immediately:

- The PM tasks for those components are not specified properly and scope of PM work is not complete.
- The periodicities of the PM tasks for those components are lacking in their scope of work.
- The PM tasks are not being performed as per the schedule.
- Work control process is not good.
- Spare parts availability is a problem.
- A design change may be necessary.

8.7.30 RCM Monitoring and Trending

You have performed a comprehensive RCM analysis and allowed some finite period of time for the program to become ongoing. In that period if there is a very clear absence of any serious consequences of failure at your plant and your work load is utilized primarily for planned maintenance activities rather than unplanned events then it shows that your reliability program is becoming healthy.

However, we need proper *aggregate performance criteria* so that we can assess the plant reliability.

What is reliability? Is it counting number of plant trips, or is it capacity factor, is it mean time between failure (MTBF). All these have some meaning but we need some deeper measure.

Reliability was defined as the "probability that an item will survive to a specified operating period under specified operating conditions without failure".

But how do you measure the reliability of an entire plant? Here in this example we need that reliability can be defined as "The cumulative rate of unwanted aggregate events per unit of time where the events are not limited to just equipment failures".

So we need to arrive at aggregate metrics to report the health of reliability program.

8.7.31 The Aggregate Metrics

Performance metrics are intended to provide senior management with a snapshot of how reliably their asset is performing. So the metrics should be simple, comprehensive and objective and provide an aggregate snapshot of reliability.

Reliability should be measured per unit of time. It is more appropriately measured as a rate per thousand unit operating hours.

1. **Unplanned plant or facility trips.**
2. **Capacity factor:** How much less than 100% of the available time did your plant operate (not counting planned outage time and other planned downtime)? Plant trips, power reductions, production delays are functions of this metric.
3. **Unplanned operator actions:** Unplanned operator intervention as there are problems. These are not their routine jobs. This is an indication that preventive maintenance program needs more attention.
4. **Unplanned power reductions:** How many times a component has failed that required immediate down power to prevent it from tripping offline.
5. **Production delays**
6. **Root-cause evaluations:** Though this is needed, but at any given moment how many such root cause evaluations are taking place is an indication of deficient maintenance practices.
7. **Injuries:** This is serious and indicates that a plant is run well or not.
8. **Rate of written corrective maintenance:** CMs are not necessarily a negative attribute. But, however, they should come down.
9. **Overdue CM backlog.**
10. **Overdue PM backlog.**

8.8 LUBRICATION MANAGEMENT

The next most important item is the lubrication management. We need to understand the difference between daily lubrication and lubrication management. These two functions are entirely different. In Jishu Hozen we have understood that daily lubrication is the responsibility of the operating teams. However, providing right kind of lubricants to the operating teams is the responsibility of the lubrication management team which is a part of the maintenance function.

Procuring, storing and making it available to the operating teams in proper quantities, is the key responsibility of the lubrication management team. This also includes conducting training to the operating teams on lubrication. This means what type of lubrication is suitable for that application, details of the lubrication method used in that equipment and what is the right quantity and frequency of lubrication needed for that application. In case of lubrication is not happening, educating the teams on the importance of lubrication, preparing a lubrication system diagram and explaining the lubrication method is also the responsibility of the lubrication management team.

8.8.1 Visual Controls

The next important aspect is the use of visual controls. In olden days each manufacturing site used to have 20 to 25 different kinds of oils for various purposes. It was really difficult to keep a track of inventory of all these lubricating oils and prevent any mix-up taking place at the use point. However, recently there have been lubricating oil surveys conducted by oil companies and there are only a few oils now in use in manufacturing sites. These are standardized and kept in inventory.

Color coding of storage bins: Since visual controls are well recognized in the manufacturing sites, color coding of lubricating oils has become quite common. The storage bins have color coding. Subsequently, the oil can is also color coded and finally the lubricating point on the equipment is color coded so that there is no confusion to the operator who is doing lubrication.

8.8.2 Standardization of Tools

Standardization of tools like grease guns, oil cans, sight glasses and lubrication cans helps in keeping inventories lower.

8.8.3 Storage Location

Storage location of oils is another important topic. Oils should be kept closer to the user point, but at the same time proper accountability has to be maintained and misuse of oils to be prevented.

8.8.4 Lubrication Training

Lubrication training is also a responsibility of PM team. This is another important responsibility of maintenance function. In the plant where Jishu Hozen is implemented, training the operators on the effective and economic lubrication method is important. The operator must learn to check the lubrication and so it is necessary to understand the complete lubrication system for.

8.9 ENGINEERING STORES

Spare parts storage is another important responsibility of the maintenance function. This starts from establishing certain basic principles of operating the stores.

8.9.1 ABC Analysis of the Stores Items

The first and the most important principle to establish the importance given to a particular stores item is based on the cost of the item. This is important to establish the inventory policy. Each company based on the cost of the parts establish which are "A" category items, "B" category items and then "C" category items. Then it is easy to establish the inventory policy for the stores.

There is also another principle called VED (Vital, Essential, Desirable) analysis. This classification is done on the basis of the criticality of the part or stores item for the maintenance purposes. This is basically established by the engineers point of view and is used in some organizations as against ABC analysis or in conjunction with the ABC analysis. In ABC analysis, the finance department establishes certain guidelines based on the cost of the parts and thereby establish authority levels for approval for buying the parts. In VED analysis it is done on the importance of the part based on consequences of failure.

8.9.2 Minimum, Maximum and Reordering Quantities

This includes right parts, in right place, at right time and right value (inventory). Most important aspect is that there has to be adequate inventory of spare parts in the store, when you take up preventive maintenance or corrective maintenance. It is also needed for breakdown maintenance on daily basis. However, there should not be too much inventory. For this the slow moving and non-moving items in the store room to be reduced carefully. This is not an easy task. Also the manufacturing site should decide about the correct level of inventory. Minimum, maximum and re-ordering levels, to be decided using experience of maintenance personnel. Once decided those levels to be maintained both in the system as well as physical inventories.

8.9.3 First in First Out (FIFO) System

This is another important principle. The parts which are procured earlier should be consumed earlier. If a store does not give respect to this principle, some parts will remain in isolated pockets and will get deteriorated due to dust and rust. It may go to such an extent that those parts may become not suitable for use at the time when needed. This will cause cost and embarrassment as the item is shown in the system but cannot be used because of the condition.

8.9.4 Centralized Store or Decentralized Store

This is another important decision to be taken by the maintenance department. This is not just the decision of the maintenance function. The finance department will also have a say in this important aspect. That is due to the accounting integrity needed of the people who are handling the spares. That means in decentralized stores keeping an account of all the parts drawn from the stores becomes difficult. In case you establish a good system of accounting right from the beginning, it is possible to have proper accountability. However, world over manufacturing sites have both models working and it is the decision of the stores management team to have either of these two methods.

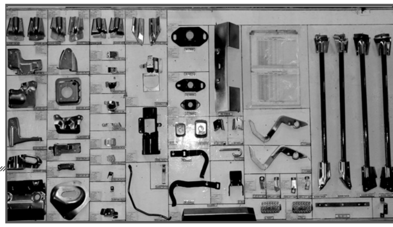
8.9.5 Visual Controls

Identification of all parts kept in the stores is the key principle. This is to enable auditing process and also establish less time for retrieval of items. The searching time is a loss and in order to retrieve a part in less time (say 30 seconds) is very important and organizing the items in proper way, identification of all the parts and storing them in a visual way becomes necessary. This is done by preparing a chart showing layout of the store's racks, which rack has which items and providing routing for the person to retrieve the parts. This will also help in identifying and displaying the slow moving and non-moving items. Yellow marks on the flooring, writing names of parts and numbering them, having identification tags for each item is the method generally adopted in industries.

8.9.6 The Quality Check on Locally Developed Spares and Rebuilds

This is another important responsibility of the maintenance function. Development of local vendors for imported spare parts and vendors for other machining jobs, rewinding of electric motors and outside repairs is the responsibility of maintenance department coordinating closely with the purchasing function.

CHAPTER 9



How to Organize for Establishing Good Maintenance Practices?

9.1 ASSESS WHERE YOU ARE TODAY

As we are on the springboard to jump into the world class maintenance practices, we need to assess as to where we are and which are the areas we need to give more focus than the others. You may just prepare an audit sheet to assess where you are based on the following points.

- Do you have downtime recording and analysis system?
- Do you have history card for all the equipment?
- Do you have breakdown analysis done for all major breakdowns?
- Do you have manual for all the equipment?
- Have you got ABC analysis done for all the equipment in the plant?
- Similarly, have you got ABC or VED (Vital, Essential, Desirable) analysis done in the spare parts store?
- Do you have a lubrication management system and daily lubrication system?
- Do you have inspection checklists for maintenance staff and inspection checklists for operating staff separately.
- Do you have equipment owners who are responsible for three shifts performance?
- Do you have maintenance skills assessment and skills development program?
- Do you have a good spare parts management system in place?

In addition to the above questionnaire and assessing your current situation, you may also use the following audit sheet to assess the current situation in detail. This may be a bit of time consuming exercise but it is worth doing it at the very beginning. This will not only give you very clear picture where to focus but also will give you a comprehensive picture of the whole game.

9.2 WORLD CLASS MAINTENANCE MANAGEMENT AUDIT SHEET

Maintenance Management System Audit Sheet

Sr. No.	*Company Name Main Function*	*Plant Name Subfunction*		*Department Name Description*		*Rating*	*Comments*
(A)	**Self-Managed Maintenance**	1.	Cleaning	(a)	Is cleaning done by equipment operators in each shift?		
				(b)	Is cleaning time optimized?		
				(c)	Is the cleaning process standardized?		
				(d)	How clean is the equipment when inspected?		
		2.	Inspection	(a)	Does the equipment operator carry out inspection in each shift?		
				(b)	Is the process of identification and rectification of defects formalized?		
				(c)	Is the process of inspection for defects standardized?		
				(d)	Is the work order system for major defects formalized?		
		3.	Lubrication	(a)	Is the lubrication inspection done by operator in each shift?		
				(b)	Is the lubrication oil or grease replenished by operator?		
				(c)	Are any leakages in lub. system rectified by operator?		
(B)	**Breakdown**	1.	Work order	(a)	Is work order system standardized?		
				(b)	How fast the work order is completed?		
				(c)	Are adequate resources deputed for breakdown maintenance?		
				(d)	What is the quality of the breakdown maintenance work?		
		2.	Analysis of breakdowns	(a)	Is there a process for analysis of breakdowns existing?		
				(b)	Is equipment history for breakdowns maintained?		
				(c)	Are chronic problems identified?		

Contd...

Sr. No.	*Company Name Main Function*	*Plant Name Subfunction*		*Department Name Description*		*Rating*	*Comments*
				(d)	Are MTBF and MTTR records maintained for critical equipment?		
				(e)	How fast can the technician get the spare parts and tools?		
(C)	**Corrective Mainte-nance**	1.	Operability	(a)	Are operator's difficulties identified and corrected by changes?		
				(b)	Are machine quality problems identified and corrected?		
				(c)	Is there a documented process for collection of data existing?		
		2.	Maintain-ability	(a)	Are maintenance difficulties identified and corrected?		
				(b)	Is there a documented process for collection of data existing?		
		3.	Reliability	(a)	Is there a documented process for calculating reliability?		
				(b)	Is reliability tracked for each shift/day?		
				(c)	Is there any methodology for improving reliability?		
(D)	**Preventive Mainte-nance**	1.	Equipment ranking	(a)	Is there a process for equipment ranking established?		
				(b)	Have all critical equipment been identified?		
		2.	History Records	(a)	Are history records for all equipment available?		
				(b)	Is the history updated timely?		
				(c)	Are the changes made and maintenance done recorded?		
				(d)	Are maintenance manuals and drawings maintained well?		
		3.	PM Master schedule	(a)	Is there a PM master schedule prepared for all equipment?		
				(b)	Is there a PM schedule on daily, weekly and monthly basis?		
				(c)	Are all the jobs completed as per schedule?		
				(d)	Are all the resources identified in advance and provided?		
				(e)	Are all the spares parts checked for such work in advance?		
				(f)	What is the quality of PM work done?		

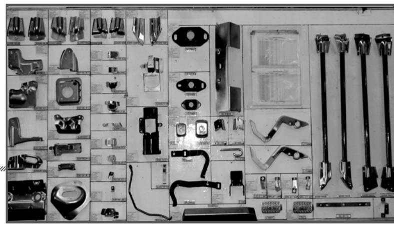
Contd...

Sr. No.	Company Name Main Function	Plant Name Subfunction		Department Name Description		Rating	Comments
(E)	**Opportunistic Maintenance**	1.	Preparation	(a)	Is there a process for identifying all jobs for opportunistic maintenance?		
				(b)	Are all parts and tools kept ready for such opportunity?		
				(c)	How is information sharing done on such opportunities?		
		2.	Implementation	(a)	Is there a good system for using the down-time for jobs?		
				(b)	What is the efficiency of completion of such jobs?		
(F)	**Shutdown Maintenance**	1.	Planning	(a)	Are shutdowns identified and planned in advance?		
				(b)	Have shutdown jobs clear resources identified?		
				(c)	Are all the spares needed for shutdown organized before?		
		2.	Execution	(a)	Is completion of all jobs done on time?		
(G)	**Predictive Maintenance**	1.	Planning	(a)	Are all equipment for predictive maintenance identified?		
				(b)	Have condition monitoring tools for equipment obtained?		
				(c)	Who will carry out the monitoring and prediction identified?		
				(d)	Has frequency at which it should be done identified?		
		2.	Execution	(a)	Are vibration analysis of critical equipment, ultrasonic thickness measurement, chemical analysis of oils and boiler water, Infrared scanning etc done?		
(H)	**Spare Parts Management**	1.	Inventory	(a)	Are max, min and reordering quantities for all A and B spares identified?		
				(b)	Are spares inventory stored with identification tags?		
				(c)	Is the spare parts accounting system working properly?		
				(d)	Is there a physical verification system of spares existing?		
				(e)	Are there proper visual controls in the stores?		

Contd...

Sr. No.	Company Name Main Function	Plant Name Subfunction		Department Name Description		Rating	Comments
				(d)	Are slow-moving and non-moving items written off and sold?		
(I)	**Tool Room Management**	1.	Planning	(a)	Are jobs at tool room identified and planned?		
				(b)	Prioritizing for the jobs done.		
		2.	Execution	(a)	All the jobs at tool room done correctly and on time.		
				(b)	Tool room takes care of preparing in advance and keeping it as spares.		
(J)	**Computerized Maintenance Management System**	1.	Hardware & software	(a)	Has there been good hardware and software installed?		
				(b)	Is the software system user friendly?		
				(c)	Does it have all capabilities to track downtime, downtime analysis, troubleshooting module, history cards, MTBF and MTTR recording etc?		
				(d)	Is there a direct link between preventive maintenance and spare parts inventory management?		
				(e)	Does this have master PM plan and separately daily, weekly and monthly PM plan?		
				(f)	Is this system capable of calculation of reliability, downtime and doing pareto analysis and management reporting?		
(K)	**Cost of Maintenance**	1.	Cost tracking system	(a)	Is there a tracking system for maintenance cost?		
				(b)	Are all costs captured properly for maintenance?		
				(c)	Does this system capable of making zero based budget?		
				(d)	Can this system do analysis and reporting of costs?		
					Total Score		
	Rating system: 5 Excellent, 4 Good, 3 Satisfactory, 2 Needs improvement, 1 Major deficiency, 0 Nothing done,						

CHAPTER 10



Maintenance Prevention

Maintenance prevention is a new concept in improving the design and coming out with maintenance-free equipment. Maintenance prevention is gaining ground these days. Especially in the third world countries where we need to develop in each and every field, it has become imperative to use maintenance prevention as a strategy for development.

So, what is it? This is not a type of maintenance nor is it a one time gimmick. However, it is a technical function to reduce or eliminate maintenance requirement. This is an example of continuous improvement to achieve zero maintenance requirement over a period. MP needs innovative ideas and thorough knowledge of materials, operations and maintenance. This is a continuous improvement journey. MP has a prominent place in reliability engineering.

However this needs a good analysis of cost before implementing. A thorough costing using "life cycle costing" has to be done. This also needs analysis using value engineering concepts.

10.1 WHAT IS MP DESIGN?

MP design is an improved version of design of any equipment or facility. As the name indicates it is maintenance prevention design. This is achieved by getting valid feedback from the users of the equipment; mainly the operating department or maintenance department. The user plant shall collect data from various sources mentioned below and hand over the data in a manner that the design department can easily understand and incorporate this data in a meaningful way. Normally, there are hardly any channels of communication to give an input to the design department who is preparing the design.

First of all we need to organize ourselves to collect this data. The source of this data is generally from the following.

10.1.1 Autonomous Maintenance Data or Jishu Hozen Data

In the plants where TPM (Jishu Hozen activities) are implemented the Jishu Hozen work is normally called steps 1, 2 and 3 activities. Here, the main objective is to identify the abnormalities and fixing them to eliminate all sources of contamination, hard to reach areas and other defects observed by the Jishu Hozen teams including chronic problems and visual control deficiencies. During these activities a number of improvement ideas are generated and implemented. Mainly the problems are operability problems, maintainability problems, reliability problems or simply the breakdowns and minor stoppages. All these defects are fixed by the teams with various new ideas. Now the question is how these ideas shall be captured and communicated to the machine supplier whenever we buy new equipment from the same or a new vendor. Such a channel of communication did not exist and even if it was there it was done in a haphazard way and the result was not satisfactory. Here, all these improvement and problem solving ideas are captured as MP data and then they are communicated to the design department of the vendor.

10.1.2 Maintenance Data History Record

This source of data is coming from the history cards of maintenance department data. After a thorough analysis on the major breakdowns and arriving at the root cause solution it is a common practice to fix the breakdown by implementing the countermeasures for the breakdown. In such areas there are opportunities for improving the lubrication system or in some cases change the material of construction of components etc. These ideas or countermeasures have a potential to be implemented in the new equipment being bought from the same vendor or in some cases a new vendor so that the equipment becomes defect-free while arriving at the users plant.

10.1.3 Corrective Maintenance Data or "Kaizen" Record

Similar to the previous source of information or data, here is another main source of maintenance prevention data. In a normal running manufacturing plant it is necessary at times to make changes in the design of the equipment or components of the equipment to suit the requirements. This is due to many reasons. However, to name a few, the specifications or requirements were not communicated to the supplier or vendor was not communicated in the beginning. In some rare cases it is coming due to changes in application of the particular machine or equipment. Due to this, it is necessary to make some design changes at the user's plant level. This particular activity is also called "corrective maintenance" or simply "design corrections". Soon after the design correction is over and successful trials are conducted, it is captured as MP data by the maintenance or manufacturing services department.

10.1.4 External Sources on "New Technologies"

This is another major source. The equipment manufacturer as a normal course of action would always keep in touch with the latest technology connected with the particular equipment. Here we are talking about the customer or the user is also finding out what is the latest technology and finding out what upgrades are available and requests the vendor to incorporate the new technology in the new equipment they are going to buy.

10.1.5 Comments During Design Review Meetings

Design review meetings are another source of MP data. The MP data collected by the maintenance department is used for the MP design and in the design review meetings it is verified that it is incorporated. Similarly, at the time of design review further data can also come in and that too is treated as MP data.

10.1.6 Reliability Data Collection

Reliability engineering deals with the subject of improving reliability of the plant and equipment. Reliability study is nothing but study conducted on the failures or breakdowns. The failures could be caused by poor lubrication, stress concentration, overloading, bad operation or bad maintenance. Studying about the failures and then coming out with the root cause of failures is the main objective of reliability engineering. Here we are talking about the data collected on the root cause and the countermeasures for the failure. This is collected as MP data and then made available to the design department to improve the design.

10.1.7 Competitor's Information Collection

In a few cases the user may get technical information from their competitors as to how they have upgraded the same equipment for getting better productivity or quality improvement. It may be even the way they are doing the maintenance work. This kind of data is also useful for the design of new equipment.

In MP design we are aiming at two distinct things; first, how to reduce the maintenance need. That means it encourages “maintenance-free” concept using new ideas and new materials of construction so that the maintenance is not needed or reduced drastically. Secondly, the time taken to do the maintenance work is reduced by simplifying by various concepts like advanced maintenance tools, modular assembly of components concept and using advanced tools in troubleshooting.

10.1.8 MP Data Sheet

In order to standardize the data collection and providing the feedback to the design department of the equipment manufacturers, standard format is designed which is called MP data sheet. So whenever the user finds an opportunity for improvement in design it is immediately collected in a technical manner using this MP data sheet. This work of collection of data in the form of MP data sheet is carried out by the maintenance department or in some cases by manufacturing engineering or manufacturing services department.

Figure 10.1 provides an example of MP data sheet generally used in a manufacturing plant. This is an example of how user can collectively provide technical data to improve the design.

Example of MP Data Sheet

MP Information Sheet

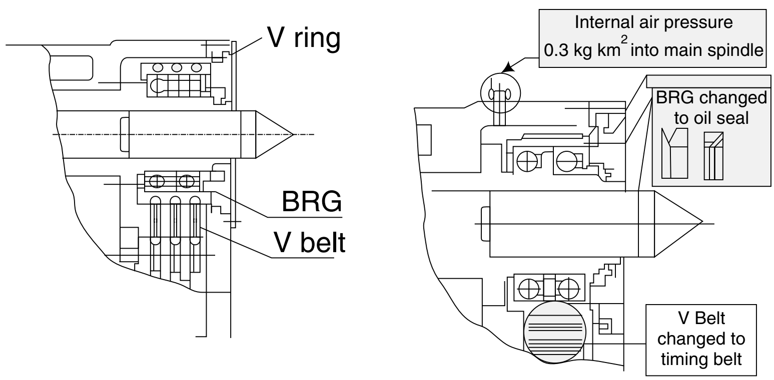
Date of Completion: 17, April 99
Completed by: Maintenance section

Improvement Theme: To prevent coolant seepage

Problem: V Belt of main spindle worn out	Registration Code: G-MP1–178 G Name fo Facility: Conical Grinder Control No: 4G–138

Cause: The V belt got deteriorated and wore out because sludge and water continuously seeped in one to on the seal leading to V belt getting stuck.	* Target of improvement 1. Reliability 2. Maintainability 3. Autonomous Maintainability 4. Operability 5. Energy Saving 6. Safety	Previous actual value: V belt Changing Time: ½ Year Target Value: V belt replacement period extended: 1/3 Year

Before Improvement **After Improvement**



Effect: Cost estimation: Possible or not possible

Reduction in spare parts, Cost and Manpower according to the increased MTBF.
Total Amount: ¥150,000 Effective amount reported: 17 April 99

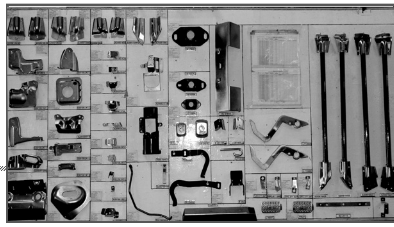
Standardisation for Maintenance work :
- Change: The procedure for adjustment, disassembling and assembling (Yes / No)
- Other
- Horizontal Deployment: 7 machines completed

A. Necessity	B. Classification	C. Cause	D. Target	E. Standardisation
1 Feedback must be	1 Change Mechanism and Construction/ Structure	1 Less process capability	1 Improvement in reliability	1 Engg. Std. Document
2. Necessary, if possible	2. Change in operation (Func.)	2. Design failure	2. Improvement in maintainability	2. Manufacturing Drawing
3.	3. Change in control circuit	3. Manufacturing defect	3. Improvement in autonomous maintainability	3. Spec. Document
4.	4. Change Raw Material	4. Spec. defect	4. Improvement in operability	4.
5.	5. Change Parts	5. Assembling defect	5. Improvement in Energy saving	5.
6.	6. Others	6.	6. Improvement in safety	6.

Opinion: At present the above mentioned type or work is not available in our facilities as a reference. Hereafter a technology sheet will be prepared and technology transmitted.

Fig. 10.1

CHAPTER 11



How to Make Maintenance More Efficient Using 5S Principles

11.1 WHAT IS 5S

These are five Japanese words for five Japanese principles for action in the manufacturing set-up. It is not necessary that it is applicable only for manufacturing site. It is applicable everywhere, even in our homes. These five words start with the alphabet S and so are known as 5S all over the world now.

Seiri: It means to sort out and discard unwanted items. In our household and in manufacturing set-up we generally carry materials and equipment which are not in use for a long time. But, however, we generally do not do anything about it and keep it. This occupies space and causes unnecessary delays when we have to search for something. This needs an important decision to start this work and an intention to improve the whole area. Sort out is the key here. Sort out means sort out good things from unwanted things. It is not simple to take a decision as to what is not needed.

Seiton: It means to organize the workplace for no-search time. In order to have an organized workplace, we need to work hard and identify each and every item properly so that we can retrieve anything in very less time. This needs organizing capability. This also needs a planning capability so that one can visualize the whole place and then convert that into action.

Here visual control becomes a necessity and these visual controls are used extensively so that the items can be identified. There should also be some logic behind for all the storage areas so that retrieving time should be minimized. Charts, color coding, numbering, yellow line marking, etc., become part of the game. The principle here is that everything has a place identified and everything should be in its place. Further, we need to have a set of principles to store items, by having right quantity at right places and at right time.

Seiso: It means to clean the whole place for checking defects. This is the basic principle of civilization. The whole place should be clean. Cleaning also encourages finding defects and abnormalities. We call that cleaning with meaning. Finding defects helps find opportunities for improvement and rectifying the defects.

Seiketsu: It means to maintain equipment and workplace for efficient functioning (standardize). In order to maintain it in good condition it needs inspection and correction of defects so that the equipment remains in working condition. This means some preventive system should be in place for fixing defects and there should be standardization in doing that work.

Shitsuke: This means a disciplined behavior is needed to sustain what you have done already. 5S does not mean that you keep on doing this work at a predetermined frequency. It means once you have created a clean, organized, visual workplace sustain it in the same way year after year. This will eliminate non-value added activities. This is what is called disciplined workplace.

11.2 HOW TO IMPLEMENT 5S

Remove unwanted items. Keep the workplace in order. Keep the inventory at needed level only. Identify each item so that you can retrieve items fast. Create an environment of happy workplace. Enable accounting to be done with ease. Incorporate systems for reducing running costs.

11.3 HOW TO IMPLEMENT 5S IN MAINTENANCE DEPARTMENT

Maintenance department can gain tremendously by using 5S principles.

First of all, the maintenance workshop can be converted into a clean, organized and efficient workplace. Similarly, the electrical workshop and then the instrumentation workshop can follow. Then comes the spare parts storeroom. It may also be followed by utilities services area.

How do we go about doing it? Decide and plan the activities on a particular day and call it 5S implementation day. Have all the people working in that area to be present in that place. You may also call the people if any are working in the second and third shifts so that they can also take part in these activities and take ownership.

Sort out: First, sort out all unnecessary things from necessary things. This is important as many people feel that those items identified as unnecessary come handy at times and so we should not discard them. That is the reason you may pull out mercilessly all unnecessary items and keep them in the middle of the floor, in a very conspicuous place. Then leave them there for a day or two so that if any item is really needed those people can take it with the permission of the leader.

Pull out all items and clean the whole area: flooring, roof, walls, then windows and everything. Discuss the layout with the team members. Decide if any re-layout is needed and start keeping things back into the respective places. Fix them if needed and draw yellow lines so that no unnecessary items enter there. Yellow line marking is done to identify the boundaries of responsibility and also to identify which item should be where. Clean all equipment, racks, storage areas and make them orderly.

11.3.1 Discard

Then undertake any repairs needed for any equipment or just about anything not working. Fix the defects and put them into working condition. It may be ventilation fans, work benches, racks, tools etc.

11.3.2 No Retrieving Time

Once you have kept everything in order find out the retrieving time for the items like spare parts, files, drawings, tools and any such thing in the workplace. Try and reduce the retrieving time to a minimum possible.

11.3.3 Sustenance

Finally, have a meeting and in the presence of all concerned decide what kind of sustenance effort is needed and document it. The people should be trained on this principle of sustenance. They should be clearly given a checklist prepared for the purpose of sustenance.

We shall take the example of the spare parts store for 5S. This takes more efforts, but having spent that amount of effort and time, you will never regret it as the spares stores is an important and integral part of world class maintenance.

How do we start the work in the spares store? Prepare a master plan for the entire store and prepare a chart for displaying the layout to be finally fixed at the entrance of the store. The layout shall now be as per the new layout prepared. Please prepare the master layout following the principle you have established for the operation of the store. One such principle is old used parts should not be kept in the same rack as the new parts. It will be kept only after getting it reconditioned. Start the work with one rack in the store. If it is a normally running store, it has to be handled in this fashion. Take out all the material kept in one rack and clean the whole rack. Then look at all the opportunities to use the visual control for identifying each part kept in this rack. Use color codes, numbering as per the codification you have chosen in your computerized management system. Use names or numbers for each part.

The test is one should be able to retrieve a spare part within 30 seconds. This is the kind of benchmark we are going to follow. Continue this practice for all the racks in the store. Identify slow moving and non-moving stores items. Immediately, start working on removing the slow moving and non-moving parts by engaging into the procedure for removal from the stores.

Also start the practice of cycle counting and also cleaning the racks on a regular basis so that dust and rust do not get into the stores.

5S activity in the store will not be complete without having a thorough accounting system. This is the question of integrity and has to be followed very strictly. This needs a certain kind of discipline which 5S normally asks for. The spares taken by anybody from the store is the person responsible for the accounting too. Finally, the quantities shown in the system and the physical stock should tally every time cycle counting is done. This is achieved by strictly following issue system no matter how much hurry you may be in.

Put in practice all those principles we have established in the beginning when we started the store. For example, FIFO system is an important principle and should be strictly followed. Similarly, old parts should not be kept in the racks unless they are reconditioned. Heavy parts in the lower racks and lighter parts in the upper racks is another principle you may follow.

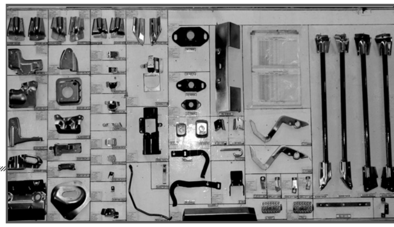
Finally, you may establish a 5S audit system so that you don't have to do the 5S activity again and again. Instead you may sustain it and maintain it in the same condition.

11.3.4 Benefits of the 5S Principles in the Maintenance Department

1. There is no search time needed for any spares, tools and files. This will be a direct contributor to MTTR effort.

2. Due to cycle counting method and good accounting practices the variance in the store will come to zero or what we call "inventory record accuracy" will improve. This will be a saving.
3. Non-moving and slow moving items will be removed from the stores and so inventory will come down.
4. There will be other indirect benefits like saving of electricity.
5. One other indirect benefit is the whole workplace will become a happy workplace.

CHAPTER 12



Role of Leadership in Maintenance Function

12.1 IMPORTANCE OF STRONG LEADERSHIP

Here I need not emphasize that a strong leadership is needed to bring about any change. Managing means managing people. First, the leaders should have a vision. The leader then needs to have strong drive to convince people about the vision he or she has. Once people are convinced about the vision, the energy gets created and people just fall in line to do whatever it takes. There are a few key things here to remember.

12.2 WALK THE TALK

This means "practice what you preach". The leader has to come forward and demonstrate to people that he or she is serious about it and that is what he or she would like you to do. This is also demonstrated by daily work. Walk the talk is about practising on a daily basis the principles the leader or the company has set forward.

12.3 LEARN BY DOING AND LEAD BY COACHING

In a learning organization everybody is a teacher and everybody is a student. That means at any given situation we are in the mode of learning more about the technology, latest developments in the business, product quality, information about your company's activities Vs competitor's activities and so on. So a good leader will provide for such a learning process and he himself takes part in such activities. The concept of a "boss" has changed and in the modern industrial world the leader has to learn it first before even venturing into such major activity. The modern bosses are no more bosses, instead they are coaches. In order to become a coach one has to learn it before start teaching others.

12.4 3ES OF LEADERSHIP BEHAVIORS

There are three distinct behaviors of a leader which we take note before we move on. They are envision, energize and enable. Let us see in little more detail as to what they are.

12.4.1 Envision

The leader creates a picture of the future and keeps the vision alive. He or she needs to communicate and share the vision with people. So a leader needs to have good communication and convincing capability. A good leader personally communicates the vision and what he/she stands for both in words and actions. There also needs to be continuity in the vision he or she has created. This means there cannot be frequent changes in the vision. It needs to continue for a longer duration. Another important aspect of envision is the leader focuses on possibilities and not limitations. There will be bottlenecks of obstacles in every process of development. One should not get deterred or disturbed by these bottlenecks. He or she needs to focus on possibilities and not get bogged down by the limitations or failures. Always keep the mind open and find new ways of doing things. Encourage others also to do the same.

Another important trait of a leader is enrolling and focusing the organization on the key objectives of the company or department where he or she is a leader and focusing on winning strategies. The winning strategies are generally formed by experience and information sharing. This is important in any business.

12.4.2 Energize

A good leader sets goals, establishes high standards, and clearly defines roles and responsibilities. This is very important to energize people. He or she demonstrates a sense of urgency. This is needed as people should feel that there is something important going on and it needs immediate action. Openly and honestly communicate and encourage others to do the same. This is also called transparency. Transparency does not mean that everybody has to know everything in an organization. That will be done as per “need to know basis”. However, honesty in communication is the paramount principle of leadership. The leader also has to personally demonstrate enthusiasm and risk taking. And finally, a good leader has to demonstrate caring for people and build trust.

12.4.3 Enable

Enabling means allowing others do the work and build capabilities in them to do it on a continuous basis. So a strong leader defines and develops the capability required to deliver the strategy. He or she needs to personally participate in high leverage system improvement. That means what is most important for the organization at that point of time and he or she will personally participate and demonstrate enthusiasm. A leader identifies and eliminates the organizational and systemic barriers. Proactively learn through benchmarking and data based problem solving. Express support and confidence in others. Effectively delegate others and finally recognize; reward and celebrate success. Celebration could be a small celebration like recognizing a good work done or identifying best employee of the month, but the scale is not important here, but the intent. Reward system; that too non-monetary rewards go a long way.

12.5 LEADERSHIP TRAITS FOR IMPLEMENTING WORLD CLASS MAINTENANCE

Why are we talking about leadership traits in people working in maintenance function? Generally, maintenance function is considered to be a back of the house service and so developing leadership traits in maintenance managers is never considered. In the maintenance function the important trait is just carry out urgently whatever is told to you. So, by virtue of these kinds of expectations the maintenance manager's leadership quality is never considered to be important.

On the contrary, however, in the modern manufacturing set-up the role of maintenance manager is ever expanding. So it is necessary to assess the leadership trait in them and consider developing it further, by training, giving exposure in higher level meetings, working in some other plant within the company and delegation.

Let us briefly discuss some of the key behaviors which can help develop leadership traits in the maintenance function.

12.5.1 Perspective of the Whole Business

In large organizations, it often happens that the employees working in a particular department might lose contact and become secluded from the mainstream of business. That means they may be working in their respective departments and contributing to the business, but there might be lack of information flow and employees may not know what is happening in the organization on a continuous basis. Hence, they may not have the perspective of the whole business. As a leader one cannot afford this. Here individual employee also needs to take interest in order to keep in touch. Perspective of the whole business is important to function in an organization.

12.5.2 Visible Manager

This is another important trait. What is a visible manager? A visible manager is one who rises to the occasion and takes responsibility. He or she has a charisma and attracts people, with his personality. Has all relevant information and can share as and when such information is required. Simply said he or she is an opinion leader and capable of bringing about a change. These people are needed even in maintenance department. Maintenance is not just a routine work as many people think. It is a very creative environment and all time bubbling with energy. We need this trait in the maintenance people.

12.5.3 Good Interpersonal Skills

This trait is generally needed for all managers. However, in maintenance it is more important as there is no industrial engineering norms set in maintenance function. This is where deputing people and motivating them is of utmost importance and needs strong interpersonal skills, that is, to get along with subordinates, peers and seniors.

12.5.4 High Technical Skills

One needs to have high level of technical skills to be a competent manager in a particular department. Especially, in the modern industrial world, there is great demand for highly technical people as the industry cannot be run by mediocre people. So, one has to learn on a continuous basis by attending training, or having exposure or by developing good reading habits. This is a bare minimum requirement in the modern world.

12.5.5 Flair to Learn and Experiment New Things

In maintenance function there is no routine kind of work. Every single day is an exciting day with new problems and new activities. It is a very creative environment. So one has to be taking a bit of calculated risk and try new things. It is also needed to learn new things on a continuous basis.

12.5.6 Have a Critical Eye

This means to find defects. Find defects in the work which is happening, find defects in contractor's work and keep vigilant. This is calling for a critical eye. That means your mindset should be not to get satisfied with the quality you are getting. You need to set high standards and find mistakes to improve; so that you achieve the high standard you have set.

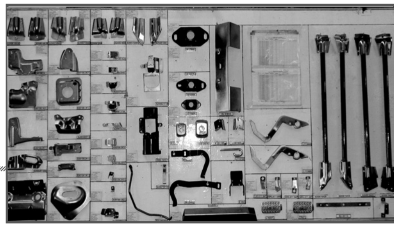
12.5.7 Set High Standards

As mentioned earlier the leader has to set high standards and encourage others to achieve those. This is a continuous improvement journey. Here it is important that you should not get satisfied by defective work and getting bogged down saying what more can we achieve in this organization. You are the person to bring about a change. You and only you can achieve the high standards you have set.

12.5.8 Establish Systems Approach

Establish a system in which less number people come to you for decisions. The department's decision making process should not be person dependent; but system dependent. This again helps delegation process and a manager who practices this policy will have more free time for himself as he has implemented systems so that people follow those systems.

CHAPTER 13



How to Develop Ownership in Maintenance Technicians?

How do we get happiness and job satisfaction: This is an important concept as to how to develop ownership in the maintenance staff? Maintenance is considered to be "back of the house service". If that is so how do we create ownership? Production technicians have a particular concept of "my machine, my department" as they work in a cell or department. They also operate a particular machine. So it is simpler to create a sense of ownership in those people. However, maintenance department does service to other departments. So how do we create ownership in such a situation?

Ownership is developed by doing meaningful work, by getting involved in creativity. Also by taking pride in what they do. This is sense of belonging or ownership.

How do we get ownership: Ownership in people in an organization cannot be developed by external sources. It has to be imbibed by them. External sources can give some direction and training if needed. The process of ownership development is generally done by the following.

13.1 LEARNING NEW TECHNIQUES

Instead of harping on development of ownership in the maintenance technicians it is better to divert their attention to learning new techniques. Develop a habit of learning in the whole plant. For this the leaders should develop and demonstrate a habit of continuous learning first. When you have any sort of communication with the technicians give examples, real life stories of something you learned in the last one week, etc. Encourage them to talk on what they have learned. Give a pat on the back and appreciate the new learning. This is where Kaizen or Poka-Yoke, problem solving tools like why-why analysis, fish bone or cause and effect analysis and pareto analysis come very handy. Give importance to learning of analytical tools to solve their own problems. In the long run technicians should be able to solve their own problems. The creation of learning environment always fosters job satisfaction and ownership.

13.2 IMPLEMENTING WHAT THEY LEARNED

The author has seen in many plants that implementing what the technicians have suggested or requested makes wonders in the plant. This is not only a morale booster, but also creates tremendous ownership. Furthermore, if you recognize the idea and reward them it really works. This is how Kaizen has come into being. But whatever system you start in the plant, we need to be fair and we have to have a system working which can take this effort on a continuous basis. Always ask a question "What is new and what did you learn". This goes a long way. They understand immediately that the leader is giving a lot of importance to learning and bringing new ideas. Kaizen is the real answer. But this is a big effort. The author has seen many versions of Kaizen. Some look like "suggestion schemes" and some like one-time gimmick. Kaizen means "continuous improvement" and it shall go on forever. There is no end to learning and implementing new ideas. So, have a structure in place, start with training on "analytical tools" and always encourage teams to come up with good Kaizen. Be fair to the teams. This is done by proper presentations to the management and then conduct real audit of the Kaizen theme. By this people start having trust on the system and they will give respect. You may have this kind of Kaizen competition every quarter. The theme could be like "productivity improvement", "quality improvement" and "safety improvement". However, always have reward system in place.

13.3 HAVE CLEAR ACCOUNTABILITY OF WHAT THEY DO

In a manufacturing plant shop floor you do see every day hundreds of people working. There is a lot of hustle and bustle on the shop floor. Many managers and officers walk on the shop floor busy in something; mostly collecting data and production numbers. However, they often do not see people working there. They are so busy that they see through people. This is not a healthy sign. Take time to go to the "Gemba" and talk to people; understanding what is new, what are their problems and appreciate their good work. This is the real-life situation. By this you will know what exactly they are doing, always create a system to measure accountability. What he or she is supposed to do and what exactly he or she has done and then institute a reward system. Many companies do not have annual performance appraisal system for technicians. That is because they cannot bring about accountability. This will ultimately become a serious matter and result in lethargy. All the technicians or for that matter an assistant in housekeeping also has to have accountability. Then they respect the management.

13.4 TAKE LEADERSHIP AND SHOW IT TO OTHERS

Always demonstrate good work done to others. Create an event in the shop floor so that everybody feels that it is a celebration. Who does not like appreciation? Every human being likes appreciation and the management should make the most of this situation. It is not necessary that monetary reward only works all the time. Even non-monetary rewards work too.

Encourage technicians to take part in inter-company competitions. State level and national level competitions give a lot of inputs to technicians. This is a learning opportunity for them. These go a long way in the development of technicians.

13.5 MAKE IT A DEMONSTRATION PIECE

In the maintenance department appreciation does not come about so easily. This is the nature of this function. So, the department manager must make it a point to always find an opportunity to appreciate and reward the person or team who has done good work. The department manager can take it up to the plant manager and create a demonstration. This is an example. The author has experience of such an event in one of the plants he used to visit as a consultant. The maintenance department had done good restoration work on the utility machines and had achieved zero breakdown in utility department. This is a major achievement.

However, the department manager had not mentioned about this to the plant manager and above. They were totally ignorant about this fact. Later the author himself took this matter to the plant manager and there was a big surprise. Then immediately the plant manager called the relevant technicians who have achieved this result and gave first big applause and later an award. So such events are worth celebrating and mostly maintenance managers are shy to express such things to the management.

13.6 EXCEL IN WHAT YOU DO

This is another key word. We need excellence in whatever we do. Mediocre results are not enough. This is a world of competition. If we want to win, then we need to produce the best results. This requires a lot of dedication. The management should develop such an environment right from the beginning or inception of the plant.

13.7 INSTITUTE REWARD SYSTEM

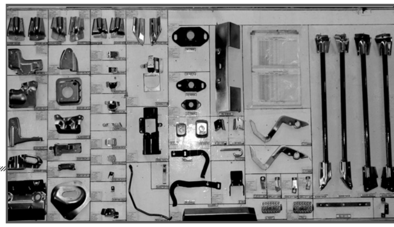
We have been talking about reward system right from the beginning. But the author regrets to say that there are many manufacturing plants where a monetary or a non-monetary reward system does not exist. This is because the management does not want to get into accountability, creating a competitive atmosphere and finally reward them. For them this is a difficult exercise and so they do not undertake such a work.

Reward system works wonders. Every human being needs appreciation and the management should take courage to say some one or some team is better than others. The reward system can be in two different forms. One, it is purely non-monetary. Second, it is monetary, but the amount of money need not be huge so that people start fighting instead of appreciating.

Just a pat on the back, an appreciation letter, information with a picture on the bulletin board, and a dinner coupon to have dinner with his or her family can make wonders in the shop floor.

(The author has a lot of experience in this field and emphasizes that the reward system really works in developing technicians and create ownership.)

CHAPTER 14



Role of Kaizen in Maintenance Function

In Japanese language "Kai" means change and "Zen" means better (improvement). So Kaizen simply means "continuous improvement'. Kaizen system is implemented to create Kaizen culture. That means the people in an organization spend sufficient amount of time on solving their problems themselves. Solving problems is developed as a culture. They identify the root cause of the problem and come out with solutions to those problems. Then implementing them with satisfaction of the whole team is called Kaizen. Once the management takes lead and inculcates "Kaizen culture" that becomes a foundation for any continuous improvement strategy like six sigma, total quality management and total productive maintenance.

So how does one create Kaizen culture in the maintenance function? Kaizen addresses the inefficient working in any organization. It is a systematic approach to change the culture of the organization. If that is so, how do we start this in maintenance function?

14.1 HOW TO START KAIZEN ACTIVITIES

There are two different approaches to start Kaizen in the plant. The first one is structured approach and the second one is unstructured approach. Let us briefly discuss the structured approach.

This is the time to decide if you want to start in the whole organization or only in manufacturing area or just one department only. The author is of the opinion to start Kaizen at least in the entire manufacturing plant. However, it is the decision of the plant management. Maintenance department can be a part of this or the maintenance department can start in their department separately.

14.2 STRUCTURED APPROACH

In the structured approach, the whole plant is divided in either zones or production cells. Each zone or the cell has a leader. Initially, the leader shall meet the team and give role and responsibility to the team members. This is very essential to work as a team. The maintenance person will be a coach and technical help for these teams. To facilitate the teams to function as a good team taking a lot of initiative, the leader shall fix a particular day in a week and a particular time in that day. So, the Kaizen meeting time is fixed. Every member of the team works naturally within that cell or zone. It is within their natural workplace.

14.3 TRAINING

Once the structure is ready and the team is formed then the training becomes the next event. Kaizen means generating great ideas and implementing them. Then why training becomes important? This is a pitfall which is happening in many organizations. They think that Kaizen just happens and only encouragement is needed from the leadership. Japanese believe that in order to have Kaizen there has to be a problem. There could be problem in the machine, problem in the productivity, problem in quality, problem in safety or problem in operability and maintainability. However, this problem becomes the center point. Using analytical tools solve the problem by arriving at the root cause solution. This solution becomes the Kaizen theme. Once the management approves it, it is implemented as Kaizen. After implementing Kaizen it is documented in the proper format. The quality of the Kaizen depends on the quality of the analysis and the root cause solution. That means after the Kaizen theme is accepted and implemented the problem should not recur again.

This is where training comes into picture. There are two kinds of training in this area. One is training on seven basic tools and why-why analysis. The second one is on the documentation part using the proper format.

14.4 TECHNICAL HELP

Once the theme is approved by the management, the time comes to implement the idea. This would require some technical help like fabrication and erection taking free time of the machine for this work. Here maintenance person has a role to play. However, it should not go to the other extreme. That means all fabrication and development work is dumped on the maintenance person and he cannot handle such large volume.

14.5 IMPLEMENT THE KAIZEN

This is implementation of the idea and taking trials to see if the idea has worked. If the analysis is good then the success rate is good.

However, sometimes rework may be necessary in the work carried out as Kaizen.

14.6 KAIZEN PRESENTATION

Once the Kaizen idea is successful, then the next step is to make a presentation to the authority to evaluate. Evaluation is done as there is a competition and is followed by a reward. The authority conducts this kind of structured approach and same is repeated three or four times a year. Each team can come out with more than one Kaizen also. Finally, it is the quality of the analysis, quality of implementation and then quality of the presentation which brings the prize.

14.7 UNSTRUCTURED APPROACH

Here, there is no structure created or teams are formed. Both individuals and teams can participate in the Kaizen competition. Training is conducted in some plants and in some other plants no training is rendered. Once the management makes an announcement that there will be a Kaizen competition Kaizen ideas are invited. The only thing mandatory here is that an individual or team comes out with an idea, the same individual or team should implement it.

14.8 METHODOLOGY OF UNSTRUCTURED APPROACH

Take any problem as challenge. Create a project around that problem. Analyze the problem to the root cause. Then come out with zero investment solutions. Challenge status quo, on methods and systems by using 5W/1H, why-why problem solving tools. Identify waste in an area. Just eliminate NVAs. Think out of the box solutions. Complete the implementation of root cause solutions and check for effectiveness. The test is that the same problem should not recur again.

Normally, in a manufacturing organization, maintenance people help in Kaizen activities by developing the idea, helping in fabrication work and finally helping erection and commissioning of the root cause solution. If that is so, what about some Kaizens in the maintenance function? Kaizen brings in creativity. So we need to be able to solve problems in maintenance. That means it does not have to be in the maintenance shop only. It can be used for reducing the breakdowns. It can be used to save energy bills. It could also be used to improve the maintenance functional activities and reduce non-value added activities. Problems could be in the method, materials or machines. They can come out with innovative ideas. They have a great opportunity to implement their own ideas with their own hands. This also leads to great job satisfaction in people.

KAIZEN IDEA SHEET	Activity	AM	FI	PM	QM	E&T	OTPM	DM	SHE	**COMPANY NAME**
	Loss Area									
	Result Area	**P**	**Q**	**C**	**D**	**S**	**M**			
Section:			**Machine:**							**Machine No:**

Kaizen Theme:	**Idea:**

Problem/Present Status:	**Countermeasure:**	**Benchmark**	
		Target	
		Kaizen Start	
		Kaizen Finish	
		Team Members	
Analysis (Why–Why):	**Results:**	**Benefits:**	

Scope & Plan for Horizontal Deployment

S. No.	Section	Target Date	Responsibility	Status

Fig. 14.1 Kaizen idea sheet

14.9 HOW DO WE START KAIZEN IN MAINTENANCE FUNCTION?

First of all form teams drawing members from all people working in maintenance. Then identify problem areas with the help of the team members. Have a meeting of all concerned. Depute each team on problems identified and selected to work on. Establish a method of collecting ideas and the approval process. The supervisors and managers to be coaches and they need to be carefully guiding them. Carefulness is needed while analyzing and coming out with the root cause solutions. The ideas implemented should be effective and so one has to take care in this area. Implement those ideas. Check the effectiveness over a period. Give credit to all, but also give reward and recognition to the deserving ones. Go for non-monetary rewards. Reward system has to be established and implemented in such a way that it is not a one time kind of thing. A system has to be developed for the reward system to be implemented throughout the year. Also it should be such that it works year after year.

14.10 KAIZEN DOCUMENTATION

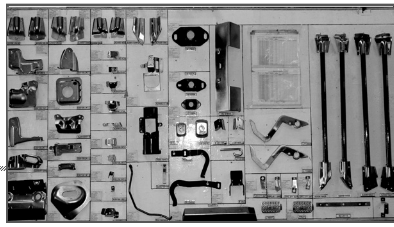
Finally, the Kaizen has to be documented so that the team can do presentation using this document or separately they can use power point slides to do presentation to the authority. There is a standard format for this purpose and everybody shall use the standard format.

14.10.1 The 7-step Kaizen Process

1. **Initial problem perception:** This is the most important step as perception of the problem may vary from person to person. Care has to be taken to perceive and state the problem. Otherwise the problem can go haywire.
2. **Clarify the problem:** The second step is a little different than the first step in that here in step 2 all details are collected. Which equipment, which component or function, what is the effect on the production and quality etc.
3. **Locate area/point of cause:** Now go to gemba and get all the details from the maintenance and operating personnel. Take photograph or video and get all information about the problem.
4. **Investigate root cause:** Use the tool *WHY-WHY analysis* and include all concerned persons in the team. The analysis has reached the root cause means once implemented the problem should not recur again.

5. **Implement countermeasure:** Make a clear action plan and implement it. Do not take too much time. Time is essence here. All team members to participate.
6. **Evaluate the results and share the results:** Evaluate the results and conduct trials if needed and make sure you have achieved the results fully. Announce it to the team and higher ups.
7. **Standardize:** Once you are clear that the problem has been resolved to the root cause you may standardize the process and reapply to other similar locations or equipment.

CHAPTER 15



How Does Value Engineering Help in Maintenance?

What is value? Value is the worth of a product, methodology or services. These days there are a number of materials coming into the market which have better value, but lower cost. At this juncture we would like to look at all those materials, ideas and efforts to evaluate them for substitution. By this, the value of the material goes higher while by the usage point of view the material, idea or effort gives equivalent or even better results.

Value means function divided by cost. In order to improve the value we need to either increase function or reduce cost or do both simultaneously. So we need ideas to do this.

Value engineering (VE) is a systematic method to improve the "value" of goods or products and services by using an examination of function. Value, as defined, is the ratio of function to cost. Value can therefore be increased by either improving the function or reducing the cost. It is the primary tenet of value engineering that basic functions be preserved and not be reduced as a consequence of pursuing value improvements.

Value engineering is sometimes taught within the project management or industrial engineering body of knowledge as a technique in which the value of a system's outputs is optimized by crafting a mix of performance (function) and costs. In most cases this practice identifies and removes unnecessary expenditures, thereby increasing the value for the manufacturer and their customers.

This is called value engineering. In short, value engineering means, coming out with solutions which are higher in value and lower in cost. Though it is not an engineering function it will need good knowledge about the properties of material, knowledge about methods and ideas to save cost. So, this is a techno-commercial function. It is all about idea generation and reducing costs by finding new materials and methods with the same or better function.

Value engineering helps in developing low cost solutions while doing Kaizen activities. So it is necessary to train the team members in value engineering and procedure to develop Kaizen in the organization. This training shall also include training in problem solving tools like why-why analysis, 5W1H analysis and cause and effect analysis. This will strengthen their knowledge in problem solving tools and going to the root cause solutions.

Let us now look at how value engineering concept helps maintenance function. In many manufacturing plants, the repairs to the building, major repairs to the equipment and flooring in the warehouse is done by the maintenance function. It is not necessary that the concept of value engineering is applied to only huge projects. In big projects, the cost of value analysis is offset by the gains. Sometimes the gains are quite big.

The author emphasizes that value engineering concept can be used in day-to-day maintenance work. For example, in one of the engineering companies the flooring was not covered by either tiles, stones or any other coating. As a result the cement flooring used to absorb a lot of oil and the deterioration used to be very fast. So the plant maintenance function used to spend money every year and it became a regular effort. Here, the example is about epoxy coating to the flooring. A layer of the cement is scraped from the surface and a thick layer of epoxy coating was then applied. Care is to be taken to do this work. But once having done this the flooring lasted more than seven years and the higher cost of the epoxy coating were clearly offset by the gains.

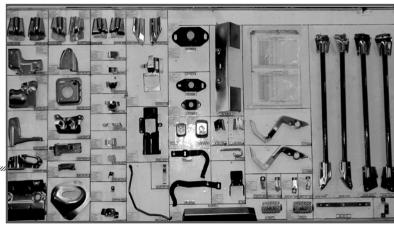
Another example would be for the repairs of a cast iron pressure vessel. This particular part was from a ship and the repairs were to be done as the ship was held up from sailing. There are two choices in methods of repairs. As it is required urgently the first method anybody would look at is cast iron welding. This requires a high quality welder and in between at given intervals the part has to be cooled. Otherwise it will develop cracks due to heat.

One other idea emerged from the team was conducting metal-locking. This technology has been there for many years, however was not extensively used. This also needed a highly skilled person to do it. The time taken to do is more than cast iron welding. And as the technology is fairly new expenditure was higher, but the enhancement of function was clear.

Finally, by conducting value engineering study it was decided to conduct metal-locking on the pressure vessel. The major gain was the bonding of the cracked parts and the pressure vessel became as good as new. This particular technology will not allow further cracking. Whereas, with cast iron welding it was not assured. This is another example of advantages from value engineering.

Value engineering and Kaizen can go hand in hand. Value engineering enhances function and Kaizen helps in solving a problem. So the maintenance team should come forward and make it happen. First of all, it is recommended that a training event on value engineering, be conducted for the engineers in maintenance. Once the concept of clear maintenance team can create wonders in this beautiful game of value engineering.

CHAPTER 16



Role of Visual Control in Maintenance

The role of visual controls is ever growing in any function of a manufacturing unit. "Visual control" means using pictures, graphs, cartoons, hand-drawn sketches, identification numbers, names, color coding, indicators, arrow marks, etc., to reduce the time taken to search or inspect. It is also a method to indicate some abnormality. It is used to highlight something in order that the operator does not miss it. In a nutshell visual control is using visuals mentioned above more extensively in order to highlight, indicate or guide and save a lot of time and resources.

As we all understand visuals have no language barrier. Anything done by using visuals becomes quick to understand. When you see a visual the message should jump out. So, it is necessary to use standard visuals. Of course you can have some creativity in visual control. But the creativity should be used to identify clearly the purpose. In one factory in Japan they used a fish tank as a visual. It is surprising to know how a fish tank found its place in a manufacturing plant. Well, they say that as far as the air bubbles are coming in the fish tank the fans to cool the motors of blowers located in the basement are functioning correctly. What is the objective here? For inspection somebody had to go to the basement regularly. Now this air bubble indication is enough to make sure the fans are working. This is a good visual but offbeat. Encouraging innovative ideas is needed to encourage people to take part in creating some visuals like this.

That is the reason you find visuals in every plant.

Internationally, the application of visual controls is ever growing. They are now extensively used in aircraft, public places, in commercial buildings, in transportation and in manufacturing plants. These visuals can be classified into various categories.

16.1 IDENTIFICATION MARKS

Numbering, naming, sizes, weights, color coding to identify type or model, etc. See Fig. 16.1.

Fig. 16.1

16.2 IDENTIFICATION OF THE CONTENTS

Color coding, pictures, naming, volume, etc. (See Fig. 16.2.)

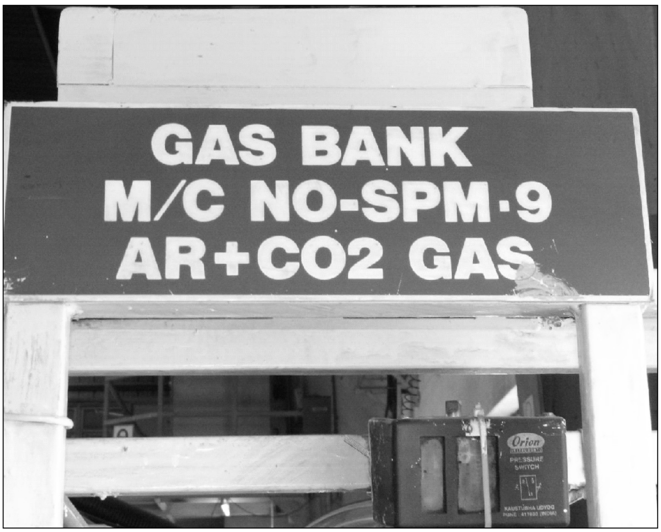


Fig. 16.2

16.3 IDENTIFICATION OF NORMAL VS. ABNORMAL

Oil level in a gear box indicating normal level and abnormal level. X mark indicates wrong practice or wrong method and check mark indicates right practice or right method.

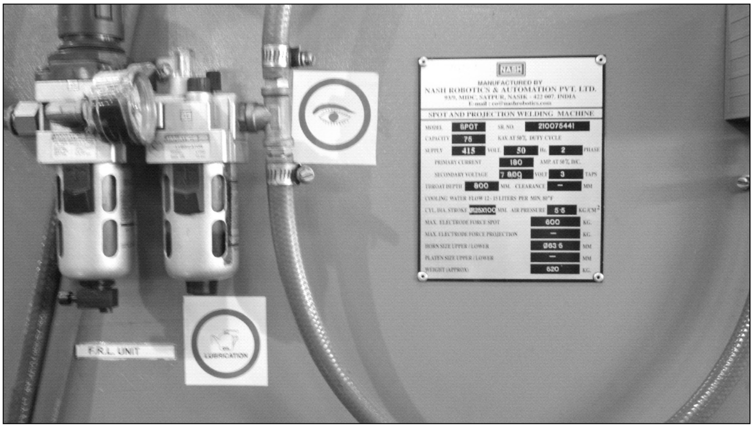


Fig. 16.3

Use the senses like touch, feel, hear, see, smell, taste, tighten, etc. (Fig. 16.4).

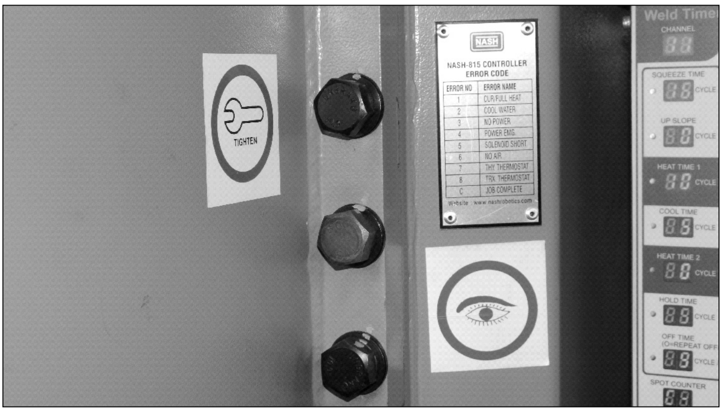


Fig. 16.4 Indicating action

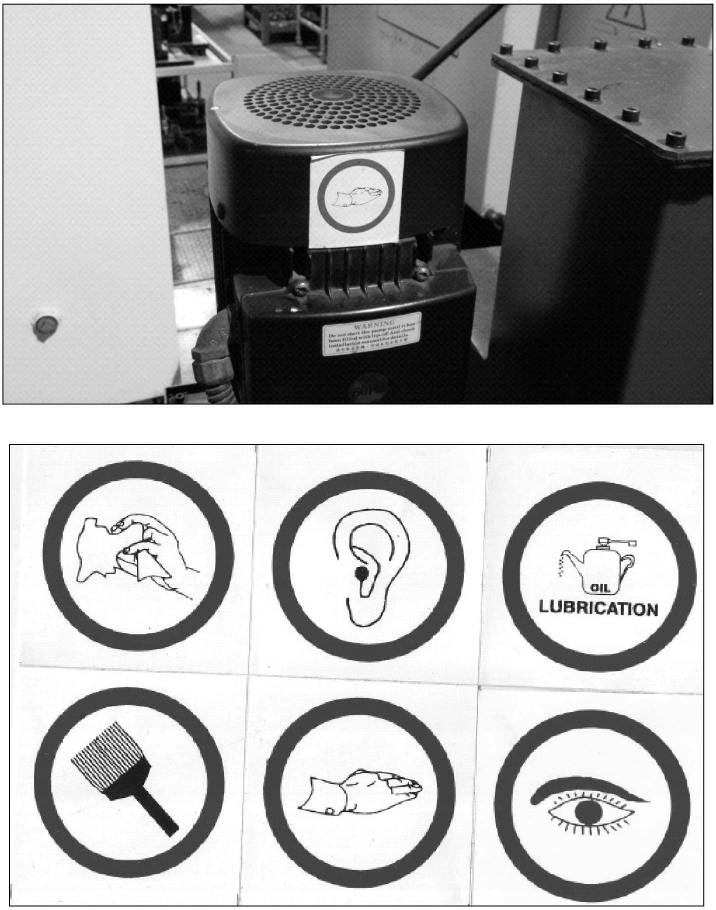


Fig. 16.5

16.4 INDICATION OF FLOW

Arrow mark showing direction of flow or showing direction of rotation.

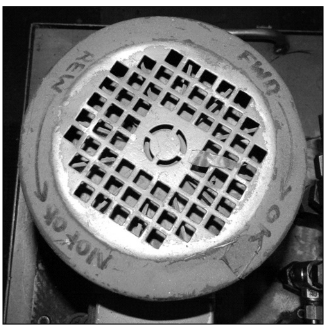


Fig. 16.6

16.5 INDICATION OF CAUTION

There are visuals indicating caution: pedestrian crossing, drive ways, electrical power. See Fig. 16.7.

Fig. 16.7

16.6 HOW ARE THESE VISUAL CONTROLS USED FOR THE MAINTENANCE FUNCTION?

Visual controls are used to improve efficiency and effectiveness of the people working in that department. How is this done in maintenance function?

16.6.1 Everything Has a Place and Everything is in its Place

This is a principle we had agreed for maintenance function. So identification numbers, names, pictures, yellow line markings, location maps, etc., will make sure that spares, tools and consumables are kept in proper places and without searching they should be available quickly so that the efficiency is improved.

Fig. 16.8 (a)

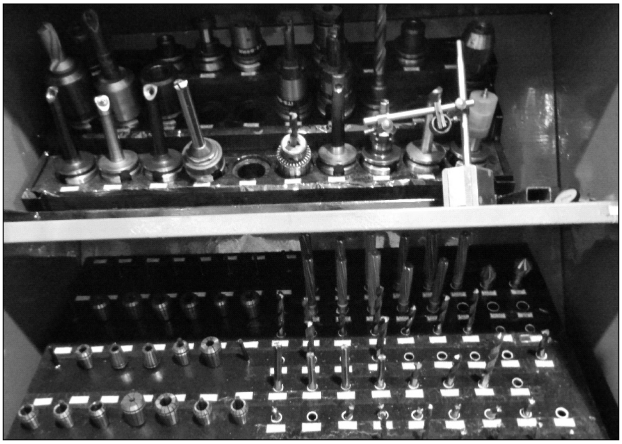


Fig. 16.8 (b)

16.6.2 Normal Vs Abnormal

This is a quick indication to the people if anything is abnormal or about to become abnormal. Examples are oil level glass with green and red markings, thermal labels on motors, flow meter indicators, current or voltage indicators, etc. See Fig. 16.9.

16.6.3 Shadow Diagram on Tools Display

This is general practice to have the shadow of each tool arranged as per the size or use. If any one tool is missing it indicates by the shadow. See Fig. 16.10. File storage has a cross line which also shows the missing file. (Fig. 16.8(a))

Fig. 16.9

16.6.4 Color Coding of Pipelines

If the manufacturing unit has too many pipelines having different materials flowing through them, then these are colored with internationally approved color codes.

16.6.5 Color Coding of Lubricating Oils in Storage and Use

This is done universally to avoid mix-up of oils. The oils are standardized and then they are indicated by color codes. The can in which it is dispensed inside the plant is also having similar color. In addition the user points are also marked with such color to indicate where exactly the particular oil is used for lubrication.

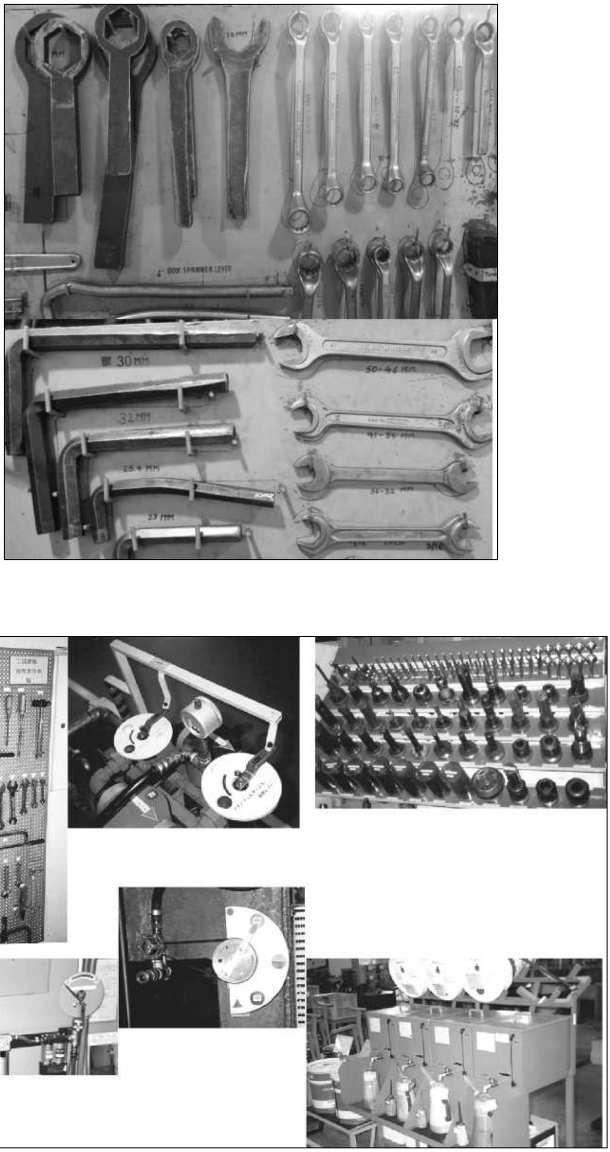
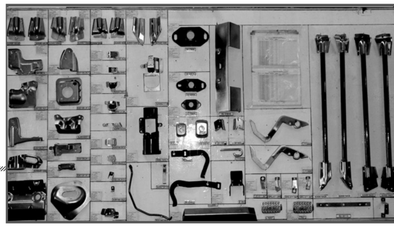


Fig. 16.10

Master layout plan and indication to retrieve spares from stores: The technician who wants to retrieve any spares or stores item should be able to do it in 30 seconds. This is efficiency in the stores. In order to do this a master display board indicates where the spares are kept in the stores and there are racks which are clearly marked. Each spare part is marked with a tag and so it is easy to retrieve it. In computerized stores this can even be done in the computer so that it is identified easily.

CHAPTER 17



Journey to Achieve Zero Breakdowns

Figure 17.1 shows the four phases of a journey to achieve zero breakdowns. The starting point could be any situation in a new or old manufacturing plant. So you may just carefully understand the four phases of this journey and start implementing. It has been proven that this path works and has been tried out by various plants globally. Before we move on we need to understand a few things.

There are thick arrow marks indicating that we shall move from phase 1 to phase 4. So we are moving from left to right in this page. What does that indicate? That means we are on a progressive path which starts from phase 1 and moves to the right till phase 4.

In Fig. 17.1, you will see a few bell curves. These are nothing other than normal distribution curves. So, what are these bell curves representing here? Starting from left you will start with a normal distribution curve which is looking very wide and lower in height. This curve represents the state of the breakdown on particular equipment chosen to achieve zero breakdowns. The curve is wide means the variability is high. Obviously the base is wide means the height of the curve is lower or it is a flat curve. The other bell curves are also normal distribution curves representing the statistics of breakdowns at various phases. You will see one interesting phenomena here. That is, as the teams undertake this journey of zero breakdowns and start working on the equipment the bell curve moves away from the starting point (from left to right). That means the average or mean of the normal distribution curve is becoming bigger in magnitude. In other words that means the mean time between failures (MTBF) is getting enhanced. This is very interesting to watch as to how the MTBF getting enhanced and how the team selects the replacement

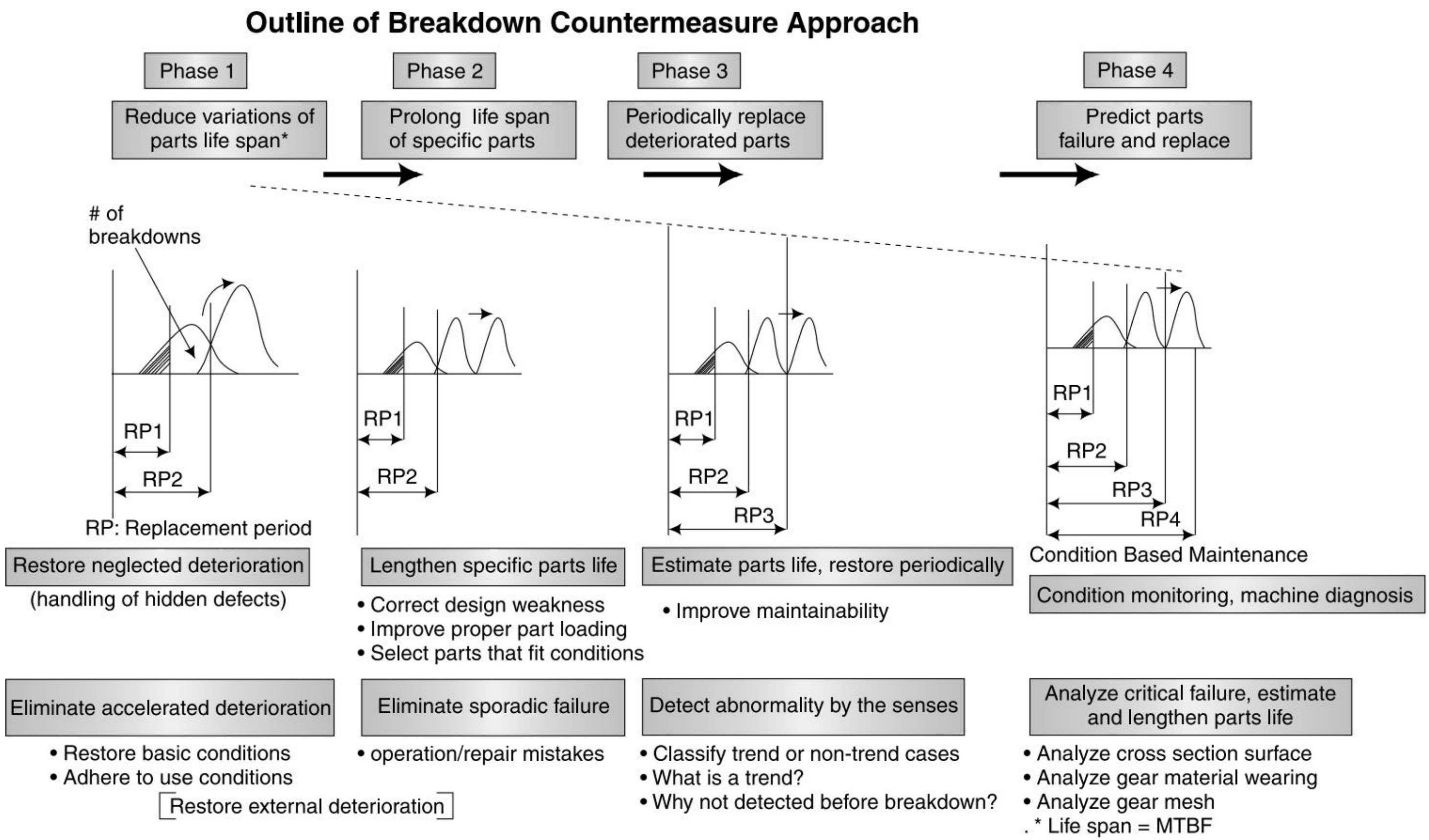


Fig. 17.1 The four phases to zero breakdowns

period (RP) for every situation. Replacement period means the periodicity to replace the components or parts. This replacement of components may take place as a result of breakdown or due to time based maintenance (TBM) or condition based maintenance (CBM) as we move from phase 1 to phase 4 as shown in this diagram. Let us now understand as to what are the activities to be carried out in various phases to achieve zero breakdowns.

17.1 PHASE 1: REDUCE VARIATION OF COMPONENT LIFE SPAN

In phase 1 the main theme or objective is to reduce variation of parts life span. That means initially you will find each component behaving any which way and you will see the life of the important components varying a lot. Why does that happen in the equipment? That is happening because of forced deterioration, natural deterioration, accelerated deterioration and also because of lack of effective lubrication. So what do we do now in Phase 1 to eliminate or reduce all this kind of deterioration?

This is done by the restoration work as mentioned in Jishu Hozen. Initially, you see the life span of any given component fitted on the equipment varies largely due to various reasons:

1. Neglected deterioration (forced deterioration and natural deterioration)
2. Accelerated deterioration
3. Lack of inspection carried on the equipment
4. Lack of effective lubrication method
5. Lack of tightening of fasteners fitted on the equipment.

Now the Jishu Hozen team will work on restoration. That means bringing the equipment to the original condition (as good as new one). If the teams identify all obvious as well as hidden problems and do the restoration work on them there are chances that the breakdowns will reduce and MTBF shall get enhanced (2 to 5 times). You may see in this diagram in phase 1, the normal distribution curve moved to the right and the magnitude of such shift will be depending on the restoration work and the attention given on the individual component which keeps failing and end up in a breakdown of the equipment.

Here, due to restoration work there will be a big enhancement of MTBF (mean time between failures). You will also see in the diagram in phase 1, there is RP1 and RP2. These represent, as mentioned earlier, replacement period (RP). RP1 is the replacement period which was established before any of the restoration work started. How was this RP1 established? This must have been done arbitrarily or without much thinking. Just to see that the part shall be replaced to reduce breakdown.

But after the restoration work you will see a big shift and the team shall establish RP2 which is larger in magnitude compared to RP1. Moreover the team also needs to institute the cleaning, inspection, lubrication and tightening (CILT) standards as mentioned in the Jishu Hozen. This is very important for sustaining the gains for a longer period. Restoration work along with cleaning, inspection, lubrication and tightening carried out by the operator of the equipment will give results to enhance MTBF and in most of the cases may totally eliminate breakdowns.

But, how was RP2 established. The bell curve has shifted to the right side. That means a new bell curve has come into picture in phase 1. The two bell curves represent breakdowns, but physically they look different. So, what is the difference? The second bell curve looks slimmer and taller compared to the first one. That means the variability has reduced due to restoration work and instituting CILT. At the same time the second curve has become taller. That means the average or mean of the curve has increased. That also means that MTBF has been enhanced to certain extent. Based on the shape of the second curve RP2 has been established. It is easier to establish replacement period when the curve becomes slimmer or variability has reduced.

17.2 PHASE 2: PROLONG LIFE SPAN OF SPECIFIC PARTS

Here, the focus is on enhancing the life span of specific parts. At the same time importance is given to elimination of the some of the sources of problems:

1. Design weaknesses.
2. Overloading of specific parts or components.
3. Bad operating methods.
4. Poor quality maintenance work.
5. Sporadic problems

17.2.1 Design Weakness Correction

A thorough study is conducted on the failures or breakdowns of specific parts or components. What are these specific parts? During the study of the failure or breakdown of the equipment one will notice that there are only a few components give problems or breakdowns. If one carefully undertakes study and identifies these parts or components of the equipment then the work becomes simple and the focus will be only on these two or three components. Extensive study of the root cause of these few components shall be carried out by using the tools like “cause and effect analysis” or in some cases “work point analysis” and if needed “PM analysis”. In this study focus is on finding the root cause specifically finding out design weakness or defects in design of those components. This analysis will give rise to “design weakness correction” or also called corrective maintenance. This needs thorough study, interaction with production, maintenance and manufacturing services department and in some cases the design department of the manufacturer of those components which are under study.

17.2.2 Overloading of Specific Parts

This phenomenon is not new in certain equipment. This is a very common feature in automobile industry. Even though the vehicle is not designed for such loads, the customer may in some cases overload the vehicle and this may result in failure of certain components. This feature is common in other industries also. This happens where certain components are made by other suppliers and then in the final assembly there is mismatch of the loading pattern or use pattern. This results in early failures or sporadic failures. This, though in some cases is not a design weakness ends up in upgrading of the component. Overloading is a very common phenomenon and failures do occur due to overloading of some components. To achieve zero breakdowns it is important to address these issues in phase 2.

17.2.3 Bad Operating Methods

In automotive industries this is a very common phenomenon. Careless or negligent operation is a common practice. Even in manufacturing industries this can happen if the operator is not trained on the method of operation carefully. This happens when there are tremendous pressures to produce more. Many a times an effective “on the job” training to the operators will help. In some rare cases the operators will need an extensive training on the method of operation with clearly identified do’s and don’ts will be needed.

17.2.4 Poor Quality Maintenance Work

Even poor quality of maintenance work recently carried out can result in breakdowns or failures of components. Generally, maintenance personnel are highly skilled and so intentionally they may not carry out work of poor quality. However there can be some cases where the skills are deficient or due to negligence of the maintenance person, poor quality work can happen. In such cases a clear “one to one” talk or a small “on the job” training will help. In a few cases calling the equipment manufacturer and getting a thorough "on the job" training imparted to the maintenance personnel may be the best solution to such issues.

17.2.5 Sporadic Problems

These are problems occurring on the equipment or components which are repetitive in nature. Many a times when the problem occurs or the breakdown takes place the maintenance personnel are quite aware of the situation and also the remedy for those problems. But due to small errors, or poor quality of spare parts or consumables the problem gets solved temporarily. This particular situation is not unique in industries. Immediately after the temporary solution has been carried out the team should look for the root cause and get into finding out a permanent solution. Otherwise the problem will appear again and even then, the team will get into a temporary solution. This is how sporadic problems take place. Since our objective is to achieve zero breakdowns addressing sporadic problems is important in phase 2.

17.2.6 Address Chronic Problems

What are chronic problems? Chronic problems are those problems which have been there in the equipment but could not be resolved due to lack of understanding. Then how can we resolve them? Chronic problems are complex in nature and so they are difficult to solve. However, since our goal is to achieve zero breakdowns, it becomes imperative to solve them. A special team is generally set up for solving chronic problems. The team shall use experts from maintenance, operation and manufacturing engineering and set up the journey.

A thorough knowledge of the complex tools like work point analysis or PM analysis is needed. So the team may start with training on PM analysis and take one chronic problem as a case study. Set a time limit of 90 days and solve the problem. PM analysis is time consuming and at times difficult since the standard value of some contributing factors may not be available offhand in the plant. However, sincere effort will always give results.

Just in case it is not possible to solve a particular chronic problem, then call a PM analysis expert and take that problem as a model, and ask the expert to conduct a workshop on PM analysis with this problem on the table.

These are the six important activities carried out in phase 2. As a result you will see the normal distribution curve shifted more to the right side. That means by completing these activities the MTBF has got enhanced in a "big-way". This will be at least 5 to 10 times the original MTBF. What does it mean? That simply means that we are moving in the path of zero breakdowns and whatever activities we have completed so far are giving good results.

Let us take a stock of what we have done so far in phase 1 and phase 2. In phase 1 we focused on restoration using the Jishu Hozen methodology. The operator teams conducting initial cleaning of the equipment. After thorough cleaning, identifying abnormalities (defects, hard to reach areas and sources of contamination) is carried out meticulously so that all the forced deterioration is completely eliminated. Then a list is prepared on these abnormalities with clearly identifying by using white tags and red tags. Further, the team with the help of maintenance function gets into fixing of all abnormalities. The team also gets into the study of the lubrication system. Improve the lubrication system to get adequate lubrication of the parts. Then they get into the study of fasteners and make sure that the breakdowns are not caused by wrong fasteners or fasteners getting loose while in operation.

All the defects are addressed, cleaning, inspection, lubrication and tightening standards are prepared and operators start implementing cleaning, inspection of the equipment, checking the lubrication system and checking for the loose fasteners. This will enhance the MTBF to a certain extent.

In phase 2 the teams get down to design corrections if needed. It does not mean all the equipment need design corrections. These design corrections are needed where due to the analysis of major breakdowns some design deficiency is identified or in some cases improvement is needed due to Kaizen activities done by the teams. Similarly, the breakdowns or failures of the components are taking place due to overloading are also addressed. Failures or breakdowns taking place due to bad operation by the operators and poor quality maintenance work are addressed. Furthermore, the root cause study was done on the sporadic problems and permanent solutions to those sporadic failures were carried out.

This is an important stage in the journey of zero breakdowns. Hereafter we shall change course and do some important work with the normal distribution curve, which has moved to the right a big distance (MTBF got enhanced 5-10 times or more).

17.3 PHASE 3

The highlight of phase 3 is implementation of TBM. We have discussed at length about implementation of TBM. Here we would not like repeat the same. But there are a few key points we would stress upon and bring them here.

17.3.1 Periodically Replace Deteriorated Parts (Components)

The main theme in phase 3 is about getting into periodic maintenance or "time based maintenance (TBM)". This part of the effort looks simple, but our objective is to get zero breakdowns and so it does not turn out to be so simple. The following are some important steps to be carried out in phase 3.

17.3.2 Estimate Part's Life in Order to Implement TBM

This again appears to be an easy game. But in practice it requires many inputs and the team will have to listen to all such inputs before estimating part's life. This does not mean that we need to go to the other extreme by becoming very cautious and estimating part's life on the lower side. This will lead into TBM which is not cost effective. In order to make it cost effective and at the same time achieve zero breakdowns, it is needed to take all the inputs. Those inputs generally are discussed below.

17.3.3 Input from Manufacturers Manual or Service Manual

This works very well in the case of a manufacturer who has done extensive studies on the life of the components knowingly for the customer who is interested in achieving zero breakdowns. These days most of the manufacturers give a list of spare parts to be kept in store. How does the manufacturer draw a list? Manufacturer has one major responsibility: that is supply of spare parts to the customer. Just in case the particular spare part is not put in the production plan, they will not be able to supply spare part. That will be a very poor show from the supplier's side. So the supplier will generally draw up a list of long lead time spares and give it to you. However, our interest is that we would like to just decrease our inventory levels, but at the same time we would like to have the spare part ready when there is a breakdown or preventive maintenance is planned. If you look at the automobile industry, all cars have a service manual and which part to be replaced when is clearly written there. How do they do this? They would have conducted research on all the parts in the list and have drawn up a clear list as to when which part has to be replaced. There is no dispute between the service station and the customer.

But this type of situation does not exist in industries. The periodicity to replace a part shall be drawn by taking inputs from various sources.

17.3.4 Input from the History Cards

This is purely using in house data. That means go back to the history data and see how often the breakdowns have taken place. From this background decide what should be the periodicity. If the data collection is meticulously done this may be a good data to rely on. However, all the changes should have been incorporated in the history cards and history cards are updated. This is a very reliable data for this purpose. However, all equipment in the plant may not have long drawn history. If the equipment is new then such history may not exist.

17.3.5 Inputs from Senior Technicians or Senior Engineers

This is another source of information. In places where the data from the history cards are not very reliable then you may get into this source of information. Some senior technicians have so much insider information which is not captured as record and it is very useful even if you have history cards or information from the manufacturer's manual.

17.3.6 By Preparing a Normal Distribution Curve and Getting into Statistical Methods

This is what is shown in the diagram. Again, before getting into making a normal distribution curve one should check the authenticity of the data on failures of those relevant components. The normal distribution curve is as accurate as the data. But it is fun to use the bell curve and establish the replacement period.

17.3.7 Your Experience

This is another method. If the component does not behave as the history, it is better to use your actual experience and decide about the life of a component.

17.4 ESTABLISH REPLACEMENT PERIOD (RP 3)

Based on the information on the life of the component one should establish the replacement period. Here, one has to keep in mind that our objective is to achieve zero breakdowns and so we need to take care that the part is replaced as an activity of time based maintenance. The time based maintenance is also called preventive maintenance; that means it is preventive in nature and will not tolerate any breakdowns after the replacement has taken place or any part has failed due to delay in conducting TBM.

17.5 IMPROVE MAINTAINABILITY

This is another important aspect. Any amount of study on estimation of part's life will be of no use if the equipment is difficult to maintain. That means there are difficulties in opening and fixing the parts and so there are hindrances to achieve good quality preventive maintenance. So, it is advisable to identify any such areas in that equipment and eliminate them before getting into detailed TBM. This may need some design changes at times or relocation to create more working space, etc.

17.6 DETECT ABNORMALITIES BY SIX SENSES OF THE OPERATOR

These six senses are touch, feel, smell, see, taste and imagine. Imagination is very powerful as we all know. The operator should conduct inspection by using these six senses and identify the problems which are cropping up. This will be a great help in achieving zero breakdowns.

17.7 CLASSIFY TREND OR NO TREND

We need to identify whenever a failure or breakdown takes place, whether it is a trend item or no trend item. As we have learned in "bath tub curve" 89% of the cases are happening randomly and so we need to identify if it is trend item or a random item. If it is a random item then we should not take any chance on the life of the component and establish safe method of replacement.

In phase 3, basically we are trying to establish the life of the component and establish the replacement period. You may see in the diagram the third normal distribution curve which has moved a distance (MTBF enhancement) needs us to establish the replacement period RP3. If the RP3 is established carefully for all the equipment under discussion, you will start experiencing zero breakdowns from that time onwards. So you will get the taste of achieving zero breakdowns; but cost of maintenance will still remain for attention. That means TBM or preventive maintenance is an expensive method of maintenance and the zero breakdowns we are currently achieving are not cost effective. We need to further work on the phase 4, to reduce the cost of maintenance by further enhancing the replacement period.

This does not mean that we have not achieved reduction of maintenance cost so far. By reducing the breakdowns, we have achieved significant amount by doing all the activities so far. In phase 1, the team has implemented restoration. During the restoration the cost normally goes higher as we are spending money in a big way. However, phase 2 gives some savings. Phase 3 gives significant savings as breakdowns have come down drastically. TBM is an expensive method of maintenance since we are at times replacing parts before they have completed the life. No matter how accurately we estimate the life of an equipment or component it will be on the lower side and since we are replacing the parts before their life is over. That means we have lost some small part of their life. This thought process gives rise to predictive maintenance and we shall discuss that in phase 4.

17.8 PHASE 4

17.8.1 Predict Parts Failure and Replace

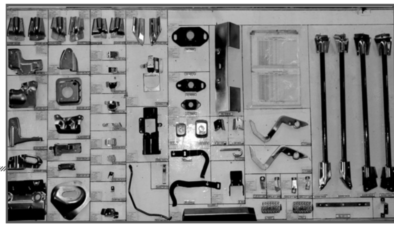
Now in phase 4 we shall get into the predictive maintenance or condition based maintenance (CBM). As a part of condition based maintenance we need to assess the condition of equipment or assess the condition of components. This science is now developing and one has to make use of the modern techniques in condition based maintenance.

As mentioned earlier in phase 3 operators carrying inspection of their equipment and assessing the condition of the equipment or component is very important. This is the beginning of condition based maintenance. Even if one organization invests heavily in the condition monitoring tools, this part becomes most important as it is not possible to assess the condition of all the equipment on a daily basis. This is where Jishu Hozen (CILT) becomes very useful.

We shall go back to the normal distribution curve in phase 3. In order to achieve zero breakdowns we have established a replacement period RP3. In other words we have established by the help of statistical method a replacement period. Before any breakdown starts in the bell curve we have established RP3; so that we would have replaced the parts before any breakdown takes place. This is a sure path to achieve zero breakdowns. But, however, as discussed earlier probably we have not made use of the full life of the component as we have gone by the statistical method of breakdown pattern and establishing the life. In order to get full use of the life of component and equipment we need to establish the condition by scientific methods and be able to predict as to how much more life is available of those components or equipment. This is achieved by using those diagnostic tools or condition monitoring tools. Here, when we do it accurately we will have a confidence of replacing the parts by condition monitoring method. This is how we will be able to establish RP4 as mentioned in the diagram. RP4 is larger than RP3 and so economy or further cost savings will come into picture.

You may see a dotted line on top flowing from phase 1 to phase 4. This is representing the saving in maintenance cost which can be achieved by implementing the four-phase methodology to zero breakdowns. A saving of 20% to 25% of the maintenance cost has been achieved in some plants.

CHAPTER 18



Progressive Maintenance Total System

This is a one page chart (Fig. 18.1) showing comprehensively all that we have discussed so far in the world class maintenance system or progressive maintenance system. There is a lot of give and take from various functions to make the maintenance function world class. The maintenance function has to take the lead in establishing the communication needed to achieve success. There are other key players in making the maintenance function successful. Let us discuss those in detail and the key activities to be done by maintenance within their department.

18.1 PURCHASE FUNCTION

In purchase we have two key activities: capital purchase or purchase of capital goods and purchase of spares and consumable items. Both these activities are very important in achieving good results. In capital purchase this department gets inputs from manufacturing services of some companies. In some other companies the input comes from maintenance department. In the initial "front end engineering work" input is given by either of these departments. This is a key function to identify the supplier or vendor for the capital goods among the alternative suppliers. Life cycle costing is an important activity to be undertaken at this juncture. Also the data to improve the design of the equipment which has been identified to buy shall be given by maintenance function and to be handed over after proper negotiation with the vendor. Ultimately the equipment bought from the vendor should be defect free and accepted by the maintenance function in letter and spirit. This capital purchase area is applicable to even building construction and installation and commissioning of utilities equipment area too. In purchase of spares and consumables the commitment of the purchase department is important.

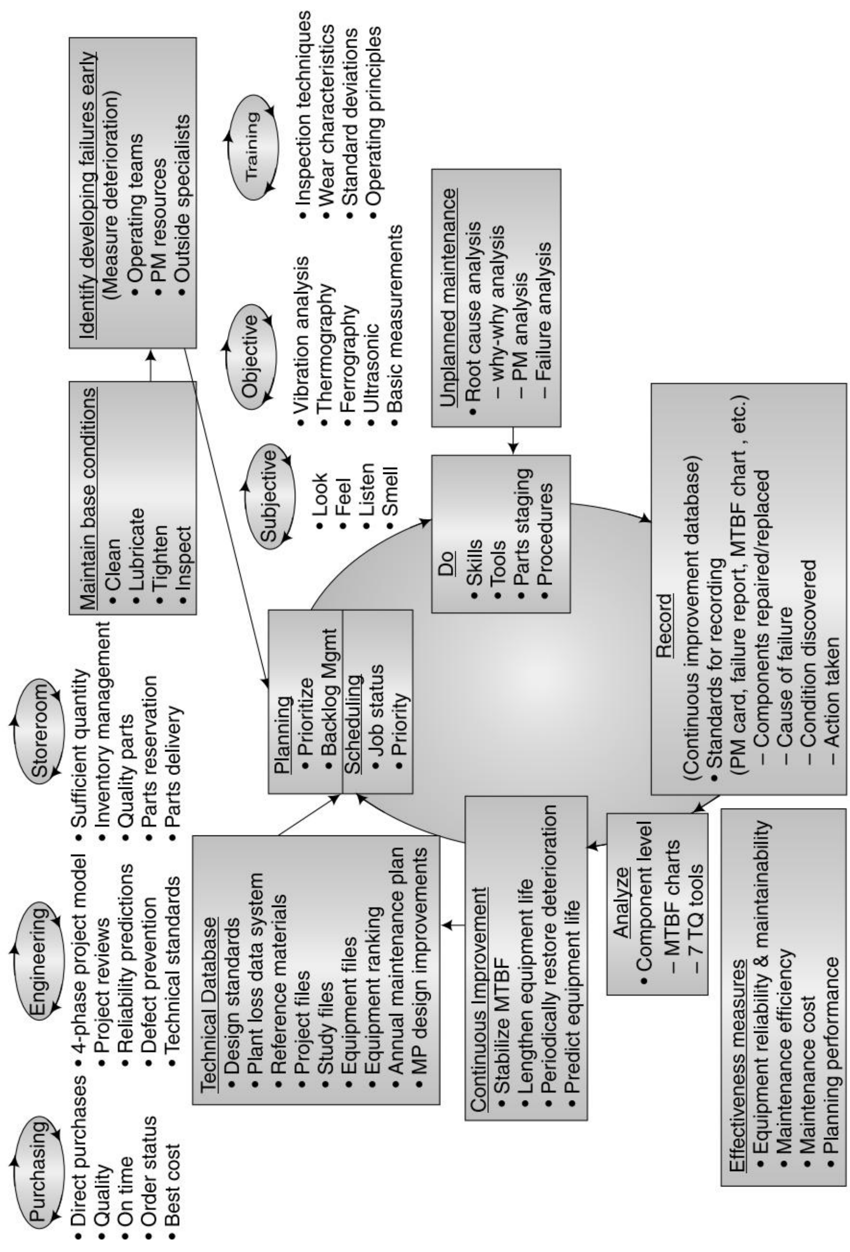


Fig. 18.1 Progressive maintenance system

Imported spares Vs locally developed parts is one key area. Secondly, cost of the spares is another important area. In order to save money and bring down maintenance cost the role of purchase is the key. Thirdly, the lead period to purchase spares is also important help from purchase function. Avoiding emergency purchases and save on premium price and premium freight is also important.

18.2 ENGINEERING (MANUFACTURING SERVICES)

Some companies have a separate department called engineering or manufacturing services. This function helps maintenance in deciding the production capacity needs, planning the layout, drafting the specifications, having technical discussions with the vendor and finalizing the vendor. It also helps in conducting inspections at suitable timing.

They also get into the four phase project model until installation, commissioning and start up of the equipment. MP data is generated and maintained. Maintenance department created MP data is used by engineering department before ordering the equipment, to ask the vendor to implement. The engineering department will also help in achieving some important results.

18.3 STANDARDIZATION REQUIREMENTS

Standardization is carried out by maintenance department and engineering department jointly to reduce inventory of spares and for ease of maintenance. This helps in reducing MTTR.

18.4 OPERABILITY REQUIREMENTS

They also need to take care of the specific requirements of the operation department in order to make the operation easy. This includes some of the requirements for clean, inspect, lubricate and tighten (CILT) which we have discussed in Jishu Hozen. Also, helps to incorporate visual controls in the new machines so that the same need not be done later by maintenance department in the plant.

18.5 MAINTAINABILITY REQUIREMENTS

This includes effort and list of items needed to improve the ease of maintenance. In some cases these are big ticket items which will include major changes in the structure of the equipment. In some other cases it may just provide some space for maintenance work.

18.6 MP DESIGN REQUIREMENTS

These are the requirements coming out of the MP data colleted on equipment. This leads to design improvement at the vendor's design department. This will finally reduce the defect levels to zero while the equipment is finally installed and commissioned.

18.7 RELIABILITY REQUIREMENTS

These inputs come from either the vendor's market feedback or the customer. The customer also can give valid inputs to improve the Reliability of the equipment.

18.8 SPARE PARTS STORE ROOM

In some manufacturing units the storeroom is directly under the charge of maintenance department. However, in some large plants like fertilizers and petrochemicals the storeroom is under the finance department and located centrally with the raw and packaging material stores. However, there is a good amount of interaction between the maintenance department and the storeroom. The store is responsible to maintain inventory as per the inventory policy of the company. At the same time the minimum, maximum and reordering quantities are decided by the maintenance team. The store also takes care of some insurance parts to be reserved and kept all the time. Cycle counting activity and maintaining the inventory record accuracy is the responsibility of the store. The delivery of spares for the maintenance department without delay is important to reduce MTTR. Maintaining the quality of parts, especially locally developed parts is joint responsibility of maintenance department and stores.

18.9 RESTORATION

The next important item is restoration or Jishu Hozen. This needs the formation of teams throughout the plant and these teams or circles performing Jishu Hozen work. This includes initial cleaning, identification of abnormalities and fixing abnormalities, study about the lubrication system and improving the lubrication system to get very effective lubrication, then finally tightening of the fasteners wherever it is necessary. Then the teams shall make tentative cleaning standard, inspection standard, lubrication standard and finally tightening standard. The operators shall be trained by the maintenance technicians on how to implement the CILT as per the standards they have made. Once they pass the audit on step 1, step 2 and step 3, the operators start the implementation of CILT regularly and find any abnormalities take place on a daily basis. By this the teams shall reduce the losses taking place on their equipment. The losses are breakdown loss, minor stoppage loss, set-up time loss, quality rejection loss and accidents. This methodology is continued up to Jishu Hozen step 7 to get full benefit of TPM methodology. This part of effort has become integral with world class maintenance.

18.10 IDENTIFY DEVELOPING FAILURES EARLY

This is a major shift from the old style of maintenance management system. What is new? That is identifying developing failures of abnormalities at an early date by introducing inspection. This inspection has three parts.

18.10.1 Inspection Carried Out by Operating Teams (Jishu Hozen): Subjective

Operators carrying out inspection by subjective methods, by touch, see, hear, smell, taste and imagine. These are the six senses a person can use to inspect.

18.10.2 Inspection Carried Out by Maintenance Team

This is carried out by the maintenance teams while performing preventive maintenance (TBM and CBM).

18.10.3 Inspection Carried Out by External Specialists: Objective

These specialists as mentioned earlier are specialists in diagnostic tools and specialists in predicting the life of the equipment or their components. The other set of specialists is internal specialists who are specialized in carrying out inspection throughout the plant. These specialists belong to the inspection department in large organizations like fertilizer, petrochemical plants etc. They carry out the inspection in a planned manner throughout the plant. They are objective measurements and are vibration analysis, ultrasonic thickness measurement, thermography, ferrography, infrared scanning, etc.

18.11 MANAGING PLANNED AND UNPLANNED MAINTENANCE

Planned maintenance needs planning and scheduling. Looking at the backlog, part staging and improving the compliance rate of preventive maintenance. Unplanned maintenance needs root cause analysis; why-why analysis, fish bone analysis and PM analysis as the case may be and completing all the work order requests from the operations department. It also needs training for improving the diagnostic skills and maintenance skills.

18.12 MAINTENANCE RECORDS

The next item in the diagram is maintaining records. This includes history cards, parts replacement records, cost records, MTBF and MTTR records.

18.13 EFFECTIVENESS MEASUREMENT

This includes reliability measures, planning performance, MTBF and MTTR measures, cost of maintenance and maintenance efficiency.

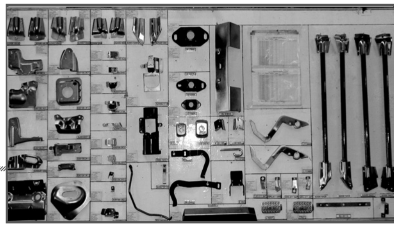
18.14 JOURNEY TO ACHIEVE ZERO BREAKDOWNS

This will include component failure analysis and continuous improvement methodology. This includes corrective maintenance and Kaizens to achieve zero breakdowns.

18.15 TECHNICAL DATA BASE

This includes equipment ranking, design standards, project files, technical standards, MP data, annual maintenance plan equipment files and manuals.

CHAPTER 19



Performance Measures for the Maintenance Function

It is necessary to establish performance measures and track them to see whatever efforts you have made are giving results. Like any other function in a corporate world, it is prudent to have performance measures in place and regularly track them. This will not only help in checking if the system you have established is effective or not, but also checking if the function is meeting overall business objectives.

19.1 IDENTIFY YOUR "PERFORMANCE MEASURES"

The performance measures you are going to establish should represent the key result areas and they should be in line with the business objectives.

19.1.1 Breakdown Time as Percentage of Total Time

This is an important measure to understand how much of the productive time is going into breakdowns. Recording this time accurately needs some level of understanding with production department. This is the practice in manufacturing units as they will finally sign as the breakdown is attended. However, care should be taken not to put all delays in communication or delay in sign off to accept the equipment after it is handed over to the production.

19.1.2 Number of Breakdowns

This is also another important measure. In some cases more importance is given to number of breakdowns rather than percentage time of total time. In a journey of zero breakdowns it is always a general practice to establish an interim target for breakdown as percentage of total time and number of breakdowns.

19.1.3 Frequency of Breakdowns

Total number of breakdown occurrences/total operating time.

19.1.4 Preventive Maintenance Compliance Rate in Percentage

Total number of PM (preventive maintenance) work completed/Total number of PM work planned.

This measure specifically talks about the rate of compliance of PM work versus the PM plan. This will clearly show if the implementation of the plan demands more resources than actually envisaged in the beginning. It also highlights the activities planned (checklist) and what parts are needed to be replaced in TBM. In case the compliance rate is lower, in order to improve the compliance rate it is needed to look into details of time taken for checklist activities and parts to be replaced by the preventive maintenance team. As an interim target it should be at least 90%.

19.2 PREVENTIVE MAINTENANCE TIME RATIO: (TBM + CBM)/(TBM + CBM + BM)

This ratio is showing clearly how much of preventive maintenance is help to reduce breakdown maintenance work. As an interim target it should be at least 90%.

19.3 COST OF MAINTENANCE

Using the computerized maintenance management it is possible to track the maintenance cost on the equipment and that cost should be trending down. Interim targets need to be established. In practice in phase 1, generally cost goes higher due to restoration work. This demands a lot of effort from the maintenance function and a lot of spare parts get consumed during this period. Hence the cost goes higher. In some cases it goes higher by 20% to 25% of the maintenance cost during phase 1. Even in phase 2 it remains lower than phase 1 but depending on the amount of design correction work it will go higher than phase 1 or lower. Later, in phase 3 and in phase 4 it goes down. For an interim target it should be at least 25% reduction. Here we need to understand one thing. Here we are talking about the maintenance cost saving or cost reduction and not manufacturing cost reduction. The manufacturing cost comes down drastically throughout from phase 1 to phase 4.

19.3.1 Mean Time Between Failures (MTBF)

Total operating time/number of breakdowns (total stops-planned stops).

This measure tells in a nutshell the health of the maintenance function. The mean time should be going higher and higher. However, tracking MTBF for equipment in a department or taking the average MTBF for the whole plant is less productive. Make a list of the equipment for which MTBF enhancement has been taken up as a project and then start tracking MTBF for the equipment separately. The MTBF enhancement work has been explained earlier in Chapter 3.

19.4 MEAN TIME TO REPAIR (MTTR)

Total time taken for fixing breakdowns/number of breakdowns.

This is also another important measure as it indicates the efficiency of the maintenance department in terms of availability of spares, time taken to analyze to root cause and how the maintenance department is organized in terms of training and arranging tools and tackles needed etc. Here again taking the MTTR for the department or the whole plant is less productive. MTTR should be tracked for those equipments which have been chosen for reduction and then track them.

19.5 NUMBER OF KAIZENS IMPLEMENTED IN MAINTENANCE

It is a live wire measure. This indicates the participation of all the people working in maintenance. Officers and managers get involved in high jump Kaizens and technicians get involved in low jump Kaizens. This indicates the enthusiasm and creativity of people working in maintenance. It is not a number game here. The quality of Kaizens is very important. However, we need all to participate and so number also becomes important.

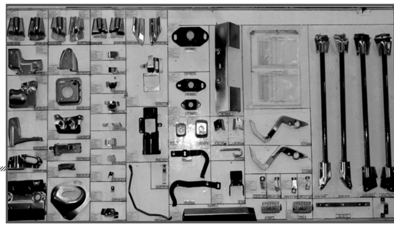
19.5.1 Start Tracking the Measures

Once the initial work of establishing the measures is completed start collecting data and establish a glide path. In the glide path on the X axis you have calendar months and in the Y axis you have the results represented by a bar. So glide path is generally a bar chart. The first bar on the left hand side is representing the current results. Current results means, average of last six months results. The next bar will be starting with result of immediate calendar month. The next shall be the next calendar month etc. The last bar is representing the target clearly showing by which calendar month the results are expected. Then a draw a dotted line from the top of the bar showing the current results to the top of the bar showing the target. This line is called glide path. Every month the tracking will show clearly the result is touching the glide path or exceeding the glide path. The glide path methodology helps tracking the results in a meaningful way. In case the results are not touching the glide path, discussions should be held in the team with ideas from all.

19.5.2 Display these on Your Department Board

Just tracking results is not sufficient. All people should be getting the information and participation to improve. In order to do this it should be displayed on an activity board and meeting should be held to communicate to all. Put team members' names and roles and responsibilities on the activity board. Display any other matter or appreciation or information on the board. This will create a lot of energy in the department.

CHAPTER 20



Industrial Safety Maintenance

Regular maintenance plays an important role in eliminating workplace hazards and providing safer and healthier working conditions. Lack of maintenance or inadequate maintenance can cause serious and deadly accidents or health problems. Besides, it can cause serious environmental issues which can result in major catastrophe like Bhopal gas tragedy (1984 Dec).

20.1 UNSAFE WORK METHODS AND PRACTICES

Accidents happen due to various reasons. Short-cuts in the method of working is one of the main reasons. Not wearing the personal protection equipment (PPE) is one such example. Wearing PPE but not wearing them properly is another such example. Accidents also happen due to faulty electrical installations such as shock and burns, fires, ignition of potentially flammable or explosive atmosphere.

20.2 LACK OF MAINTENANCE AND CERTIFICATION OF LIFTING TACKLES

Accidents also happen because the lifting tackles are not inspected, certified and maintained. Lifting chains are dirty and corroded and fail, causing heavy load to fall and create lot of damage to people and equipment. They can also happen due to slippery floors or ramps which are not maintained. Potholes on the surface of the shop floor and warehouses can cause accidents.

20.3 BAD FLOORING

Accidents also happen as a result of lack of maintenance of working and walking surfaces and traffic routes. This will cause accidents of forklifts and other material handling equipment.

20.4 BAD LAYOUT AND INSTALLATION

Accidents can also happen due to bad equipment layout and installation, both mechanical installations as well as electrical installations. These can also happen due to lack of maintenance or handing over the maintenance to outside contractors. One of the major accidents witnessed by the author is a chimney collapse. Contract people were deployed to do annual maintenance and painting of the boiler chimney. Due to corrosive atmosphere the metal chimney wall had become paper thin and just came crashing down like a cardboard partition. It was a major accident and several people lost their lives. Besides facing the bad publicity, the company had to give heavy compensation to the families of the people who lost their lives.

20.5 LACK OF COMPREHENSIVE FIREFIGHTING SYSTEM

Accidents can also happen due to fire which is quite common in industries. Industrial fires happen due to short circuit in electrical installations and again due to bad installation of electrical circuits and poor quality of maintenance. Fires can also happen due to processes like arc welding, gas cutting and spot welding processes. Hence, many steel industries are now realizing that they need to have carbon dioxide flooding systems for the furnaces and hot working areas.

Many industries do not have adequate fire fighting installations. This is because understanding by the owners of such industries have firefighting equipment installed as per their requirement. Instead, it should be standardized for the level of fire hazard the units have. Statutory bodies are realizing and are now insisting on most comprehensive installations for the new plants. Plants are located far away from the fire brigade stations and it takes hours sometimes to reach the place of fire. Due to this reason statutory bodies are making it mandatory to have a comprehensive firefighting systems consisting of hydrant systems, sprinkler systems, carbon dioxide flooding systems and dry powder systems for electrical fires.

20.6 LACK OF AWARENESS

Another major reason for accidents is lack of awareness of the safety hazards in the people who are working in the shop floor. This happens mainly due to new recruits being deployed in hazardous areas and lack of training to the employees on working methods.

20.7 BUILDING SAFETY

We cannot miss out on one major contributor for the accidents, that is, building safety. In developing nations this is very prominent. Due to poor design of the structural elements or poor maintenance of the structural members these failures take place. This is not so common in developed countries, but quite apparent in developing countries. Due to this reason statutory bodies in developing countries have made it mandatory to get the structural drawings approved by them and also carry out inspections by structural engineers on a predetermined frequency.

20.8 OVERLOADING AND UNEVEN USAGE OF THE BUILDING SPACES

It is quite common to note that once the building is approved by the statutory structural engineers the loading of the slabs and terrace spaces become haywire and can result in building collapse or portion of the building coming down.

Breakdown of material handling equipment can also cause accidents. Misuse of the equipment by unauthorized people, or careless operation done by the regular operators can also be the reason for accidents. There is a statutory regulation that all the material handling equipment, overhead cranes, lifting tackles, and wire ropes used in the equipment are tested once a year and certified for certain duration. Despite having such stringent statutory rules we may hear about accidents taking place in plants.

In many engineering industries scrap handling is also a hazardous process. This is one such area, where clear cut methods are not defined and locally made equipment and tote boxes are generally used. This lapse can create accidents and are quite common. Especially in engineering industries there can be a possibility of having sharp edged metal scrap pieces, which can give rise to accidents while moving both within and outside the shop floor. In the scrap yard also the scrap material movement is very dangerous and needs to define a particular system of receiving, storing or retaining and disposal of the scrap to the outside agencies.

20.9 NATURAL CALAMITIES

Another important area which also needs attention from the top management is accidents due to natural calamities like storms, heavy rains, floods, lightening and earthquakes. These happen in certain geographies.

It is necessary for the plants to have disaster management plans and mock trials should be conducted to see that everything is working properly.

20.10 FATIGUE

It is another main contributor for accidents. The energy level of the operator does not remain same throughout the day. In addition fatigue of the operator is high in the late evening hours for first shift operators or in the third shift (mainly around 3 AM to 4 AM). The management has to recognize this fact. There are some methods to reduce fatigue levels including reduction in operating speeds could be potential solutions to the problem.

20.11 LACK OF CONTROLS AND WORK PERMITS

Some major accidents take place in the plants due to lack of controls in the area of working without supervision or work permits, especially in chemical plants where there may be already hazardous environment. Generally, it is observed that on weekends or holidays a number of maintenance jobs are carried out without work permits or approvals. Lack of guidelines to workmen to work in such hazardous areas and lack of preparation to counter accidents while working, are some of the reasons for fatal accidents. Maintenance department plays a major role in this area since on weekends and holidays maintenance personnel are generally present for carrying out preventive maintenance and breakdown maintenance activities. There was a major accident in one of the plants which was using alcohol as a raw material. This was one of the most reputed plants and the management team was very conscious about the consequence of such negligent actions. Without completely cleaning the alcohol and gas freeing the reaction vessel permission was granted to do hot work (welding). Within a minute of starting the welding, the alcohol caught fire and there was a flash killing several people who were working near the manhole of the reaction vessel. Strict discipline is necessary in such plants and the proven method of issuing work permits after completely inspecting the area in which such work is carried out.

20.12 TRANSPORTATION

Transportation, both within the plant and outside, is another potential area of concern. In developing nations there are no stringent rules to scrap the vehicles once they complete a number of years of service. Also there is no standardization on the size and height of the vehicles. Due to this a number of major accidents take place both within plant premises and outside on the roads. Even methods of loading and unloading are not standardized. This is the reason a number of incidents take place causing damage to goods and major injuries to people. Most of the loading and unloading activities are done manually with or without proper lifting tackles and cranes. In developed nations one can see standard size trucks arriving at the plant and loading is done by drive-in forklifts and proper securing or lashing is done so that during transit no shifting of goods takes place.

20.13 BOILERS AND PRESSURE VESSELS

These are special category of equipment and there are statutory regulations for maintenance and upkeep of the equipment. Since they have common phenomena (that is, high pressure) they come under government regulations. Boilers and pressure vessel are quite common equipment in process industries. Maintenance of the boilers and pressure vessels is important and carried out every year without fail in a phased out manner if there are more than one in number. Since in boilers the steam water interface is commonly exposed to high level of corrosion, the boiler inspector focuses on this area. Since compliance of the regulations is mandatory, the boilers are dismantled by removing all components, thoroughly cleaned and then offered for inspection. If the corrosion is within limits prescribed by the statute it is approved for assembly. Lack of maintenance or lack of thorough inspection can result in major accidents. Then the boiler is subjected to at least 1.5 times the pressure by raising steam and checked for over pressure just in case the boiler is subjected to such situation due to malfunctioning of pressure safety valves. Safety valves are sealed so as to prevent tampering by operating people. Water level is also inspected at the same time and the boiler is finally set for the operation for a certain period. By carrying out thorough maintenance in this area major accidents are avoided.

Pressure vessels are also dealt with in almost similar manner, but pressures could be somewhat lower and disaster could be at a lower level. Pressure vessels are also tested by subjecting the equipment to higher than operating pressure so that the accident is prevented in case of excess pressure. Again here too the pressure safety valves are tested and sealed so that nobody tampers with the setting.

20.14 SAFETY OF ROBOTIC EQUIPMENT

These are some concerns which have been discussed at various appropriate forums. Robotic equipment are generally bought and used in the plant where the work area is hard to reach or safety is in question or due to difficult to carry out for a human being. However, there are chances that programming of the robotic equipment goes haywire and the robot can misbehave or come out of the workplace designed for it. Providing an appropriate fencing is first level measure to prevent accidents. There could be more regulations as per the requirement in the future.

20.15 HEALTH HAZARDS

20.15.1 Dust

Health hazards are very prominent in woodwork industry, quarries, building construction sites and in industries where dusty processes exist.

Maintenance of dust control equipment is crucial in all dust producing processes to prevent exposure of workers to dust. Ventilation ducts must be kept free from blockages and repaired if damaged. Filter units need to be maintained regularly according to manufacturer's recommendations. For equipment where density of dust is high there has to be locally installed dust control system so that the operating people are not affected by the dust. In order to reduce the effect of dust to the operators PPEs such as breathing masks and training to wear them while working should be given.

20.15.2 Heat

Heat is another area of concern particularly in steel industries. The workplace air temperature is high (above 50 degree Celsius) in some cases. This can cause health problems in the long run. Process control automation helps as air-conditioned control rooms are provided and the concerned people are not exposed to heat all the time. However, for an inspection round there will be exposure to heat. In smaller steel plants such control rooms are not provided and so obviously such exposure to heat is going to be there. In such plants a big draft of fresh air is provided in order to compensate for the heat.

20.15.3 Radiation

Radiation is another health hazard. This includes radiation of all kinds. Especially in atomic power plants, atomic research laboratories and other places where nuclear radiation is a possibility.

Analytical x-ray equipment makes use of very narrow collimated x-ray beams of high intensity. Exposure of the eyes or the skin of the body to the primary x-ray beam may result in severe radiation burns in a matter of seconds. These burns heal poorly, and on rare occasions require amputation of the affected parts.

Localized radiation burns produced by the high intensity primary x-ray beam is the principal hazard associated with the use of analytical x-ray equipment.

20.15.4 Scattered Radiation

A hazard may also exist from exposure to scattered radiation. Scattered radiation is produced when the primary beam strikes collimators, samples, beam stops or shielding. The intensity of the scattered radiation is a couple of orders of magnitude less than that of the primary beam. It is possible for these scattered radiation fields to result in exposures, which exceed regulatory limits, however. Scattered radiation may exceed regulatory exposure limits.

20.15.5 Hazards Associated with X-Ray Exposure

The hazards most often associated with exposure to x-ray radiation include increased risk of cancer and increased risk of genetic defects in exposed populations.

20.15.6 Toxicity

Exposure to dangerous chemicals and gases is another area of health hazard. Stringent rules are in place from the statutory bodies so that these chemicals and gases are contained and treated so that such chemicals and gases are not emitted into the atmosphere. However, due to some leaks or disorders the operating people can come into contact with these chemicals and gases. Thanks to science, due to research and development activities for each of those chemicals and gases there is a method by which these are contained and disposed of so that the people who live in the surrounding areas of the plant, people who are operating the plant and the environment are not affected. Wherever such plants are installed and commissioned the first and foremost responsibility of the plant management is to install such equipment and processes to safeguard the society at large and their operating people in particular.

20.15.7 Noise

Noise is another hazard. Most of the plants have high levels of noise. Statutory regulations do cover prescribed noise levels. If the noise level is more than 90 decibels in the workplace it is the responsibility of the management of the plant to take action so that the operating people on the shop floor do not get hearing problems. Medical tests are carried out every year on such people who are exposed to noisy work place and necessary action initiated in order to safeguard the people. The following steps are initiated.

Firstly, the operating people should wear the PPEs to protect their ears and so providing ear muffs and training them to wear all the time inside the plant is the responsibility of the management team. Secondly, there has to be a study conducted to see if the noise level can be reduced by acoustic insulation or study the noise in detail so that the mechanical noise can be reduced by doing proper maintenance for reducing the friction or improve lubrication system. There are such examples that the noise level can come down by taking proper counter measures. Despite these actions the yearly medical tests reveal if anybody lost hearing ability. Proper actions are initiated so that those people who have got affected are taken care of.

20.15.8 Ergonomics and General Health

Ergonomics is the science of human body movements. There are some movements of the body which are quite comfortable for the human body and there are certain other movements which are not comfortable to human body. Such activities, if forced on the body, can cause fatigue or pain or discomfort and the person may not be able to work in some cases.

Awareness on ergonomics has been there since long. However, complete realization of the subject especially in plants performing manufacturing activities is not apparent. However, modern plants are showing interest in providing ergonomically designed workplaces and ergonomically designed work methods. However, operator movements are tracked and study is carried out as to how many bending movements are there, how many lifting movements are there and what is the weight. Similarly, how many movements are there which require both hands to work together. These inputs are used to study further so that some changes are incorporated in the method of working to make it less fatigue prone. This is the advantage of studying ergonomics. Lifting tackles and hoists are provided so that the operator can lift it without strain.

Implementation of ergonomics helps reduce human discomfort and reduce fatigue and enhance ease of operations. This may not reduce accidents per say but surely helps in improving work methods and enhancing human comfort to improve productivity.

We have so far discussed the work of operating staff and the accidents in their work area. We also saw briefly how accidents can be avoided by instituting good management practices in the workplace. Of course, it needs constant endeavor and training effort to achieve the objective of zero accidents. Let us now look at the maintenance function and the type of work they do in a plant.

20.16 MAINTENANCE IS A HIGH-RISK ACTIVITY

Maintenance operations also involve specific risks. These include working alongside a running process and in close contact with machinery. During normal operation, automation typically diminishes the likelihood of human error that can lead to accidents. In maintenance activities, contrary to normal operation, direct contact between the worker and machine cannot be reduced substantially. Maintenance is an activity where workers need to be in close contact with the processes.

Maintenance often involves unusual work, non-routine tasks and it is often performed in exceptional conditions, such as working in confined spaces. Maintenance operations typically include both disassembly and reassembly, often involving complicated machinery. This can be associated with a greater risk of human error, increasing the accident risk.

Maintenance involves changing tasks and working environment. This is especially true in case of contract workers. Subcontracting is an aggravating factor in terms of safety and health; numerous accidents and incidents relate to subcontracting maintenance.

20.16.1 Time Pressure

Working under time pressure is also typical for maintenance operations, especially when shutdowns or high-priority repairs are involved. Maintenance personnel, especially contract maintenance technicians often work round the clock and the risks involved are very high. However, these risks can be reduced by selecting a competent and highly skilled contractor with highly conscious workforce. Thorough planning, in advance for deploying the right kind of workforce and creating rotation among them so that the work hours can be reduced. This is the way the contractors are organized, but chances of human error and accidents cannot be ruled out.

20.16.2 Hazards, Risks and Health Outcomes

Because maintenance is carried out in all sectors and workplaces and involves a wide range of tasks, it is associated with a great variety of hazards.

Due to poor design of machinery, process and work environments from the point of view of maintenance it is hard to reach the objects to be maintained — strenuous movements (bending, kneeling, reaching, pushing and pulling, working in confined spaces). Generally, the maintenance work needs strong physique and a flexible body. This gets developed over the years, however the probability of maintenance technician's meeting with ergonomics related accidents cannot be ruled out.

20.16.3 Typical Tasks Carried Out by Maintenance Technicians

- Drilling, grinding, filing, sanding
- Working outdoors, maintenance of industrial plant (e.g., ovens and furnaces, chilling units)
- Welding, inspection of pipes, rail maintenance

20.16.4 Potential Health Outcomes

Hearing problems due to noise, musculoskeletal disorders

20.16.5 Chemical Hazards

- Asbestos, glass fiber
- Vapors, fumes, dust (e.g., asphalt fumes, diesel exhaust, crystalline silica)
- Solvents

20.16.6 Typical Tasks

- building maintenance
- electrical arc welding
- carrying out work in confined spaces
- working in car repair shops
- maintenance of industrial installations where hazardous chemicals are present

20.16.7 Potential Health Outcomes

Breathing problems, occupational asthma, allergies, asbestosis and cancer.

20.16.8 Biological Hazards

- Bacteria
- Mould and fungi

20.16.9 Typical Tasks

- maintenance in waste treatment plants
- maintenance where biological agents are handled such as laboratories
- maintenance in places where bacteria, moulds, and fungi are likely to proliferate, such as air-conditioning systems

20.16.10 Potential Health Outcomes

Breathing problems, asthma, allergies, Legionnaires' disease

20.16.11 Psychosocial Risk Factors

- Time pressure
- Shift work, weekend work, night work, on-call work and irregular working hours
- Working together with staff from contractors / several contractors — communication issues

20.16.12 Potential Health Outcomes

Work-related stress, fatigue, increased accident risk.

20.16.13 High Risk of All Types of Accidents

- Many accidents are related to work equipment and machine maintenance, e.g., crushing by moving machinery, unexpected start-up
- Falls from height, accidents involving falling objects
- Electrocution, electrical shocks, burns
- Confined spaces, asphyxiation
- Explosion, fire

20.17 REGULAR MAINTENANCE

Regular maintenance is essential to keep equipment, machines and the work environment safe and reliable. Lack of maintenance or inadequate maintenance can lead to dangerous situations, accidents and health problems. Maintenance is a high risk activity with some of the hazards resulting from the nature of the work. Maintenance is carried out in all sectors and all workplaces. Hence, maintenance workmen are more likely to be exposed than other employees.

Maintenance concerns the "combination of all technical, administrative and managerial actions during the life cycle of an item intended to retain it in, or restore it to, a state in which it can perform the required function.

Maintenance is a generic term for variety of tasks in different types of sectors and all kinds of working environments. Maintenance activities include inspection, testing, measurement, replacement, adjustment, repair, upkeep, fault detection, replacement of parts, servicing, lubrication, cleaning, etc.

Maintenance is critical to ensure continuous productivity, to produce products of high quality and to keep company's competitiveness. But it also has an impact on occupational safety and health.

Firstly, good maintenance is essential to keep machines and work environment safe and reliable. Secondly, maintenance itself is a high-risk activity and it has to be performed in a safe way, with appropriate protection of maintenance workers and other people present in the workplace.

It is estimated that around 15-20% (depending upon the country) of all accidents and 10-15% of all fatal accidents are related to maintenance operations. Accidents increasingly tend to happen not during normal operation, but rather during repair, maintenance, cleaning, adjusting, etc.

According to a survey, maintenance is the most strenuous function in industry. An analysis of maintenance employees shows they were the second most frequent victims of accidents related to subcontracting, just behind construction workers.

Around 25% of all electrical injury accidents are caused by portable electrical equipment. Faulty leads to equipment cause fires each year. A major cause of such accidents and fires is the failure to carry out inspections and maintenance.

20.18 INDUSTRIAL SAFETY

Industrial safety is a major concern in this modern world. In order to bring about safety of people, safety of machines, processes, buildings and environment, a thorough maintenance system is necessary. Since it is a statutory requirement a lot of attention is needed and it becomes a specialized area of knowledge. Let us first look at various topics in order to maintain safety at workplace.

20.18.1 Unsafe Condition

Unsafe condition means a particular physical condition in the workplace both within the plant boundary and outside which can transform into or cause an accident to the people working in the area. It is not necessary that the unsafe condition has to be within the boundaries of the plant alone. Accident can happen just outside the gate. For example, a branch of a tree fell on a person who was waiting for a transport. Similarly, an employee slipped and met with a road accident while negotiating a curve on the road to the workplace. These are all unsafe conditions. The branch of a tree which was precariously holding on to the tree and fell down when there was wind is an unsafe condition. Similarly, the accident took place while negotiating a curve; the curve on the road constitutes the unsafe condition.

For practical purposes here we may not discuss unsafe conditions outside the plant limits, but it is always appreciated if the management of the plants wants to cover safety to all employees and at all times. It is rather considered to be a good precedent or gesture if the management wants to get into safety to its employees even outside the plant and at their homes, roads and public places. The subject of unsafe conditions is large, however let us restrict to the unsafe conditions within the boundaries of plant which becomes a focused workplace.

It is established that there are unsafe conditions in machines, workplaces, buildings, material handling systems, shop floor and in the method of working. These unsafe conditions do not reveal themselves, but often have to be identified and eliminated. This requires constant endeavor on the part of the management and every employee day in and day out. A safe workplace is the result of meticulous design work and relentless effort to achieve zero accidents.

Let us understand unsafe conditions a little more. In a press shop a metal plate is pressed by a hydraulic press and a metal part with proper as per specifications and dimensions is produced. However, during the operation while sheering off the metal plate with a die on the hydraulic press sharp burrs are produced. This is a potential unsafe condition here. Now the operator has to remove one part and insert another plate for the next piece. While handling the metal part produced the person can get a cut on his finger or palm. It is understood that there is an accident and the equipment which produced the part has an unsafe condition. In order to counter the accident a pair of hand gloves is given to the operator. However, after some use the hand gloves tore and the operator had a cut on his finger and met with an accident.

So, what is the inference? There is an unsafe condition in the equipment and a sharp burr is existing on the metal part produced. Hence, attention and focus is needed to resolve this unsafe condition. How to eliminate the sharp burr which is the unsafe condition? There is a need to analyze this and thorough root cause solution is needed. Only when the root cause solution is implemented the unsafe condition is resolved.

Instead, often a pair of new gloves is given to the operator and warning is given that he or she should take care. Similarly, a particular motor in the plant does not have terminal box. The box is missing and the three wires (red-yellow-blue) for the supply are taken inside the motor directly without any gland. Now look at this unsafe condition. A little bit of pull on the wires is enough to create short circuit and burn the motor. It can also create an accident to the people. Generally, such unsafe conditions are not easily noticed and they cause accidents and damage to equipment.

A missing coupling guard is another example of an unsafe condition. While rotating with good speed it is not noticed. However, it can cause an accident if some one crosses it. Serious accidents have happened on just missing coupling guards. A lot of research work has been done on this subject and a number of “safe design” coupling guards have come into the market. However, one can witness many such instances in the shop floor and it is a matter of concern.

Similarly, one can give many examples of the unsafe conditions in the plant. Walkways are not marked in the shop floor and hence the path for people to walk and path for the material handling equipment are not identified. A number of accidents can take place in such shop floors.

Audio-visual alarm system installed on the forklift, convex mirrors installed where forklift takes 90 degree turn and path for forklift movement marked on the floor, are some safe practices to counter the unsafe conditions.

Oil spill on the shop floor, potholes on the shop floor, loose wires hanging, places where the head can hit and cause injuries to employees, places where hand injuries or even major accidents can be caused while loading and unloading material from the equipment, scrap metal which has sharp edges and is protruding from the tote boxes, movement of cranes without audio-visual alarms, reversing the truck without someone giving guidance to back up, welder is performing welding work without proper containment of spatter and without keeping handy the hand appliances for firefighting, ladder without side railings, increasing the speed of the machine beyond permissible limits, storing paper or cardboard material used for packing beyond certain limits, entering the storage tanks without gas freeing or work permit, leaving the heavy load of material overhead and leaving behind the lifting tackle or crane, leaving robotic equipment without switching off, running the robotic equipment without providing proper safety measures are all examples of unsafe conditions. There are innumerable unsafe conditions in the plant and it is a continuous improvement journey to achieve zero accidents or safety incidents.

Here an effort has been made to create awareness as to what is an unsafe condition and how to identify it. There are places where currently there are no accidents, however with some small changes in the situation it can become a reason for the accidents. These are called potential accidents. For example, an overhead crane is running normally and maintenance had taken the equipment for preventive maintenance. Maintenance technicians were working without switching of the equipment. Suddenly the crane started moving and luckily accident did not take place. The maintenance personnel raised alarm before accident could take place. These types of accidents are also classified as “potential unsafe conditions” and the auditor has to have sufficient knowledge of such potential unsafe conditions.

Now, how do we first identify the unsafe condition and then how do we eliminate unsafe condition. How to conduct the audits for identifying the unsafe condition is described later in this chapter. In fact, when the auditor goes to the shop floor to conduct this audit he needs have a critical eye to notice an unsafe condition and also invite discussions or debate and confirm that it is an unsafe condition. In order to achieve this, the auditor can ask questions from the operating teams and maintenance technicians if they have noticed any unsafe conditions or do they have any potential unsafe conditions. This method is better because the operating teams will feel satisfied as they had identified unsafe places and have taken keen interest in reduction of accidents.

Further, it is always better that instead of conducting audit single-handedly, it is always better to form a committee. That means audit is conducted as an auditing team and that produces better results. This is because there are more brains working and discussions if any can be initiated and sometimes root cause solution can also be worked out then and there itself.

20.18.2 Unsafe Practice

Unsafe practice means unsafe act or behavior demonstrated by people working in the plant and mostly these accidents take place due to these unsafe practice.

In other words unsafe practice means people use unsafe methods or short cuts to carry out their work in the factory premises. In such a situation what is a safe method and what is an unsafe method has to be decided and documented. The people working should be trained in these safe methods and strict discipline has to be enforced so that people do not tend to use unsafe practices even after creating enough awareness among them. However, there can be many nonstandard activities which people in the plant do and often these cause accidents. Standard work methods like operating a machine, assembly of the final product in the assembly shop and testing various samples in the laboratories are good examples where the work methods are well defined.

However, in maintenance function there are such activities to be carried out which are nonstandard or not done on a daily routine and there the people use their own experience and work methods. Here is an area where there can be short cuts or judgment errors and they result in accidents. These are called unsafe practices and often end up in accidents. Here again it does not mean that all such activities should not be carried out in the maintenance function, but use of standard practices and safe methods or proven and established methods are to be encouraged and put into use. This is how the maintenance technicians should be trained on safe and proven methods to reduce accidents in maintenance function.

Unsafe practice is a bit difficult to comprehend. For example, there are Personal Protection Equipment (PPEs) given to operating and maintenance staff. This is given to them and training is imparted to use them on regular basis. Consider for a moment that a particular operator is wearing the appropriate PPEs. However, that person met with an accident which was an injury to the palm. The hand glove worn by him got torn during this activity. So it is not an appropriate hand glove for that work. Now the question is it an unsafe method or unsafe practice. The operator was wearing hand glove which was not torn earlier but got torn during the operation it is called unsafe condition and not unsafe practice. Had the operator been not wearing the hand glove which is prescribed for the kind of operation it would have been unsafe practice. Here what is needed is to find out and establish if the hand glove was of poor design or poor quality. This will lead to coming out with root cause solution to the accident and provide an opportunity to prevent such accidents. If the root cause turns out to be that the person was not wearing the hand glove properly or not covering his palm completely then it is an unsafe practice. This kind of situation may also arise because the operator is expected to work continuously and such human error can also take place.

In such situations it is recommended that focus is given to unsafe condition (that is the hand glove) and also the unsafe practice of not wearing it. This will give a root cause solution to the problem.

20.18.3 Unsafe Practices: Hesitation to Wear PPEs

However, in the plant situation some employees may not have enough respect for the PPEs and as result not wear them at all or do not wear them in the proper manner. This is the responsibility of the management to strictly enforce it at the same time discuss with people if there are any difficulties or uncomfortable feeling while wearing them and improve the design of such PPEs so that people are encouraged to wear them for their safety.

20.18.3.1 Helmet

For example, a person wearing a helmet: The helmet has to be worn properly to give intended result of protection to the head. While working in the plant the helmet gives protection to the head in many ways. A maintenance technician is working in a corner of the machine where he or she can get head injury while getting up. So wearing a helmet is a must and wearing it properly is also necessary. A helmet gives head protection by three things which are incorporated in the design of the helmet.

First thing is the helmet should fit properly on your head and for that provision for adjustment (plastic belt) is provided in the rear inside of the helmet.

Secondly, there is a gap between this plastic belt and the outside dome shape. This gap is essential to give head protection and in the situation of an accident or fall from a height. This is built into the design but often due to impact or damage to the belt the gap can reduce and head can touch the dome. If this is happening, the helmet will not give proper protection.

Fig. 20.1 Standard helmet to work in a plant

Thirdly, there is a strap below the chin and tightening the buckle of the strap is necessary so that the helmet does not fall off from the head. Adjustment of the strap is a requirement; but many employees wear the helmet without it. No protection for a fall from a height will be provided by the helmet if the chin strap is not adjusted.

20.18.3.2 Safety Shoes

Let us now look at other PPEs. For example, wearing safety shoes is a requirement in the plant to protect the feet of the people working in the shop floor and warehouses. In some developed nations it is minimum requirement. That means all people whether they are working in the shop floor or not they are required to wear the safety shoes. This is compulsory as the people may have to go to other areas for their work. So it is understood that all people working in the plant whether there is a likelihood of foot getting damaged or not they need to wear safety shoes.

Safety shoes are standardized and there need not be any ambiguity in the manufacturing of safety shoes and the quality of material used. The objective is to protect the feet of employees at all levels in the plant. Safety shoes should be rugged in construction. In addition, it has to protect the toes. So it is again standardized and shall have steel toes and withstand heavy impacts arising out of tripping over some objects or dropping metal objects like hammers, spanners and other heavy tools. It also protects the toes from dropping heavy machine parts or products while working on them or while transferring.

So, it is understood that every employee must wear the safety shoes within plant limits. However, one will see a large variation from plant to plant. This variation is due to lack of understanding of the objective of wearing safety shoes. This activity if handed over to purchase department there can be a large variation in the quality of safety shoes. Purchase department looks always to save money by getting heavy discounts and hence the variation in quality may take place. Secondly, in some plants the management of the plant may take a decision that all people in the plant need not wear safety shoes. Instead the employees working in areas where foot injury is possible due to the nature of work, only such areas are considered for safety shoes. So people working only in such areas are expected to wear safety shoes. For example, people working in areas where handling heavy parts, dies, fixtures as a part of their jobs are expected to wear safety shoes. The maintenance technicians are always expected to wear safety shoes again due to nature of their heavy work they handle.

While this is the logic behind, it becomes difficult to identify people who are habitually not wearing safety shoes and other PPEs. So it becomes difficult for the management to enforce such rules. It is not a big expense to provide relevant PPEs to all employees. It is also worth spending that money early on to inculcate safety culture in the plant. So if wearing the safety shoes and other appropriate PPEs is made compulsory and not left to the discretion of the department managers, then it becomes easy to enforce such rules.

Fig. 20.2 Standard safety shoes

20.18.3.3 Safety Goggles

Wearing safety goggles is required to protect the eyes of employees from dust, metal chips, and light radiation from welding jobs, etc. Here again, there are no standards and one can find large variation from plant to plant. So it is absolutely necessary to wear safety goggles in such areas of work and so the management has to provide safety goggles to employees working in such areas of the plant. The variation can also be observed due to handling them. Broken goggles, or deteriorated goggles and lost goggles are some of the reasons. In some cases the operator takes risk of not wearing goggles either by ignorance or negligence. Strict discipline is needed to be enforced for safety.

20.18.3.4 Safety Harness

Working at heights is another area of risk. Wearing safety harness before starting such work is essential. People who work at heights like plastering the walls, working on the overhead crane, fixing something on the wall at heights and work on the trusses of the building, electrical cable laying at a height, all need to wear the harness to protect. In safety harness again variation can be seen. However, harness has to be worn properly and it should be strong enough to take load of the employee and the impact it generates while falling.

There are two things which are very important in a safety harness.

Firstly, it has the part of the harness which is wrapped around the chest and the stomach. This provides support while the person working at a height slips. Similarly, this portion of the harness should also have provision to suspend spanners or brush, tools, etc., so that injury to people down below does not take place due to items falling down. This portion of the harness must also provide cushion around the chest from inside so that injury due to the fall does not take place to the person working at a height.

Secondly, the hook is also an important part. As soon as the person working at a height has reached the work place at that height, the harness has to be hooked to some solid object with full support. This is how it provides the protection to the person if he or she slips from the place where the person is standing. The hook, the place where the hook is hooked or fixed and the whole thing should have enough strength to withstand the impact created while falling. Depending on the height from the person working and the place where it is hooked, the impact will create the load. This needs some practice to wear safety harness and so training has to be provided to people working at a height.

Fig. 20.3 Safety harness

Providing the harness to the employee is important on the part of the employer. Enforcing the law to make sure they wear the harness while working at a height is also equally important on the part of the employer. The consequences are fatal.

20.18.3.5 Earmuffs

Protection to the ears is another important point. Except a few industries where the processes and equipment do not create noise to such levels, (above 90 decibels) earmuffs have to be provided to the people who are subjected to such noise. Permanent damage to the hearing capability can happen if the person is subjected to such noise levels. At the same time if the earmuff is worn during the working hours without fail or without leaving any time gap, it can give enough protection to the ears.

Fig. 20.4 Earmuff

20.18.3.6 Earplugs

There are various types of protection equipment for ears available in the market. Just providing earplugs can also provide the protection needed. However, it has to be changed with a new one from time to time. Otherwise there are chances of catching up infection as it becomes dirty very fast. Also life of earplugs is comparatively smaller. Due to this reason earmuffs are better and give longer service life. Also earmuffs cover the ears completely from outside and are usually stronger in construction.

Fig. 20.5 Earplugs

People working in the shop floor, at times do not understand the importance of covering their ears with earmuffs and so creating awareness is very important. Strict discipline has to be enforced in the shop floor to make sure that everybody wears ear protection equipment while working in areas where the noise level is higher.

20.18.3.7 Breather or Respirator

Similar to the ear muffs, breathing protection is also necessary for people working in dusty areas. There are statutory requirements for the dust levels for working in such dusty areas. There is a very clear mandate for the particle density in the air around the workplace.

Fig. 20.6 Standard respirator

The dust could be of different kinds or the source of the dust could be different in different industries. For example, dust emanates from a sand blasting machine. Depending upon the construction of the machine and type of dust coming out, the breather is provided to protect the people from exposure to such dust. But there other examples like chemical dust emanating from the machine. In toothpaste industry, it is observed that there is chemical dust coming out during the raw material addition into the reaction vessel. Though the reaction vessel has been provided with adequate exhaust fans, chemical dust flies when the silica powder is added to the reaction vessel manually. Silica powder can create serious problems to people who are exposed to such dust. The silica powder goes into the lungs and can get hardened inside the lungs. This creates serious breathing problems. If good breathing equipment be provided to people who work in such areas and they wear them always while working, protection is provided.

Similarly, exposure to enzymes in detergent making industries is another such area. Enzymes are added into the reaction vessel manually. This is the time the operator may get exposed. Exposure to enzymes can cause serious health problems to people who are exposed. So providing appropriate breathing equipment for such applications is of utmost importance.

There are different types of dust originated from different processes. In a welding shop there are fumes emanating from the weld. In a road repair or flooring repair work there again heavy dust is generated and not usually measured for density. Similarly, in a paint shop there is heavy spray of paint dust and if exposed can create breathing problems. In a housekeeping work a lot of dust can come out from places where it is accumulated for a long time. In a marble cutting industry people are exposed to marble dust, which can also result in health hazard.

Providing appropriate breathing equipment and ensure that people wear them always while working is important. The construction of the breathing equipment varies for different applications and selecting proper breathing equipment for the application is key responsibility of the management.

20.18.3.8 Hand Gloves

Hand gloves are the most common PPEs generally seen in industries. Different applications have different types of hand gloves. For example, simple cotton hand gloves are given to employees working in the shop floor. If the job does not create much wear and tear, cotton hand gloves are enough. Making sure people wear them in the workplace is responsibility of the management.

Fig. 20.7 Simple cotton hand glove

If the job creates much wear and tear, better quality hand gloves are provided. That means, it is necessary to analyze the job and study the wear and tear it creates. For example, an operator is lifting very sharp metal plate from the machine. Due to the sharp edges of the metal plate the hand glove gets torn after some use. Torn hand gloves can be a reason for an accident that is a cut on the palm of the operator. In such situations special hand glove is needed.

In a particular application a specially designed hand glove with PVC lining inside the hand glove was procured. This hand glove gave better resistance to wear and tear. Also a sleeve was introduced to cover the hand from such cuts on the hands of the operator. The tailor made hand glove and the cotton sleeve on the forearms is a better solution to the problem.

A welder needs different kind of hand gloves to give protection from heat generated from the weld and also electrical shocks. Due to the nature of work, strong design hand gloves are chosen by industries for welder's job.

Fig. 20.8 Welder's hand gloves

Similarly, where the operator has to work with his hands lifting hot objects or work in furnaces, heat treatment areas and the like, appropriate leather gloves are used.

20.18.3.9 Maintenance Technicians

These people use different hand gloves for different applications. Separate hand gloves are used for the work in high voltage areas. These are generally made of special rubber which can withstand high voltage. Scraping and grinding work in maintenance department requires appropriate hand gloves. Similarly, tightening heavy nuts and bolts needs special hand gloves.

The hospital hand gloves are normally made of latex rubber. This provides hygiene (zero bacteria) as well resistance to wear and tear. Doctors normally use "one use" or "disposable" hand gloves.

In a mining industry, a different helmet with a torch attached to it is a special kind of PPE generally used.

Fig. 20.9 Miner's helmet

The manufacturers of PPE equipment are continuously doing research and coming out with new types of PPEs for different applications. For example, in construction industry, people have to carry materials like bricks, cement and sand on their heads and this application needed to introduce a helmet with a ring on top of the helmet so that the utensil carrying the material does not fall. This kind of innovation is needed to suit the requirement so that safety is provided at all the time.

20.18.4 Tampering with Safety Devices

There are many cases in developing countries about tampering with safety devices. This is a dangerous practice carried out by operating people and maintenance technicians. For example, safety guards in front of a machine. Often it comes to light that the operator in order to meet with the quantity requirements by-pass or tamper with such equipment which result in an accident. Here the management has to create awareness and take disciplinary action on such individuals.

In one other case the operator is required to operate the machine by pressing two green buttons simultaneously. This is required to keep his both hands occupied so that the second hand does not get caught in the machine.

The operator of the machine keeps one of the green buttons permanently pressed for ease of operation and operates the machine by one button. However, the irony of the situation is that operator gets the intuition to by-pass the safety and operate the machine ignoring the safety aspect. Here is a case where strict discipline has to be enforced in the plant by the management.

20.18.4.1 By-passing Safety Alarm

Many times it is brought to the attention of the management that the safety alarm was buzzing but somebody put it off thinking that it is a false alarm. Here again people are taking these kinds of decisions due to ignorance and lack of awareness. In any case these kinds of unsafe practices are dangerous. Safety alarms and safety guards, etc., are introduced to take care of the safety of people and the operating staff tampers with them causing accidents.

20.18.4.2 Fuses

Similarly, there are many such cases. The fuses in the electrical circuits are replaced by a thick copper wire. A proper fuse with suitable current rating is needed for the circuit and not replace it with thick wire. This will eliminate all safety in that electrical circuit and may even cause a fire. This also applies to replacing fuses with higher rating fuses. This is equally dangerous.

20.18.4.3 Speed of the Machine

Increasing the speed of the machine for higher productivity is another example of unsafe practices. This is generally done in the night shifts while no supervision is usually available. This amounts to indiscipline and unsafe practice. This is again dangerous and can cause major breakdowns or accidents.

20.18.4.4 Lack of Vigilance

There are many things in a plant that require constant inspection and vigilance. This is called supervision. That means the supervisory staff taking vigilance rounds and carrying out inspection. This is needed for the safety of people, safety of the processes and assets. There could be some pipeline leakage or some breakdown or some environmental issue or people issue. Proper log entries are done after the vigilance rounds and observations if any are sent to the management.

20.18.4.5 Not Using Walkways

This is a disciplinary issue. In industries there are walkways marked on the floor. If there are material handling equipment there are separate lines identified and walkways are clearly marked on the floor. The people are expected to use these walkways while walking in the plant. This is a safety aspect and to be strictly adhered to. However, many accidents take place due to people not using these walkways and loitering around with ignorance or lack of awareness. For forklifts or material handling equipment audio-visual alarms, convex mirrors where 90 degree turn is marked and horn, all safety measures go waste if people are loitering without any respect for such rules.

20.18.5 Near Miss

A near miss is an unplanned event that did not result in injury, illness, or damage but had the potential to do so. Only a fortunate break in the chain of events prevented an injury, fatality or damage; in other words, a miss that was very close to an accident but actually did not take place and gave enough warning. Although the label of 'human error' is commonly applied to an initiating event, a faulty process or system invariably permits or compounds the harm, and should be the focus of improvement. Other familiar terms for these events is a "close call", or in the case of moving objects, "near collision" or a near "hits".

Most safety activities are reactive and not proactive. Many organizations wait for losses to occur before taking steps to prevent a recurrence. Near miss incidents often precede loss producing events but are largely ignored because nothing (no injury, damage or loss) happened. Employees are not enlightened to report these close calls as there has been no disruption or loss in the form of injuries or property damage. People think that no damage has taken place and so why report and get into problem. Thus, many opportunities to prevent the accidents that the organization has not yet had are lost. Recognizing and reporting near miss incidents can make a major difference to the safety of people within organizations. History has shown repeatedly that most loss producing events (accidents) were preceded by warnings or near accidents, sometimes also called close calls, narrow escapes or near hits.

In terms of human lives and property damage, near misses are cheaper, zero-cost learning tools for safety than actual injury or property loss.

An ideal near miss event reporting system includes both mandatory (for incidents with high loss potential) and voluntary, non-punitive reporting by witnesses. Important point to remember is that about any near miss report is the "lesson learned". Near miss reporters can describe what they observed of the beginning of the event, and the factors that prevented loss from occurring.

The events that caused the near miss are subjected to root cause analysis to identify the defect in the system that resulted in the factors that may either amplify or be the origin.

To prevent the near miss from happening again, the organization must institute teamwork training, feedback on performance and a commitment to continued data collection and analysis, a process called continuous improvement

Near misses are smaller in scale, relatively simpler to analyze and easier to resolve. Thus, capturing near misses not only provides an inexpensive means of learning, but also has some equally beneficial spin-offs.

Reporting problems of near-miss incidents is to try to create an open culture whereby everyone shares and contributes in a responsible manner. Near-miss reporting has been shown to increase employee relationships and encourage team work in creating a safer work environment.

20.18.6 Root Cause Analysis (RCA)

Root cause analysis (RCA) is a method of problem solving that tries to identify the root cause of faults or problems.

RCA practice tries to solve problems by attempting to identify and correct the root causes of events, as opposed to simply addressing their symptoms. Focusing correction on root causes is the goal of preventing problem recurrence.

Thus, RCA is an iterative process and a tool of continuous improvement.

RCA is typically used as a reactive method of identifying causes, revealing problems and solving them. Analysis is done after an event has occurred. Insights in RCA may make it useful as a preemptive method. In that event, RCA can be used to forecast or predict probable events even before they occur. While one follows the other, RCA is a completely separate process to incident management.

Root cause analysis is not a single, sharply defined methodology; there are many different tools, processes, and philosophies for performing RCA. However, several broadly defined approaches or "schools" can be identified by their basic approach or field of origin: safety-based, production-based, process-based, failure-based, and systems-based.

Safety-based RCA comes from the fields of accident and occupational safety, health and environment

Despite the different approaches among the various schools of root cause analysis, there are some common principles. It is also possible to define several general processes for performing RCA.

20.18.7 General Principles of Root Cause Analysis

1. The primary aim of RCA is to identify the factors that resulted in the nature, the magnitude, the location, and the timing of the harmful outcomes (consequences) of one or more past events in

order to identify what behaviors, actions, inactions, or conditions need to be changed to prevent recurrence of similar harmful outcomes and to identify the lessons to be learned to promote the achievement of better consequences. "Success" means the near-certain prevention of recurrence.

2. To be effective, RCA must be performed systematically, usually as part of an investigation, with conclusions and root causes that are identified and backed up by documented evidence. Usually, a team effort is required.
3. There may be more than one root cause for an event or a problem, the difficult part is demonstrating the persistence and sustaining the effort required to determine them.
4. The purpose of identifying all solutions to a problem is to prevent recurrence at lowest cost in the simplest way. If there are alternatives that are equally effective, then the simplest or lowest cost approach is preferred.
5. Root causes depend on the way in which the problem or event is defined. Effective problem statements and event descriptions (failures, for example) are helpful, or even required.
6. To be effective, analysis should establish a sequence or timeline to understand the relationships between contributory factors, root causes and the defined problem or event to prevent in the future.
7. Root cause analysis can help transform a reactive culture (that reacts to problems) into a forward-looking culture that solves problems before they occur or escalate. More importantly, it reduces the frequency of problems occurring over time within the environment where the RCA process is used.
8. RCA is a threat to many cultures and environments. Threats to cultures often meet with resistance. There may be other forms of management support required to achieve RCA effectiveness and success. For example, a "non-punitive" policy towards problem identifiers may be required.

20.18.8 "Why- Why" Analysis

Why-Why analysis forms the most critical part of successful corrective action, because it directs the corrective action at the true root cause of the problem. Knowing the root cause is secondary to the goal of prevention, but without knowing the root cause, it is not possible to determine what the effective corrective action for the defined problem would be.

1. Define the problem or describe the event factually. Include the qualitative and quantitative attributes (properties) of the harmful outcomes. This usually includes specifying the natures, the magnitudes, the locations, and the timing of events.
2. Gather data and evidence, classifying it along a timeline of events to the final failure or crisis. For every behavior, condition, action, and inaction specify in the "timeline" what should have been done when it differs from what was done.
3. Ask "why" and identify the causes associated with each step in the sequence towards the defined problem or event. "Why" is taken to mean "What were the factors that directly resulted in the effect?" Keep asking "why" until you get answers to go to root cause.
4. Classify causes into causal factors that relate to an event in the sequence and root causes that if eliminated, can be agreed to have interrupted that step of the sequence chain.
5. Identify all other harmful factors that have equal or better claim to be called "root causes." If there are multiple root causes, which is often the case, reveal those clearly for later optimum selection.
6. Identify corrective action(s) that will with certainty prevent recurrence of each harmful effect, including outcomes and factors. Check that each corrective action would, if pre-implemented before the event, have reduced or prevented specific harmful effects.
7. Identify solutions that, when effective, and with consensus agreement of the group, prevent recurrence with reasonable certainty, are within the institution's control, meet its goals and objectives and do not cause or introduce other new, unforeseen problems.
8. Implement the recommended root cause correction(s).
9. Ensure effectiveness by observing the implemented recommendation solutions.
10. Identify other methodologies for problem solving and problem avoidance that may be useful.
11. Identify and address the other instances of each harmful outcome and harmful factor.

20.18.9 Horizontal Deployment or Reapplication

Once the root cause solution is achieved it is time to implement the solution. Implementing a root cause solution is not easy, since in the "near miss" there was no damage or loss of life or loss of property. This is the

WHY - WHY ANALYSIS SHEET

Breakdown, physical phenomenon					
What is your final action?					
☐ In case of spare part replacement	Describe Countermeasure				
☐ In case of spare-part no replacement					
	Why did you take above action	Due to			
Why 1					
Why 2					
Why 3					
Why 4					
Why 5					
* Root cause is one of the following 5 items		JH	PM	Desingn	E&TSkill
(1) ☐ Poor basic Condition					
(2) ☐ Poor operating Condition					
(3) ☐ Deterioration					
(3) ☐ Weak Design					
(5) ☐ Poor Skill					
(Note: Please fill up this form in pencil immediately after m/c is started)					
Kaizen Idea and schedule					

time the root cause solution is tested. Once implemented it does not give any assurance immediately. The team may have to wait until the success is achieved. Having achieved the “success” means no recurrence of the near miss will happen. Once this is clear it is time for horizontal deployment or reapplication.

That means there are similar situations and similar observations and root causes. There is possibility of accidents taking place in such places or situations. A list is prepared for all such places or situations and horizontal deployment plan is prepared. Only and only after all such places are covered it can be declared as complete and the whole plant is free from any fear of such things occurring in other places or situations.

20.18.10 Management of Industrial Safety, Occupational Health and Environment

20.18.10.1 Safety Committee

Generally, all plants have a safety committee headed by a qualified safety engineer or industrial safety, occupational health and environment professional. There is representation from all important departments in this safety committee and the maintenance engineer has a key role to maintain all safety equipment, utilities and buildings.

20.18.10.2 Owner or Occupier

Every organization is required to give the name of a senior person; vice president operations or manufacturing director or managing director. This name has to be in the declaration form submitted to the factories inspector who represents the state. Factories inspector is an official from the state government and responsible for ensuring safety and occupational health. Environment comes under the charge of state government pollution board and is a separate government body to ensure that the factories follow the state rules for pollution and environmental conditions.

Occupational safety and health officer will inspect all work areas annually and “increased-risk” work areas or operations twice a year. Supervisors are responsible for regular hazard inspections of their workplaces on a daily or weekly basis, depending on the nature of their work.

In addition to the inspections conducted by the personnel of this section, construction engineers licensed in the civil, mechanical, and electrical disciplines must inspect construction site activities involving administered contracts.

Supervisors are responsible for regular inspections of their workplaces on a daily or weekly basis, depending on the nature of the hazards included in the work.

An increased risk or high-risk activity is a workplace or environment with a high potential for mishaps or occupational illnesses. Included are activities involving machines, electrical or electronic functions, including transmitting antennas; chemicals or chemical applications; materials storage and handling; construction; maintenance; and repair and others.

Inspections include a comprehensive hazard assessment addressing the potential for losses and exposure to fire, safety, health, and environmental hazards. A complete risk analysis of each work operation will be done that includes environmental factors, training needs, materials used, hazardous or toxic chemicals used, control systems, protective equipment used, and any other relevant factors. Quantification of potentially harmful exposure to hazardous or toxic chemicals, materials, noise, lead, asbestos, radiation, biological materials, or other hazards must be accomplished by or under the supervision of industrial hygienists certified in comprehensive aspects of industrial hygiene.

Occupational safety and health personnel are authorized to enter unannounced and without delay for the purpose of inspecting any building, installation, facility, construction site, or area where work is being performed by employees of the department or agencies. Inspecting personnel are authorized to question, privately, any employee, supervisor, or official in charge of the establishment.

Inspection personnel on construction projects will provide written reports of findings and recommendations to the project director.

In cases where immediate danger exists, inspection personnel will immediately inform the project director in charge, orally and then in writing, of the potential danger and the actions required to correct the problem. The project director will take appropriate action to ensure that work is stopped until the imminent hazard can be abated.

The safety and occupational health personnel conducting inspections will give officials in charge of the facility and employee representatives an opportunity to accompany them during the physical inspection of the workplace. The inspector will obtain the appropriate security clearances to inspect areas or workplaces where classified operations or information requires such security clearances.

20.18.10.3 Responsibilities of Safety Committee

Conduct meetings: The meetings of the safety committee are conducted every week or the frequency can be increased if necessary. Presentation is done to other members of the safety committee regarding analysis of accidents or incidents, going to the root cause and taking remedial action. Results of the safety rounds conducted in the last one week are also shared. Responsibilities are shared among team members so that everybody is involved and job satisfaction due to achievements derived by each individual. The safety committee meeting is also used to conduct analysis of past accidents and establish trends. Same is also used for preparation of the report to higher authorities.

20.18.10.4 Conduct Safety Audits

Conducting safety audits is the responsibility of the safety committee. As mentioned earlier the safety committee head should have expertise in conducting audits and so a certified person is needed. If such skills are not there within the plant outside agencies can be hired to conduct such audits and training can be given to the members of safety committee. Also there are statutory requirements that comprehensive audits are conducted by certified agencies.

There are three important points to be covered: unsafe conditions, unsafe practices and near misses. Handling all these three aspects is the joint responsibility of the safety committee and every individual working in the plant.

20.18.10.5 Unsafe Condition and Unsafe Practices

Identifying unsafe conditions and practices is the main part of safety audits. In order to identify unsafe conditions and practices the auditor needs to have a critical eye and good skills to find out what is right and what is wrong. It is normally recommended that somebody accompanies the auditor for these audits. That will be a training opportunity for others to do the auditing job. The auditor can have interactions with the operators and supervisory staff about any unsafe conditions or such behaviors.

Audit is conducted throughout the plant. That means starting from the main gate to the scrap yard is covered. There is no way an audit can be conducted in a hurry. If the volume of work is large it can be split into sub areas and audit can be done in a phased out manner.

Identifying unsafe practices is somewhat different from identifying unsafe conditions. This is because the person who may be doing unsafe practice or unsafe behavior suddenly comes to know that the auditor has come to the plant to do the audit and may even discontinue that practice. Surprise audits are needed to catch the person who does unsafe behavior. Alternatively the responsibility of identifying unsafe practices is given to the supervisor of the workplace.

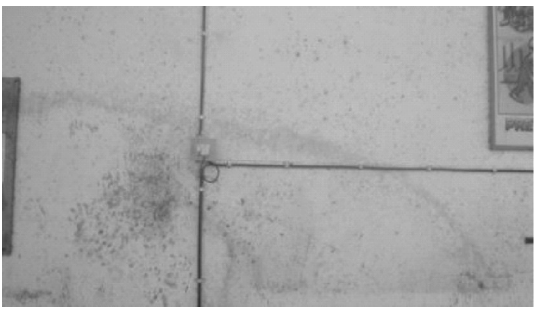
It is not a straightforward game to identify unsafe behaviors. However, it has a big potential to reduce accidents and so identification of unsafe practices is more important.

20.18.10.6 Special Safety Round

This kind of round was conducted at a scrap yard by safety committee and the following were the observations.

1. **Steel containers at scrap yard after unloading of industrial refuse**

2. **Hanging of electrical wires eliminated.**



3. Metal chips are cleared.

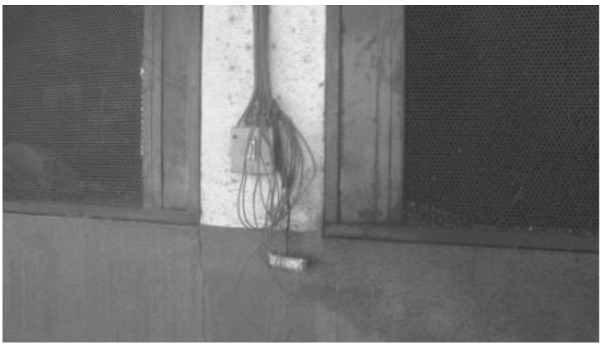
4. Door found hanging with a steel wire.

5. Fire extinguisher found lying on floor without PEEP.

6. Industrial refuse overflow

7. Asbestos scrap material cleared.

8. Telephone wires found hanging



20.18.10.7 Near Misses

Near miss has been discussed in this chapter earlier. Near miss cannot be identified during the safety audits or safety rounds. Near miss happens only sometimes and it is the duty of the supervisory staff to document the near misses. There is a real issue here. The supervisory staff is generally not inclined to document these and report. However, it is the responsibility of the management that all near misses are documented and reported. Since we have seen that near miss does not cause any damage or injury to people but gives an indication that major calamity or accident can take place if indications are neglected.

Documentation needs some training. The near miss has to be thoroughly analyzed by going to the root cause and action plan to see that such thing does not happen. So documentation has to include all the details of physical phenomena, sequence and timing, etc., to be written clearly. This will enable to know the root cause and thereby prepare appropriate action plan.

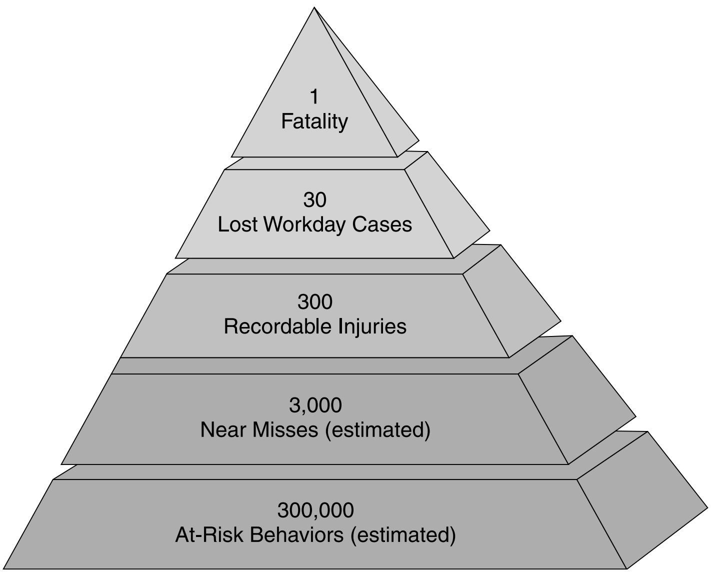


Fig. 20.10 Safety pyramid

The picture is self-explanatory. There are so many at risk behaviors happening everywhere in the work situations. For every 300,000 such behaviors there will be 3000 near misses. And for 3000 near misses there shall be 300 recordable injuries. For all such cases there are 30 cases of lost workdays. And finally, there will be one fatal accident.

This kind of pyramid is created by a statistician to create awareness in people and the top management.

Root cause analysis: (Detailed root cause analysis has been discussed earlier in this chapter.)

20.18.10.8 Management Reporting

The safety committee is responsible for management reporting. For management reporting proper metrics have to be decided beforehand and management approval is obtained in advance.

1. Number of accidents
2. Number of incidents
3. Number of unsafe conditions
4. Number of unsafe practices
5. Number of near misses
6. Compliance rate of unsafe conditions
7. Compliance rate of unsafe practices
8. Compliance rate of near misses
9. Accident-free days for the plant
10. Accident-free days for each dept
11. Cost of accidents
12. Number of training events conducted on safety.

20.18.11 Role of Maintenance in Industrial Safety and Occupational Health

Industrial safety is of utmost importance throughout the world. As developing countries are getting more and more industrialized, these concerns are becoming more prominent. A number chemical companies are setting up new plants in the developing countries, the government needs to come out with stringent regulations and enforce them seriously. Maintenance function has a major role in maintaining the safety equipment and making sure they function when needed.

20.18.11.1 Basic Rules to Get it Right

The specific details of maintenance vary between industry sectors and depend on tasks. But there are some common principles:

- Integration of organizational safety and health (OSH) management into maintenance management
- Structured approach based on risk assessment
- Clear roles and responsibilities
- Standardized safe systems of work and clear guidelines to follow
- Adequate training and competence

- Involvement of people in the risk assessment and maintenance management process
- Effective communication

20.18.11.2 Basic Rules for Safe Maintenance

1. Planning
2. Making work area safe
3. Using the appropriate equipment
4. Carrying out work as planned
5. Final check

Planning

Maintenance should start with proper planning. A risk assessment should be carried out and workers should be involved in this process. Issues to be covered at the planning stage are:

The Scope of the Task: Needs to be done and it will affect other workers and activities in the workplace. Barricading and secluding work should be undertaken.

Risk Assessment: Potential hazards have to be identified (e.g., dangerous substances, confined spaces, moving parts of machinery, chemical substances or dust in the air and measures need to be developed to eliminate or minimize the risks.

- Safe systems of work have to be defined (work permits, lock-off systems)
- The time and resources that the activity will require
- Communication between maintenance and production staff and other parties if any.
- Competence and adequate training.

Employers need to ensure that workers have the skills to carry out the necessary tasks, are informed about safe work procedures, and know what to do when a situation exceeds their competence. Employers should think carefully about the 'chain of command' among those who are involved in maintenance task, and any procedures that will be used for the duration of the activity, including reporting procedures if there is any problem. This is especially important if maintenance is carried out by subcontractors.

Consulting workers and keeping them informed is vital throughout the planning stage. Not only should employees carrying out maintenance task be informed of the outcomes of the initial risk assessment, but they should also be involved in it. Because of their familiarity with the workplace, they are often in the best position to identify hazards and the most efficient ways of dealing with them. People participation in the planning process increases not only the safety of maintenance work, but also its quality.

Making the Work Area Safe

The work area needs to be secured by preventing unauthorized access, for example, by using barriers and signs. The area also needs to be kept clean and safe, with power locked-off, moving parts of machinery secured, temporary ventilation installed, and safe routes established for workers to enter and exit the work area. Warning cards should be attached to machinery, with the date and time of lock-off, as well as the name of the person authorized to remove the lock – this way, the safety of the worker performing the maintenance on the machine will not be jeopardized by another worker inadvertently starting it up.

If possible, guards should be designed so as to allow minor maintenance on the machines without removing the safeguards. If the guard must be removed or deactivated, then lock-off procedures should be followed. Maintenance operators and workers shall be trained on how and under which conditions safeguards may be removed.

Using Appropriate Equipment

Workers involved in maintenance tasks should have appropriate tools and equipment, which may be different from those that they normally use. Considering that they may be working in areas that are not designed to have people working in them, and that they may be exposed to a variety of hazards, they must also have appropriate personal protective equipment.

With respect to the **equipment and tools** to be used, employers should ensure that:

- The right tool and equipment for the job is available together with instructions for using it if required.
- It is in appropriate condition.
- It is suitable for the work environment (e.g., no sparking tools in flammable environment.
- It has an ergonomic design.
- All personal protective equipment must be appropriate for the risk involved without itself leading to any increased risk.
- It should correspond to the existing conditions at the workplace.
- Take account of ergonomic requirements and technician's health.
- Fit the wearer correctly after any necessary adjustment.

For example, workers cleaning or replacing filters on extraction ventilation may be exposed to concentrations of dust that are much higher than normal for a particular workplace. Access to these filters, which are frequently located in the roof area, has to be made safe

Working as Planned

Safe work procedures have to be communicated, understood by workers and supervisors and applied correctly. The work should be monitored so that the agreed safe systems of work and rules are observed. Maintenance is often carried out under pressure, for example, when a fault has brought the production process to a standstill. Safe procedures need to be followed, even when there is time pressure: shortcuts could be very costly and may lead to accidents, injuries, or damage to property.

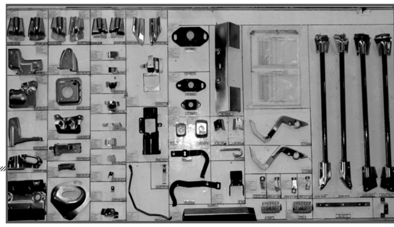
Procedures need to be in place for unexpected events. Part of the safe system of work should be to stop work when faced with an unforeseen problem or a problem exceeding one's own competence. It is very important to remember that exceeding the scope of one's own skills and competence may result in accidents.

Making Final Checks

The maintenance process needs to end with checks to make sure that the task has been completed, that the item under maintenance is in a safe condition, and that all waste material that has been generated during the maintenance process has been cleaned away. When all is checked and declared safe, then the task can be signed off, and supervisors and other workers can be notified.

The final step involves completing the report, describing the work that has been performed and including comments on any difficulties that have been encountered, together with recommendations for improvement. Ideally, this should also be discussed at a staff meeting where the workers involved in the process, as well as those working around them, can comment on the maintenance activity and come up with suitable suggestions to improve the process.

CHAPTER 21



Maintenance Forecasting, Planning and Scheduling

21.1 MAINTENANCE

Maintenance is to maintain and preserve plant and capital equipment in a condition suitable for its designate purpose and includes preventive, predictive, and corrective (repair) maintenance and many more tools/techniques.

21.2 MAINTENANCE STRATEGY

Asset lifetime management requires a comprehensive strategy driven by the organization that covers design, procurement, installation and operation at the beginning stages of capital investment. It clearly lays down the strategies for preventive maintenance, reliability centered maintenance, total productive maintenance, condition based maintenance and breakdown maintenance. They all are conceived well and find the place in the company strategy. Result oriented measures of performance or key result areas (KRAs) to be established how individual and team performance is connected to company results. In addition the strategy should clearly indicate commitment to continuous improvement and defect elimination. At the same time it has to find its place in selection of competent personnel for maintenance and training in skills needed.

Finally, management needs to support by having SAP or equivalent system for information.

21.3 MAINTENANCE FORECASTING AND PLANNING

Maintenance forecasting is a very complex exercise. No one will be able to predict maintenance requirements. How will a forecast be useful when no one has any idea of tomorrow's workload?

Forecasting provides an opportunity to respond proactively and resolve material and scheduling problems. In fact, improved materials planning, scheduling and supplier coordination raises department utilization, shrinks inventory levels and enhances customer service.

21.4 FORECASTING DEFINED

Forecasting is the business function that attempts to predict the use of products so they can be purchased or manufactured in appropriate quantities in advance. A forecast is an estimate of future demand. A forecast can be determined by mathematical means using historical data, it can be created subjectively by using estimates from informal sources, or it can represent a combination of both techniques.

21.5 WHY FORECAST?

A company derives benefit from a maintenance forecast, especially companies operating in a run-to-failure maintenance mode, waiting for a breakdown before procuring material. The goal of maintenance forecasting is to have the right material available at the right time, in the right place, in the right quantity without tying up inventory or tolerating material shortages. Maintenance department with a forecast better serves internal customers by anticipating maintenance requirements and having material available to meet these needs. Forecast helps to respond to emergencies and other scheduled maintenance activities quickly.

Maintenance forecasting is essential for maintaining a high level of operational readiness. It can help balance the cost of carrying high inventory levels on every item against numerous rush orders to support maintenance activities and its potential for causing downtime.

21.6 FORECAST PRINCIPLES

The basic forecast principles are that there's no such thing as a reliable forecast and one should expect the forecast to be wrong. Tracking and using forecast (difference between forecast and actual) to calculate a standard deviation for the error improves forecast effectiveness. Use the standard deviation to calculate safety stock levels that cushion demand variability. Forecast principles also state that current-period forecasts are more accurate than later periods. A general understanding of these basic principles should help users improve their ability to forecast.

The maintenance department forecast should help predict repair frequency on the basis of qualitative or quantitative measures. Qualitative forecasts reflect a person's intuition, make use of informed opinions and tend to be subjective. Qualitative forecasts are used in the absence of historical data. For example, a new machine won't have a repair history. The forecast will be based on the manufacturers' suggested maintenance cycle and parts list. The maintenance department also will forecast other material critical to the operation performance.

21.7 QUALITATIVE TECHNIQUES

- Delphi method
- Market research
- Opinion of the panel members
- Historical analogy

21.7.1 Delphi Method

It is forecasting method based on the results of questionnaires sent to a panel of experts. Several rounds of questionnaires are sent out, and the anonymous responses are aggregated and shared with the group after each round. The experts are allowed to adjust their answers in subsequent rounds. Because multiple rounds of questions are asked and because each member of the panel is told what the group thinks as a whole, the Delphi Method seeks to reach the "correct" response through consensus.

The word "Delphi" refers to the Oracle of Delphi a site in Greek mythology where prophecies were passed on.

The Delphi Method seeks to aggregate opinions from a diverse set of experts, and can be done without having to bring everyone together for a physical meeting. Because the responses of the participants are anonymous, individual panelists don't have to worry about repercussions for their opinions. Consensus can be reached over time as opinions are swayed.

The quantitative technique uses historical demand data to calculate a future forecast. This technique assumes that the demand pattern will be repeated in the future. For example, if the maintenance department used 1000 liters of oil each month, a quantitative forecast will project a demand similar to the past demand. This logic remains valid as long as no structural changes appear. For example, replacing a machine with a new model alters the underlying structure of the forecast.

21.7.2 Quantitative Techniques

- Historical time series
- Causal studies
- Simulation models

This quantitative technique will help to identify characteristics such as trend (demand change), seasonality (use varying regularly over time), randomness (one-time occurrences), or cyclicality (time interval).

21.7.3 Forecasting Steps

1. The first step is to capture monthly or weekly usage data going back one to three years. Forecast accuracy improves with the number of periods for which data is captured. Collect records such as maintenance work order number, material and quantity used; issue date, and reason code. In addition, demand activity may require user-specified adjustments or modifications to accommodate material substitutions, resource constraints, equipment replacement, cancelled work orders and the like. Failure to validate and correct demand data skews forecasted quantities.
2. The second step is to determine the number of maintenance items to include in the forecast. Large numbers are not practical. Use a stratification process to identify items to be forecasted based on cost, frequency of use or lead-time.
3. The third step is to produce a bill of material for repairs to identify the parent item, along with the components required to perform a preventive or scheduled repair. For example, the engine repair kit defines the material used historically to make the repair. Place these items on a repair bill-of-material, along with a defined replacement factor (percent of time the repair used the part). The engine repair kit then will be forecasted based on historical use.
4. The fourth step is to control non-forecasted items through the explosion of the repair bill-of-material or, for items of limited use, on a min/max basis. Base this decision on the material's cost and the consequence of not having material available. Other stocking considerations include long lead-times, critical need, or the desire to stock just-in-case.
5. The fifth step is to generate the forecast item record, including item number, description, planning data, ordering data, cost data, or more periods of demand history, and so forth. Although it is quite laborious and time consuming, analyze, massage the data and clean item data records before executing the forecast.
6. The sixth step is to run the forecast system and order material based on the forecasted quantity and period required.
7. The seventh step is to monitor the forecast error. Take time for periodic reviews to validate the basic assumptions and data used in developing the forecast to ensure the forecast process remains

on target. Failure to perform this function leads to a poor forecast and a subsequent increase in inventory level.

8. The final step is to have management review and adjust the forecast to ensure the results meet strategic business plans and objectives. A computerized maintenance management system (CMMS) assists in forecast development by providing information that helps analyze and monitor the need for repairs, their planning and scheduling, repair orders, and to track demand. The CMMS output enhances the forecast process.

21.8 TYPES OF MAINTENANCE PROGRAMS

Forecasting can help in material planning; for example, predictive maintenance seeks to forecast quantities for materials identified through nondestructive testing or statistical analysis. Materials to support these efforts need to be forecasted on the basis of historical use.

Preventive maintenance requirements, such as replacement machine parts and cleaning consumables, are forecasted on the basis of a user-defined, time-based, meter-based, or calendar-based schedules. Integration to and from enterprise resource planning, manufacturing execution systems or CMMS systems helps to define the maintenance time frame.

Scheduled maintenance activities are forecasted on the basis of management input. For example, management dictates the maintenance operations during a plant shutdown by specifying the repair activities, developing bills of material and identifying material requirements to support the plan.

Unplanned maintenance is required whenever something fails unexpectedly. Even so, limited material use forecasting is possible on the basis of historical demand for motors, gauges or manufacturer's suggested parts. However, most unplanned requirements need to place orders immediately. Establishing a minimum quantity for selected items is the best way to control these inventories but the uncertainty involved makes the holding cost expensive.

Forecasting won't resolve every material-related problem in the maintenance area, but it is a proactive approach. Understanding demand patterns adds place and time value, which results in improved material planning and workload scheduling. It improves supplier negotiations and setting up a supplier stocking program. This effort reduces equipment downtime, reduces maintenance inventory levels, increases equipment utilization and permits better scheduling of maintenance workers.

21.9 MAINTENANCE PLANNING AND SCHEDULING

Planning decides what, how and time estimate for a job. Scheduling decides when and who will do the job. Planning of a job should be done before scheduling a job.

Maintenance planning and scheduling of work orders is the hub of a well functioning maintenance organization. In order for maintenance planning and scheduling to work many other systems need to work well. Most importantly equipment inspections through preventive maintenance, technical database such as bill of materials, work order history, and standard job plans. Maintenance spare part stores have to function well (see Fig. 21.1).

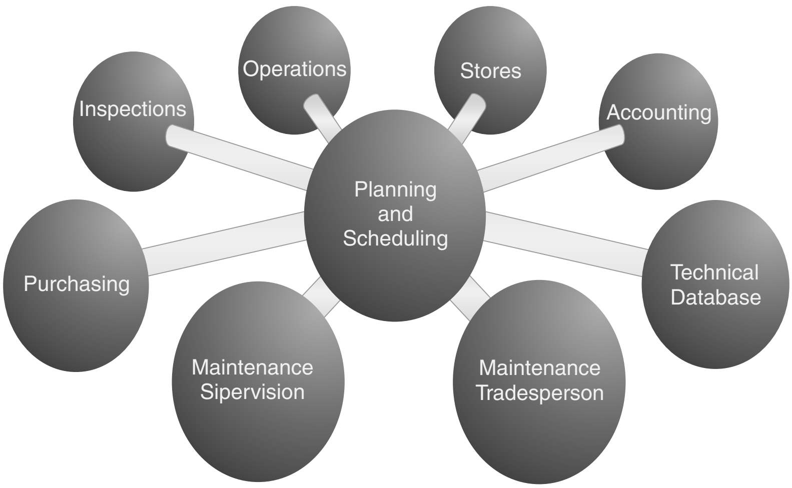


Fig. 21.1

21.10 WHY IS MAINTENANCE DIFFICULT TO CONTROL?

Maintenance work is very diverse. Establishing standards is a difficult task, however to decide the manpower requirement it is necessary to understand the work content and thereby decide the resources needed. Specifying what is to be done is not easy as there are norms in certain jobs and in some areas there are no norms. Jobs have to be done in the order of priority and needs to have a lot of flexibility. In addition tradesmen have different capabilities and so it is not uniform in all kinds of jobs. Many a times the extent of jobs is not known clearly. Jobs are dependent on parts availability and the jobs are undertaken only after proper coordination from production. Also weather has an impact on outdoor work.

21.10.1 Effective Work Planning and Control

Chance of success is much higher when there is a well designed system that is well documented and there is discipline in its use. A correct and efficient planning function requires that management provide guidance on the level of control necessary to ensure "consistent" quality maintenance of plant and equipment.

21.10.2 Vital Aspects of Maintenance Management

- Requesting work
- Planning and estimating of work
- Effective scheduling of work
- Quality feedback of work done and other information into equipment history
- Managing and controlling the workload
- Provides information for reliability analysis, supports decision making and continuous improvement

21.10.3 Maintenance Workload Analysis

Understanding the workload is important for planning. This requires clear definitions of the type of maintenance as dictated by the situation, weather it is an emergency or is it a minor work like changing air hose etc. or may be lubrication checking or condition monitoring and major overhauls. It is required to understand if it is improvement maintenance (Kaizens in maintenance) or finally it could be installations and commissioning of small equipment or a small project.

21.10.4 Planning, Scheduling and Control

- Anticipating future work
- Visualization of the nature and details of the work
- Determination of the best method to perform the work
- Arranging for the required materials
- Securing alterations in production program or scheduling of maintenance work to conform to production plans
- Allocation of work to individuals
- Instructing the individuals about the schedules and methods

- Follow-up and monitoring the progress of work
- Evaluation of the work and performance.

21.10.4.1 Anticipation of Maintenance Work

The most important function of maintenance is anticipation of future work. This can be done by information provided by the following sources:

- Instructions and guidance given by manufacturers of the machine.
- Technical knowledge of the maintenance and production personnel.
- Firsthand knowledge or the degree of utilization of the machine.
- Record of the behavior of the machine (history cards) and work done on it.
- Complaints and requests from production personnel on the basis of difficulties experienced by them while operating the machines (operability issues).
- Complaints and requests from maintenance personnel while doing maintenance work on the machine (maintainability issues).
- Examination of the state of the various parts of the machine during their life span (inspection of the condition).

21.10.4.2 Visualization of the Nature and Details of Work

Planning for materials, man-powers, methods and time required for a job depends on the nature and details of the job. Visualization of the details of the work to be undertaken in the future can be done on the following basis.

21.10.4.3 Types of Maintenance

Maintenance activities can be categorized as follows:

(1) Preventive Maintenance
(2) Predictive Maintenance
(3) Corrective Maintenance (attending breakdowns)

21.10.4.4 Preventive Maintenance System Incorporates the Following

(1) PM Master schedule
(2) Routine Lists
(3) PM Cards
(4) Maintenance Instructions

21.10.4.5 PM Master Schedule Contains the Following Information

1. Unit Number
2. Machine or Part of machine
3. Time Interval

4. Special or Routine
5. Category of Workmen & Type of work
6. Maintenance Instructions
7. Activity Description
8. Routine List/PM Card Number

21.10.4.6 Preparation of PM Schedule

All PM activities to be carried out by a particular trade at a particular frequency for a sub-assembly of a unit should be grouped as one activity. The relevant details are to be given in the maintenance instruction. Frequencies should be minimum possible to facilitate planning & control.

21.10.4.7 Routine Lists

Routine lists are prepared from main schedule. Routine lists will consist of PM activities of routine nature of not requiring special planning or stoppage affecting the production schedule for a group of equipment in a division or section. All such activities will be carried out during a specified week by a designated category of technicians. Each routine list will be numbered and scheduled over the year.

21.10.4.8 PM Cards

PM card consists of all PM activities which require special planning or stoppage involving production loss and whose frequencies are same. Activities in each PM card will be scheduled in a particular week of the year with due consideration to the production plan.

21.10.4.9 Maintenance Instructions

Maintenance instructions give the detailed description of the maintenance activity. This is to enable the technicians to carry out the activity as per the specified method.

21.10.4.10 Corrective Maintenance

Corrective maintenance arises out of the following:

1. Breakdowns
2. Malfunctioning reported by production
3. Abnormalities observed by inspection

The operating personnel should be asked to provide information about the nature of trouble experienced by them in a formal way. Reports of inspectors should indicate the part needing attention and the type of attention required. Drawing of the machine should be used to determine the work required to be done to reach, remove and replace the defective parts.

21.10.4.11 Determination of the Method to Do the Work

The discipline of method study aids the maintenance engineers in deciding the most effective methods of performing work. The techniques of PERT help in sequencing and scheduling different activities carried on a plant or machines.

21.10.4.12 Scheduling of Work to Specific Time Period

Scheduling of maintenance requires concurrence of production personnel to release the machine during the specified time. Maintenance personnel cannot expect to carry out their own plan and then to assume that it will be acceptable to production people.

Scheduling of maintenance work can be done on the basis of the importance of this work in relation to production requirements and the duration of machine downtime and its consequent effects on production and sales program.

Scheduling of maintenance work requires dovetailing of maintenance and production schedules. For this purpose, it is necessary to involve production personnel in decisions regarding the job to be carried out, priority of each job and the time when it should be undertaken. Maintenance department should for this reason prepare a tentative schedule of maintenance work for at least two weeks and circulate it to production department and then get their agreement.

The maintenance department should for its own work, think in terms of a long-term schedule and a short-term schedule. Each of these schedules would include the following activities on the basis of the information provided by the source indicated.

21.10.4.13 Types of Schedule Activities and Source of Information

Long term:

1. Lubrication
2. Manufacturers inspection recommendation
3. Overhauling
4. Technical expertise
5. Cleaning
6. Analysis of history of machine
7. Replacement
8. Analysis of life span of some items

Short term:

1. Repairs
2. Inspection reports

3. Replacement
4. Complaints and requests of operating personnel (operability issues)

Here, the term 'long term' means a plan for a period of a year or more. Short-term plan can be for a period between 15 days to two months. It can sometimes even be a plan for the next week.

21.10.4.13 Work Orders

The individuals who are required to execute the work need to be instructed about the work to be done by them, the method they should adopt, the time when they should commence work and the time at which they are expected to complete the job. One good way of passing on necessary information is the use of work orders.

Work orders are absolutely necessary to control the execution of the plan and for later evaluation for the following reasons.

The work order contains a number which assists in identifying the job on schedule boards or for future references. The work order number should preferably also indicate cost centre where the work is carried out. The work order contains information that is necessary for correct allocation of maintenance costs. It provides information about scheduling time (and the consequent labor costs) and material as well as actual time taken and material actually consumed as a necessary means of assessing performance.

For reasons stated above, every maintenance work should be undertaken against a work order. Routine work which is carried out every day (e.g., cleaning and oiling) can be done against a standing work order. For other jobs a work order should be issued every time such job arises. This is the only way to correctly account for and apportion every minute of time spent by maintenance.

21.11 PLANNING & SCHEDULING OF MAINTENANCE WORK

Basic requirements of organizing planning and scheduling of maintenance work are to the extent possible a separate and a capable person should handle the planning and scheduling work and he would report to the in-charge of the maintenance department. He should be responsible for coordinating the following:

(1) Schedule of maintenance personnel
(2) Spare parts stock control
(3) Shutdown or breakdown time control

This person will assist maintenance in-charge in evolving the maintenance methods, develop and improve them, development of new maintenance tools and materials. He will also assist the in-charge in establishing 'time' for various works which will be the basis for working out the maintenance schedules.

Maintenance in-charge will have the full responsibility for the work of the maintenance department. He should report only to the top manager of the establishment. The planning and scheduling person has the basic responsibility for determining the job priorities, ensuring that required tools and materials are available and written schedules of jobs are prepared and distributed.

The person holding the charge of maintenance planning should be the same level as that of the in-charge of production departments to be effective. His understanding of various maintenance methods, crafts and shop services is important.

21.11.1 Sources of Scheduling Data

1. Repair note is the primary source of information for scheduling purpose.
2. Maintenance methods and time estimates, evolved earlier for various maintenance works will give information regarding the various trades and the workload involved.
3. Load schedule and the progress report of the various maintenance crews will give information with respect to their availability.
4. Special material for maintenance and spare parts records in the stores will be the source of information as to their availability.
5. Plant production schedule is the source of information as to the time when the equipment could be available for maintenance work and necessary servicing.

21.11.2 Types of Schedules

The size of the maintenance organization and the complexity of the plant's maintenance functions will determine the types and frequency of schedules. In general, however, there are three principal classes of schedules which should be used regardless of the plant size. They are:

1. The preventive maintenance master overhaul and inspection schedule.
2. The daily workmen deployment schedule.
3. The area maintenance schedule.

21.11.3 Preventive Maintenance Master Schedule

In most plants, there are many items of equipment which must be taken out of service at regular intervals for inspection and overhaul. The frequency of such occurrences varies with the equipment. Experience, guided by statistics, permits establishing the frequency, so that the lowest overall maintenance costs are achieved. After the frequencies have been determined, long-range master schedules are prepared. These must be coordinated with plant production schedules.

The maintenance overseer prepares detailed write-ups which include step-by-step descriptions of each inspection and/or overhaul. The work to be done by each trade and shops is set forth in detail so that their activities can be measured and scheduled accurately.

The master schedules are integrated into the daily and weekly schedules so that the regular preventive-maintenance work becomes a part of the overall plan-maintenance program. This ensures continuity and regularity of the preventive phases of maintenance work.

21.11.4 Weekly Work Schedule

Weekly schedule provides information to each trade and the machine shop concerning the work to be done on each job for each day in the following week. It should be prepared and released on the 4th day or at least latest by 5th day noon, to cover work to be done for the next week.

The weekly schedule must be prepared in cooperation with the shop supervisors and integrated with the plant production schedule. This schedule contains the number of man-hours required daily for each trade for each job. Information derived from statistical analysis of plant maintenance department records is used to estimate the amount of time to be allowed for each trade for handling emergency work that are not possible to be scheduled in advance.

The man-hour data provides the basis for scheduling the maintenance force. Also by reviewing the unscheduled backlog at the time the schedule is made, the need for hiring additional craftsmen, shop personnel, or laborers is evaluated. When the backlog shows tendency to increase, steps should be taken to enlarge the workforce. Another advantage to be derived from the weekly schedule is related to the statistical analysis of emergency work. If such an analysis shows that 10 percent or more of any trade's time is required to handle unscheduled work, further analysis should determine the cause of this emergency work. In most cases, a more effective preventive maintenance program based on these facts will permit the amount of unscheduled work to be reduced substantially.

21.11.5 Daily Workmen Deployment Schedule

Towards the close of each day, each foreman prepares a daily deployment schedule for each person under his supervision. These schedules are based on the weekly schedule, but are modified as necessary to compensate for change forced by fluctuating amounts of unscheduled work and unexpected delays in the scheduled work.

The scheduling group should be advised by the foreman of all variations from the weekly schedule, as well as of all completed work. Whether or not the daily schedule is written depends on the size and complexity of the organization. Generally, there is no need for a formal schedule. The scheduling usually consists of the foreman's handling the trades-men, one or more work orders, or job plan with the sequence in which they are to be done. Upon completion of the work, the foreman notifies the scheduling group. Each day's progress is reflected in the next day's schedule. By 4th day noon, sufficient data are available to prepare the weekly schedule for the next week on a realistic basis.

21.11.6 Area Maintenance Schedules

Many of the functions performed by the area maintenance personnel can be scheduled on detailed weekly schedules. Such items as lubrication, instrument inspection, machine inspection and adjustment, and the like are of this nature. Usually, these activities can be scheduled with considerable accuracy. Periodic audits of these schedules are made by the scheduling group to determine the validity of their time estimates.

21.11.7 Size of Maintenance Force

The number of people in a department and the types of maintenance trades represented will determine the number of different types of functional organizations required. Maintenance supervision is of greatest value to the company when it makes use of certain definite skills and abilities. The skills are not always used in a uniform manner but are needed in different proportions at different levels of management.

It is understood that the higher the level of maintenance supervision, greater the emphasis on broad management functions, such as planning, organizing, coordinating and controlling.

It is better to expand the span of control of each supervisor to the maximum he can handle; this will cut down the number of levels and the number of supervisors. In actual practice, this provides for closer relationships between supervisors and their workers. In the area of communications, it results in closer coordination and more control since it will decrease the length of communications.

The size of the maintenance force which will be required to support any individual plant can seldom be stated in general quantitative terms. There should be sufficient manpower to meet the demand in peak loads, but not to create a surplus of labor or the problem of idle labor will occur. The size of the staff doesn't effect the adoption of a maintenance control system (work measurement program) since the system itself can be adapted to any size of maintenance department and will work effectively.

Management can project its planning to forecast peak load periods and staff for an overall, annual average which will plan for production departments to help out at peak load times. When maintenance is performed on a break down basis, it must, necessarily, use excessively large crews since break downs must be repaired at once.

Ratios such as:

1. Maintenance manpower to total plant manpower,
2. Maintenance expense to value of equipment
3. Relation of design to maintenance workload.
4. Maintenance cost as a percentage of company's turnover.

These are useful guides to be used accordingly. The strict application of ratios should be performed with great caution for maintenance varies greatly from industry to industry and from plant to plant, depending on the equipment used, type of manufacturing process, variation in accounting, design, and purchasing procedures, and size of the plant. Once a ratio is developed from historical data for a particular plant, it can be extremely helpful in maintaining a proper size relationship between maintenance and plant manpower.

21.11.8 Maintenance Control

Maintenance control can be of three types as follows:-

1. Work control
2. Equipment control
3. Cost control

Work control is done through periodic reporting of the progress of various maintenance activities.

Equipment control is the process of carrying out failure analysis, downtime analysis and of taking corrective measures such as design-out maintenance and design-for maintenance.

21.11.9 Cutting Maintenance Cost and Increasing Value

Cutting costs has become a high priority, due to the recent economic conditions. Maintenance shutdowns are a major part of the annual budget, and are a target for cost reduction using effective maintenance management.

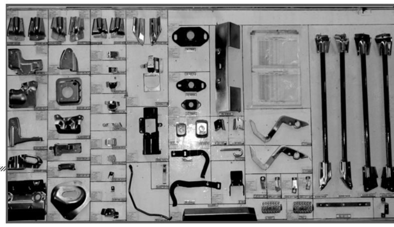
Costs can be reduced by 30-50 percent from historical levels using simple and effective maintenance techniques can effect major improvements. It is critical to the operation of most facilities. Without well-planned and executed shutdowns, equipment reliability suffers.

Proficient maintenance management reduces downtime costs and increases the value of maintenance. Maintenance management is about waste reduction (all types of waste).

Conclusion

Though there are many factors and ratios suggested as a tool for maintenance performance evaluation, it is essential to choose only such factors which are quite relevant, easy to generate necessary data and easy to interpret the results and monitor the maintenance, planning, organizing and control activities.

CHAPTER 22



Managing Turnaround Maintenance

22.1 WHAT IS A PLANT MAINTENANCE TURNAROUND?

In order to ensure that a process plant continues to run at peak efficiency, it is prudent to do a sort of overhaul of huge sections of the plant. This cleaning and repair process is called a turnaround (stop the plant, clean and repair, then start the plant). In certain industries and areas, a turnaround may also be called a shutdown, an outage, an overhaul, a slowdown. In all cases, an operating plant or plants are carefully and safely shutdown. Maintenance technicians work round the clock for days or weeks to make the plant ready to run again. Plant downtime is money lost and the owner is willing to pull out all the stops to ensure that the plant is up and running (and earning money) as soon as possible.

The management of a plant shutdown is known as the "plant turnaround." The plant turnaround procedure is a continuous process from one major scheduled maintenance outage to the next. It starts much before the plant is taken off-line and continues for a period of time after the scheduled major maintenance work has been completed. The plant shutdown period is part of the plant turnaround procedure called the "execution phase."

Plant shutdowns for scheduled major maintenance work are the most expensive and time-consuming of maintenance projects because of the loss of production and the expense of the turnaround itself. They can be complex; and as the complexity increases, they become more costly and difficult to manage. A plant shutdown always has a negative financial impact. This negative impact is due to both loss of production revenue and a major cash outlay for the plant turnaround and shutdown expenses. The positive side is not as obvious; therefore, it is often overlooked. The positive impacts are an increase in equipment asset reliability, continued production integrity, and a reduction in the risk of unscheduled outages or catastrophic failure.

A major scheduled plant shutdown is of short duration and high intensity. It can consume an equivalent cost of a yearly maintenance budget in four to five weeks. It also requires the greatest percentage of the yearly process outage days. As the plant shutdown is the major component of plant downtime and maintenance costs, proper plant turnaround management will have a significant impact on the bottom line.

Owners or senior management teams trade off the economic balance of a plant's process integrity and equipment asset reliability against the business plan budget and overall process outage days. Business plan budgets and process outage schedules are estimates predicted long before detailed estimates are derived from the maintenance work packages and plant turnaround support plans. To have realistic estimates, it is imperative that several conditions be recognized and accepted by the owner or senior management team. Without scheduled maintenance outages, equipment will fail, and an unscheduled outage is up to ten times more expensive than a scheduled outage. The cost is much higher again if the outage is due to a catastrophic failure. A business plan that has developed a formal plant turnaround management process and procedure, which supports a plant turnaround management philosophy and long-term strategy, will produce a higher level of business plan budget and schedule accuracy.

The strategic planning, detailed planning, organizing, execution, and close-out phases of the plant

Turnaround procedure is important for predicting and maintaining the business plan, budget and schedule. Plant equipment archives and current knowledge of the plant equipment asset conditions are major keys for developing the plant turnaround business plan strategy.

22.2 PLANT TURNAROUND PHILOSOPHY

The development of a plant turnaround philosophy is formal recognition of the plant turnaround's impact on the corporate business plan. Once formally recognized, the philosophy can be integrated with the corporate vision and mission statements as part of the overall corporate philosophy. The recognition of plant turnarounds is the first step for maximizing the benefits and reducing the costs when taking the plant off-line for a major scheduled outage.

The philosophy should be clear and concise with a descriptor of both plant turnaround management and plant shutdown. Different groups interpret the definition of a plant shutdown in their own ways. Operations may consider the plant shutdown to be “material in to material out” marketing will look at the “loss of salable product” days; and maintenance usually quotes in “mechanical days.” The owner or senior management team now turns the philosophy into action by developing the plant turnaround management process.

22.3 TURNAROUND MANAGEMENT PROCESS

The plant turnaround management process document supports the turnaround philosophy, and is considered the fundamental building block for initiating and completing a plant turnaround. As a standard, it provides consistency from plant turnaround to plant turnaround. The process defines a framework that is not restricted to major scheduled plant outages. The owner or senior management team develops the management process document. The document sets out the policies, procedures, and guidelines for developing and implementing an effective plant turnaround. Each plant under the care and control of the owner will need a plant turnaround management process document tailored to its specific needs. These needs include the type of plant, the geographical location, the size of the plant, and the general complexity of the expected plant outage. The document is dynamic and should be reviewed at the end of each plant turnaround to ensure that it is consistent with the needs of the facility.

The framework of the document should address several key issues. To optimize plant run time and avoid major unscheduled outages, a long-term plant turnaround frequency strategy should be developed.

The framework will recognize that the plant turnaround procedure has five fundamental phases:

1. Strategic planning
2. Detailed planning
3. Organizing
4. Execution
5. Closeout.

22.4 TURNAROUND MANAGEMENT ORGANIZATION

In order to manage all of the work that is involved in a turnaround, the maintenance manager and plant manager typically assign the position of turnaround manager to a seasoned engineer or project manager. The newly-assigned turnaround manager has a number of challenges to confront. These include:

- Immediate need for a strong team of support staff to help manage the turnaround
- Coordinating the efforts of 10 or more contractor companies and their personnel
- Assimilating and managing the scope of work to be done during the turnaround
- Planning the work in the upcoming turnaround
- Scheduling the turnaround work
- Coordinating with operations and process personnel regarding availability of operating assets, as well as approval tracking
- Managing the safe execution of the work
- Accurate tracking of costs
- Timely and accurate payment to contractors
- Logistical planning and support of the turnaround effort
- Accurate recording of work done in the historical record of the plant's assets

All these challenges, and their relevance to the turnaround management process, is discussed in turn. We use the features of the work management system to highlight how an integrated tool that supports all these efforts is the turnaround manager's best option to ensure that a successful outcome is guaranteed.

Too many turnarounds today still result in the turnaround manager having an abrupt and involuntary career change. This occurs for a variety of reasons, including poor decisions with respect to the timely handling of turnaround-related information.

22.5 TURNAROUND TEAM

Many plants troll for turnaround personnel from the ranks of their in-house staff or from their contractor companies. It is important to ensure that the people chosen are knowledgeable in the management of maintenance work. A person that understands how to use a software tool is not the equivalent of a person who knows how to plan the disassembly, cleaning, repair and re-assembly of a tower, an exchanger bundle or a heater. In fact, the team that makes this wrong choice has a huge problem from the very start of the turnaround. This is a fatal flaw in the organization.

The turnaround data management tool should never determine who is on your team. Ensure that you have good people who understand the scope and nature of the work.

Web-based turnaround work management tool is available 24 × 7 on the Web. Any application on the Web is, by definition, an easy application to master. It will not require experts in scheduling, database, word processing or spreadsheet software to be used effectively and accurately.

The turnaround team should represent all areas of responsibility: administration, operations, engineering, maintenance, health, safety, and environment (HSE); quality assurance (QA); procurement, planning, and scheduling and turnaround supervision. As the organizational chart increases in complexity, it is normal to contract out to third-party consultants and contractors to supplement the company's internal resources. This organizational chart expansion, which is for the facilitation of the owner's responsibilities and the management of the plant turnaround, requires a corporate commitment to train all personnel in the owner's plant turnaround procedures, goals, and objectives. The turnaround management process lends itself to the standardization of a checklist known as a "master milestone schedule". The MMS uses activities and time periods to guide the turnaround team through the plant turnaround procedure's five phases.

A major scheduled outage is an opportunity to make significant design changes in piping, equipment, buildings, and structures; and to update critical job procedures. If a management of change (MOC) process is not in place, the owner should take the steps to develop one. This process will control and justify any significant changes and therefore the turnaround costs. In order to capture these changes, there must be a process to justify and record them. The initiation of the MOC process begins before implementation, to allow for interdepartmental review and input, including senior management review and authorization. For future reference, a copy of the MOC should be included in the hard files of the asset that has been changed. Replacement-in-kind or routine job procedure updates, normally, do not require an MOC. The completion of one plant turnaround is the start of the next. The owner should identify the next turnaround manager before the closeout phase of the previous turnaround. This gives the incoming turnaround manager an opportunity to carry on the work of the previous team, and to participate in the review of the inefficiencies and good work done during the post-mortem meeting. The justification is that the next plant turnaround work list begins the day the operations group has the plant back on line. For smaller plants, the position of turnaround manager may carry over from turnaround to turnaround. Nevertheless, the company organization should identify the next plant turnaround manager and the responsibilities of the position. It should also make it clear that this person is now the focal point for collecting the next major scheduled outage maintenance work list items. To maintain the consistency of cost control and reporting, the plant turnaround management process document should provide an accounting or cost-control structure framework compatible with the corporate accounting system. Within this framework should be an interpretation of a capital cost versus a maintenance cost, and a work package direct cost and an indirect or support cost. This will provide comparison consistency from turnaround to turnaround and business plan to business plan. With the fundamental building block of the plant turnaround management process document in place, the next step is to prepare a long-term strategy for impending plant shutdowns.

22.6 CONTRACTOR MANAGEMENT

You may have five to ten major contractor companies, each supplying 10 to 100 people for the turnaround effort. Each of these may have a few subcontractors. In addition, you may have service contracts for smaller numbers of specialty people such as painters, technicians, compressor mechanics, etc. You have to have a plan for distributing the work to the available workforce. You have to decide whether you will have time and materials (T&M) or lump sum (LS) contracts. Do you plan to have contractors with union people work alongside those with non-union people? If you do, you need to have an agreement with the unions that outlines the rules of engagement. You certainly do not want to be surprised by labor action at the beginning of your turnaround.

You will need to prepare a bid package for each chunk of work. Along with the scope of work, each contract needs to include your expectations for the contractor's timekeeping and progress reporting. You will need to have a team to prepare these packages for issuance to the contractors. Another team needs to review the bids that are received.

Your team then needs to work closely with the winning contractors to ensure that the plans are workable within target timeframes. A detailed review and walk-through of the site by your planners and contractor planners is a mandatory requirement that pays dividends in ensuring that there are no surprises once the work starts.

There are some web based software tools available in the market and of great help for having both your staff and the contractors work from the same playbook as yours. Bids can be prepared based on the estimates and plans already completed in the software. Bid comparisons and awards can be made from the system. You can coordinate meeting agendas and minutes, as well as training for your in-house and contractor personnel. Also provides a means for attaching contract bids and other documents to the turnaround project. This provides everyone in your team with ready access to all relevant contract documents.

This saves immensely in meeting time, and prevents redundant communications such as, “What does the contract say about supplying safety PPE?” or “Where is the contract?”

22.7 SCOPE MANAGEMENT

Just what exactly is the scope of the turnaround? Currently, each department in the plant maintains its own “wish list” of items for the next turnaround. These lists are maintained laboriously in Excel spreadsheets or standalone Access databases. They are pulled out and provided to plant managers about six months prior to a turnaround. Turnaround scope items should be collected and maintained in the same place that all maintenance work scope is maintained—the asset work manager. When this is done, the opportunity for completing turnaround scope is possible during unplanned plant outages. The asset work manager also allows for routine maintenance work to possibly be delayed until a turnaround, thus reducing the cost of having to ready a site for two different work cycles.

The benefits of a transparent scope development tool that is accessible to all people in the plant—operations, maintenance, reliability, inspection, environmental, engineering and safety ensures that there are no surprises, and that unnecessary work is avoided.

The work management tool is a robust and complete tool for collecting work to be done on each asset. In addition, electronic links to condition-monitoring (CM) systems provide for automatic generation of environmental and inspection work requests. It is a coordinated, asset-focused work management system ensures that all people in the plant can access, review, add to and comment on any work that is being considered. In addition, the system supports electronic approval cycles that ensure that a record is kept of each business-rule-mandated approval, its date and its approver. The systems document management also ensures that any backup information for each work request is available by simply accessing the work request itself.

22.8 PLANNING MANAGEMENT

The work that a good planner does is like a warranty that ensures the success of the turnaround. A detailed plan is the basis of a great schedule, as well as an accurate estimate of costs. Your planner's time should be maximized by the provision of a planning system that ensures that he/she spends the majority of his/her time walking the site and discussing the logistical issues with operators, inspectors, etc. The planning tool should be simple and focused on easily collecting the plan data from the planner. A hand-held mobile device is optimal as the planner can accomplish a large amount of planning without returning to his/her desk.

The plan should be integrated directly with the asset work management system that is used for collecting the work scope, as it makes no sense to plan in a different system than your scope development system. This simply invites errors (such as asset number inconsistencies) and requires the maintenance of redundant data in a separate spreadsheet or scheduling program. Using a scheduling program for the planning process puts an undue focus on scheduling issues, when the focus needs to be simply and completely on plan development. Too many schedule-based plans are severely flawed because scheduled-based considerations are included in the plan. Similarly, planning considerations are often trumped by schedule concerns. Certain small duration, but critical, work items may be ignored by a scheduler for being too insignificant when viewed alongside larger duration, big-ticket, schedule items.

The above systems simple, planner-focused tool is designed to maximize the cash for the time the planner spends with it. With it, a planner creates a work package for an asset. He/she adds detailed work items for each work package. He/she links each work item to ensure that there is a logical flow to the work in the work package. He or she estimates the manpower needed to complete the work item in the estimated timeframe. He or she also estimates the consumable materials as well as delivery timeframes for these. Costs due to specialty work that is needed to complete the work item are also estimated. The complete plan is the foundation of the entire tracking system and must be accurate. The system also includes a status-based change management system. This allows the planner to modify the plan based on newer information as the work progresses.

22.9 SCHEDULING

The scheduling process for a turnaround project takes a well-planned scope of work, marries it to a well defined human and equipment resource availability matrix, and then computes possible dates for each work item in the schedule. A number of data affect the computation of the schedule, including turnaround periods (which define timeframes within which certain work, such as pre-shutdown work, is done), milestones (which provide target dates and also act as the start and finish of each period), date constraints, logic, duration and progress data dates. Applying resource limits to the availability of manpower and equipment resources further affects the computation of these scheduled dates.

Your system should be able to pretty much automatically (without human intervention) use the data provided by the target milestones and the availability of manpower and equipment to do the scheduling function. Your head planner and turnaround manager working with the contractor planners can provide the information required for scheduling directly to the system.

The automated scheduler that does the work with data that is provided. It can be set to run automatically at a certain time(s) each day. Sophisticated, priority-based multiple forward pass scheduling ensures that the optimal dates are computed for work items. The result of the schedule is presented in a simple, easy to read milestone variance format. Critical path is determined as the shortest duration from start to finish. Use of resource leveling ensures that many critical paths can emerge in order to help finish the work more quickly.

22.10 COMMUNICATION

A substantial volume of communication types are required during a turnaround, including:

- Meeting agendas
- Meeting minutes
- Scope request spreadsheets turnaround
- Contract documents
- Training records
- Estimates
- Engineering drawings

Now look at the distribution lists that seem to be an integral part of every turnaround. A team of clerks will copy incessantly prior to and during a turnaround in order to keep the distribution list supplied with paper. This wasteful approach, rather than a "green" alternative, is required because there is no single system available to each of the turnaround players: the manager, the planners, the foremen, the superintendents, operators, inspectors, safety personnel, contractors, etc. So, give them one system!

The system has all of the tools needed to ensure that your communication gets to its intended recipient. It records the recipient's responses and tracks each issue identified on the communication. If the recipient needs a hard copy, they have that option.

22.11 APPROVALS

You really cannot do anything safely in a plant without having the appropriate person sign-off on it. These approvals are often a big reason for demanding that paper be printed. The arrival of electronic signatures has now provided a means for ensuring that all business-rule-based approvals for expenditure of company funds or for safe work are tracked accurately.

The system supports the routing of electronic materials for approvals based on a business-rule-based routing map. There is no longer any doubt about whether someone has approved something. A person may assign approval ability to a designee. Approval ability is inherently available to a supervisor. Simply managing all of the approvals centrally, in the same system as the rest of your work is accomplished, is a huge time savings. It also lends an air of high professionalism to the process. It certainly saves a lot of time.

22.12 EXECUTION MANAGEMENT

The people that actually do the work need to be a part of the picture as well. A hand-held mobile wireless system is a critically useful tool for foremen in the field. They can quickly see what needs to be done next. They need to also be able to quickly indicate when they have completed a task or work item. In addition, at the end of their shift they should be able to easily record the people that worked on work items that day. This would save them the tedious and error-prone task of filling out timesheets.

The frontline of the work is where the foreman is often hit with deviations to the plan. Currently, these deviations are often lost as the foreman simply assigns people to the work and it is done right away. This happens because current systems for planning and tracking work are tedious.

The systems execution management tools provide frontline supervision with a tactical advantage to help them get their work done more quickly and far more accurately than they can with current tools and approaches. Tools for accurately collecting scope changes, progress data and actual time expended by labor and equipment are all easily and quickly maintained by foremen. This approach leaves them with more time to actually direct their crews than they currently have available.

22.13 TRACKING OF COSTS

Your labor, equipment, materials and contracted expenses are costs that are incurred in real time during the execution phase of the turnaround. When these incurred costs are compared, also in real time, with the earned value (based on progress) and the target costs, the turnaround manager has an extremely useful and effective tool to help in making real-time decisions based on how things are developing in the field. Add to this a real time comparison of the commitments and the expenditures to date, and the manager has a holistic picture of the entire turnaround project. This is the single most important tool that the manager has, and its success in communicating the story is based on the close integration of each data source—scope development, planning, scheduling, execution, purchasing and accounting.

The system provides the tool that accomplishes a complete integration of work management with external accounting and purchasing systems. Electronic integration reduces the need for redundant and error-prone data entry. Integration of turnaround tasks enables it to also provide mission-critical, timely decision-support reports for turnaround management. This is also done with a lessened need for costly contracted (temporary) help. Skill building opportunities for plant personnel are enhanced.

22.14 INVOICE VERIFICATION

Your contractor, with 100 people on-site, has just presented you with a bill. This bill is due in a week. His line of credit will not let him have four weeks in a row of these expenses, so it is imperative that you pay him quickly. You need a system that has already tracked the time each of those 100 people spent working. You should know what they worked on. You should know if they worked overtime and whether that was authorized. You should have signed acknowledgment that the equipment that he is billing you was actually on site and used. Also, you need validation that the materials that were delivered were, in fact, received.

The timekeeping and tracking modules are integrated with the work scope being executed and provide a tight link between the work done and who did it. As this data is collected in real time from frontline foremen, it is quite accurate more so than the timesheets that are filled after the fact in most scenarios today. With this tool available, you can be confident that your contractors' invoices can be quickly validated and that they will also stand the test of a company audit.

22.15 LOGISTICS

Every turnaround has a list of items that must be done in a certain order. These have been developed at each plant usually as "lessons learned" process following a turnaround. In order to not have to redundantly re-learn all of these lessons and to help you get things done expeditiously, you can use previously developed checklists and lists.

The integrated system has built-in locations for documentation, as well as numerous locations for note-keeping. These provide a way to ensure that the best practices that you evolve during your turnaround remain readily available to the people that follow you. They will be grateful that you were as thorough and were as attentive to detail as you needed to be. Successful turnarounds will become routine.

22.16 WORK HISTORY RETENTION

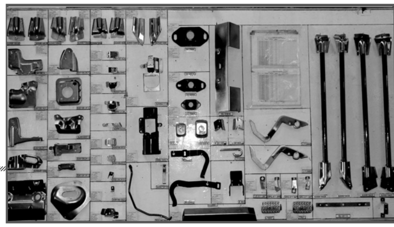
A quick review of current paradigms in plant turnarounds will show you that the work history is seldom effectively recorded in the asset's history. Now that the turnaround is done, everyone's attention is focused on completing things and getting the costly contractors off the payroll. So, little attention is given to the asset history. This never gets done. And if it is done, it is riddled with errors as it is entered after the fact.

The system has an asset management system at its core. This allows you to manage all asset-focused work in a way that the work is always a part of the asset history—whether the work is already completed or simply being considered. The whole story of the asset is always ready to be viewed at any time.

22.17 TURNAROUND CLOSEOUT

Project closeout is as important as the turnaround. Commissioning the plant after every work is finished is a tough challenge. In some companies they have a system in place called commissioning, qualification and verification (CQV). The team has identified all resources required to do commissioning. This CQV process is much more difficult compared to the commissioning done on new equipment. So care has to be taken to commission the plant and bring it up to speed.

CHAPTER 23



Computerized Maintenance Management System(CMMS)

CMMS systems are computer software that help maintenance teams keep a record of all assets they are responsible for, to schedule and track maintenance tasks and to keep a record of work they performed.

CMMS are utilized by facilities maintenance organizations to record, manage and communicate their day-to-day operations. The system can provide reports used in managing the organization's resources, preparing facilities, key performance indicators/metrics to use in evaluating the effectiveness of the current operations and for making organizational and personnel decisions. In today's maintenance world the CMMS is an essential tool for the modern facilities maintenance organization.

Prior to the computer age, paper records were maintained to track the work. Reports were simple but costly to prepare. With the dawn of the computer age it was recognized that computer software could be used to record work requirements, track the status of the work and analyze the recorded data for managing the work, produce reports and help control costs. Computers are powerful, relatively inexpensive, easy to use, and provide tools to support improved maintenance practices.

Tools are available for facility professionals that can manage the planning and day-to-day operations and maintenance activities required for a single facility or a large complex, providing all the information required to manage the work, the workforce, and the costs necessary to generate management reports and historical data.

23.1 DESCRIPTION

The goal of a maintenance manager is to employ a management system that optimizes the use of scarce resources (manpower, equipment, material, and funds) to maintain the facilities and equipment that are the responsibility of the maintenance organization. The system should provide for integrated processes giving the manager control over the maintenance of all facilities and maintainable equipment from acquisition to disposal. The following identifies what the system should do:

- Address all resources involved
- Maintain maintenance inventory
- Record and maintain work history
- Include work tasks and frequencies
- Accommodate all methods of work accomplishment
- Effectively interface and communicate with related and supporting systems ranging from work generation through work performance and evaluation
- Support each customer's mission
- Ensure communication with each customer
- Provide feedback information for analysis
- Reduce costs through effective maintenance planning.

A modern CMMS meets these requirements and assists the facilities maintenance manager with work reception, planning, control, performance, evaluation, and reporting. Such a system will also maintain historical information for management use. The manager should evaluate management data requirements and establish electronic data needs prior to acquiring a CMMS or additions to or replacement of an existing system. The evaluation should include a return on investments analysis before investing in additional or new CMMS capabilities. The manager should only acquire what is necessary to accomplish the maintenance organization's goals. The following paragraphs include details of capabilities that may be included in a modern CMMS.

23.1.1 Operating Locations

The CMMS may include an application that allows an operator to enter and track locations of equipment (locations in which equipment operates) and organize these locations into logical hierarchies or network systems. Work orders can then be written either against the location itself or against the equipment in the operating location. Using operating locations allows for tracking of the equipment's life cycles (history) and provides the capability to track the equipment's performance at specific sites.

23.1.2 Equipment

The CMMS may include a module that allows an operator to keep accurate and detailed records of each piece of equipment. This module would include equipment related data, such as bill of material, preventive maintenance (PM) schedule, service contracts, safety procedures, measurement points, multiple meters, inspection routes, specification data (name plate), equipment downtime, and related documentation. This equipment data is used for managing day-to-day operations and historical data that can be used to help make cost effective replace or repair decisions. The data can also be used to develop additional management information, such as building equipment downtime failure code hierarchies for use in maintenance management metrics.

23.1.3 Resources

The CMMS may include a separate module to track labor resources. This module typically includes records for all maintenance personnel, including their craft or trade categories, such as mechanic, electrician, or plumber. Additionally, this module may include labor rates in order to capture and track true labor costs against any asset or piece of equipment. Some CMMS will allow maintenance managers to also track skill levels and qualifications for each resource to help in planning and scheduling work. Grouping labor categories into common associations can help a manager assign work to particular shop rather than an individual.

23.1.4 Safety Plans

With the emphasis placed on safety throughout government and private sector industry a capability for safety plans/planning may be included in a CMMS. The following capabilities should be available:

- Manual or automatic safety plan numbering.
- Building safety plans for special work.
- Track hazards for multiple equipment and locations.
- Associating multiple precautions to a hazard.
- Track hazardous materials for multiple equipment and locations.
- Once hazards and precautions are entered they should be available for reference and data entry.
- Track ratings for health, flammability, reactively, contact, and material safety data sheets for hazardous materials.
- Define lock-out/tag-out procedures.
- Define tag identifications for specific equipment and locations.
- Define safety plans for multiple equipment or locations.
- View and linking documents.
- Associate safety plans to job plans, to preventive maintenance masters and to work orders.

- Print safety plans automatically on work orders.
- Allow tag-out procedures to be associated to hazards or directly to locations, equipment, and safety plans or work orders.

23.1.5 Inventory Control

An inventory control module may be included to allow an operator to track inventory movement such as items being moved in or out of inventory, or from one location to another. Stocked, non-stocked, and special order items could be tracked. The module should also have the capability for tracking item vendors, location of items, item cost information, and the substitute or alternate items that can be used if necessary. Some CMMS recommend and provide the ability to track tools and provide basic tool-room management features as part of the inventory module. This feature will allow work planners the ability to see what tools are in stock and assign tools to various work categories to reduce research effort on the part of mechanics and technicians working in the field.

23.1.6 Work Request

A work request module should be an integral part of a CMMS. The module can provide the capability for a requestor to input a request, such as a trouble call, or it can be entered by the maintenance organization's work control. The data entry screen should be designed for minimal data entry. The work order number can be assigned manually or automatically. A requester can enter minimal data and work control can enter additional information as required. Data should be entered once, and pop-up tables in the system should eliminate the need to memorize codes.

23.1.7 Work Order Tracking

A CMMS must include work order tracking because it is the heart of a work order system. The data should require entry only once, and pop-up tables should eliminate the need to memorize codes. The tracking system should provide instant access to all of the information needed for detailed planning and scheduling, including work plan operations, labor, materials, tools, costs, equipment, blueprints, related documents, and failure analysis. Of course, this depend on how many modules are installed and how much information has been entered in the system. The manager must evaluate data requirements and the practicality of adding modules.

23.1.8 Work Management

A work management module may be a part of the CMMS. The module could provide the capability that would let a planner specify which labor to apply to specific work orders and when. The module permits planning and dispatching.

23.1.8.1 Planning

In planning, labor assignments would be planned for future shifts. Each person's calendar availability would be considered when the assignments are made. The assignments would be created sequentially over the shift, filling each person's daily schedule with priority work for the craft. It could even split larger jobs over multiple shifts automatically.

23.1.8.2 Dispatching

In dispatching, labor assignments would be carried out as soon as possible. This system could begin tracking labor time from the instant the assignment is made. The system operator could interrupt work already in progress in order to reassign labor resources to more crucial work.

23.1.9 Quick Reporting

The CMMS could provide a rapid and easy means for opening, reporting on, and closing work orders, and reporting work on small jobs after the fact. Labor, materials, failure codes, completion date, and downtime could all be reported.

23.1.10 Preventive Maintenance

The following capabilities may be provided in a CMMS to manage a preventive maintenance (PM) program:

- Support multiple criteria for generating PM work orders. If a PM master has both time based and meter based frequency information, the program should use whichever becomes due first, and then update the other.
- Generate time based PM work orders based upon the last generation or last completion date. Next due date and job plans should be displayed.
- Permit and track PM extensions with adjustments to next due date.
- Trigger meter based PM by two separate meters.
- Print sequence job plans when wanted.
- Create a PM against an item so new parts have PM automatically generated on purchase.
- Specify the number of days ahead to generate work orders from PM masters that may not yet have met their frequency criteria.

- Consolidate weekly, monthly, and quarterly job plans on a single master.
- Assign sequence numbers to job plans to tell the system which job plan to use when a PM work order is generated from a PM Master.
- Permit overriding frequency criteria in order to generate PM work orders whenever plant conditions require.
- Route PM with multiple equipment or locations.
- Generate work orders in batch or individually for only the equipment wanted.
- Should have the capability to be used with the system scheduler to forecast resources and budgets.

23.1.11 Utilities

A utilities module may be included that contains detailed information on utilities consumption, distribution, use, metering, allocation to users, and cost. It could include modeling capability and linkage to utility control systems.

23.1.12 Facility/Equipment History

A history module may be included that would contain the maintenance histories of the facilities and equipment. It would contain summaries of PM, repairs, rehabilitation, modifications, additions, construction, and other work affecting the configuration or condition of the items. It would include completed and cancelled work orders. The maintenance history records can be used to support proactive maintenance techniques such as root cause failure and reliability engineering.

23.1.13 Purchasing

A mature CMMS may also include a purchasing module to initiate the requisition of material against a work order and track the delivery and cost data of the item when the material arrives. This capability will allow the maintenance manager improved visibility of matters that can impact work planning and efficiency. Procuring required material outside the CMMS can often leave information gaps that can inhibit the effectiveness of work execution and result in redundant parts orderings and non-standard procurement practices. The purchasing module may include many functions such as a vendor master catalog, invoicing, purchase orders, receiving, and even request for quotations.

23.1.14 Facilities Maintenance Contracts

A CMMS may contain a contracts module that includes information on maintenance contracts. With other database files, it provides a picture of each contractor's past performance, current loading, and planned work. It could include information on specifications, government furnished property, quality assurance, payment processing, delivery orders issued, schedules, and related matters. It could cover both contracts for facilities maintenance and support services.

23.1.15 Key Performance Indicators (KPI)/Metrics

The CMMS can be utilized to accumulate the data for KPIs for use in evaluating the organization's maintenance program. The maintenance management organization must select the metrics to utilize in establishing their goals and to measure progress in meeting those goals. The importance of selecting the key performance indicators cannot be overstated. The KPIs must be based on data that can be obtained and provide meaningful information that will be utilized in managing the organization.

23.1.16 Specialized Capabilities and Features

Some CMMS providers have also developed specialized capabilities and features for particular business sectors, functions, or requirements. Maintenance managers today can use their CMMS to track transportation and fleet inventory, including maintenance history, mileages, lease terms, rates, and accounting data. Other managers are using their CMMS to track deployed assets such as computers and other IT equipment. Through their CMMS they track changes, additions, and movement of equipment, including software inventory on computers, tablets, and smart phones. When selecting a CMMS; consider the full scope of asset management options, with a focus on consolidated IT solutions.

23.2 APPLICATIONS

A CMMS can be used to manage simple or complex facilities, from a single building to a complete campus. A CMMS can also be used to manage the maintenance program for a grouping of equipment such as a fleet of vehicles. The systems are versatile since most are in modular form for the various maintenance functions and can be customized to fit the particular application. Whatever system or set of modules are selected for use, careful consideration needs to be given to functional requirements and a sound deployment plan. The CMMS must meet the needs, constraints, and opportunities of the business and be implemented in a way that users will welcome the technology and have a vision for the benefits it brings. Proper configuration, testing, and training cannot be overemphasized when bringing a new CMMS or upgrading an existing system to an organization.

23.3 LESSONS LEARNED

Before procuring and implementing a CMMS determining if the system is to be an asset and a usable tool in the managing of the day-to-day maintenance and operations within an organization must be taken into account.

23.3.1 General Considerations

Understand what other systems are in use by your organization with which the CMMS will have to interface such as financial and geospatial systems, and ensure that this interface can be easily managed. Users and managers of these systems should be involved in developing your CMMS, including your IT group. When considering a new system, make sure that the data from your existing system can be easily and accurately transferred. Look for full support from the vendor during installation and testing. Ensure this includes ample training of your staff in the use of the system in both operating the system and how to maximize the benefit of the information within the system. The vendor should leave you with a clear understanding of what it can and cannot do, as well as annual maintenance and upgrade costs.

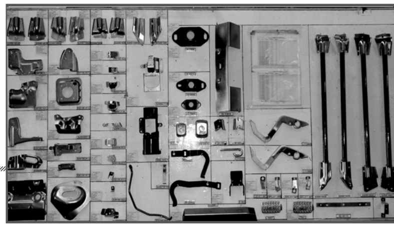
23.4 EMERGING ISSUES

Failure of CMMS implementations is a continuing problem voiced by industry experts. To avoid this pitfall a thorough management study of the system is required to evaluate the use of such a system in their organization and to determine the costs benefits. Not all maintenance organizations require the use of a complete set of CMMS modules. Those that have implemented CMMS programs without a complete study, typically fail to use the capabilities incorporated in the software and may eventually view the program as a failure.

Avoiding the pitfalls in decision-making concerning implementing or modifying CMMS in a maintenance organization means research must be a high priority.

CMMS would benefit significantly from a standardized asset identification system in which each piece of equipment or building component is given an identification number common to all facilities throughout an organization. The acquisition of a CMMS or adding to or replacing an existing CMMS a Return on Investment (ROI) should be performed to obtain data to justify the acquisition. An ROI calculator to determine an organizations potential savings from an improved management of their maintenance program is available.

CHAPTER 24



Warranty and Maintenance

In contract law, a warranty has various meanings but generally it means a guarantee or promise which provides assurance by one party to the other that specific facts or conditions are true or will happen. This factual guarantee may be enforced regardless of what is the materiality which allows for a legal remedy if that promise is not true or followed.

Although warranties are used in many contractual circumstances, they are a common feature in automobiles and real estate purchases. For example, new car sales typically include a factory warranty which guarantees against the malfunction of the car for a certain time period.

Warranties may be either express or implied. Express warranties are created by affirmative acts of the seller that are an affirmation of fact or promise made by the seller which relates to the goods and becomes part of the basis of the bargain. Express warranties can be created when the seller describes the goods or furnishes samples. Express warranties create strict liability for the seller, so that negligence need not be proven. In general, express warranties are based on factual statements rather than opinions about the future. An exception is made when it is a professional opinion which can create a warranty. Manufacturer, distributor, and retailer could all be jointly and severally liable, so that the full amount of damages could be collected from one or any of them. The distributor and retailer may be able to escape liability if the manufacturer is not bankrupt. Purchasers, consumers, users, and even bystanders are entitled to sue for breach of warranty.

There are implied warranties in every sales transaction that the goods sold are fit for the ordinary purposes for which such goods are used. This is called the "implied warranty of merchantability". Under the implied warranty of merchantability, the goods sold:

- Are fit for the ordinary purposes for which such goods are used
- Would pass without objection in the trade

- Are adequately packaged, labeled, and contained
- Conform to the promises made in the label

  There may also be an "implied warranty of fitness for a particular use".

  This warranty is created when at the time of sale, the seller has reason to know the uses the buyer has for the goods, and
- The buyer relies on the sellers judgment in selecting the goods
- This implied warranty is not created if the buyer's knowledge of the goods is as great as the seller, or the buyer has a professional consultant
- The buyer supplies specifications to the seller.

Implied warranties are part of every contract unless disclaimed by the seller. Implied warranties are often disclaimed, which is legal as long as the disclaimers are conspicuous, such as in bold face print. Warranty disclaimers have been held a material alteration, such that they would not be part of the contract if the term was added in the acceptance. Although a seller cannot disclaim an express warranty, he can disclaim implied warranties.

A contract may contain the phrase "represent and warrant", which means to indicate and guarantee or assert something. For example, a disclaimer of warranties may provide as follows:

"We do not endorse, represent or warrant the accuracy or reliability of any of the information, content, advertisements or other materials contained on, distributed through, or linked, downloaded or accessed from our service. We do not endorse, represent or warrant the quality of any products, information or other materials displayed, purchased, or obtained as a result of or in connection with the service, and we do not endorse, represent or warrant the service, security or practices of any of the vendors whose products or services are included on the service. Any reliance upon any information, content, advertisements, materials, products, services or vendors included on or found through the service shall be at the user's sole risk."

24.1 ADDITIONAL DEFINITIONS

A product or service warranty (also known as guarantee) is a promise, from a manufacturer or seller, to stand behind the product or service. It is a statement about the integrity of the product and about the seller's commitment to correct problems should the product or service fail. Product and service warranties have become standard practice in most industries, although opinions vary somewhat regarding their impact on sales. But misleading language in these guarantees has the capacity to spark significant legal troubles for small businesses that run afoul, however inadvertently, of legal guidelines. Consumers can ask the courts to enforce warranties, whether they are express, implied, written, verbal, or given in any other way. Local government entities establish the regulatory basis upon which warranties are judged.

24.2 IMPLIED AND EXPRESS WARRANTIES

The law recognizes two basic kinds of warranties: Implied warranties and express warranties.

24.2.1 Implied Warranties

Implied warranties are unspoken, unwritten promises, created by state law, that go from the seller or merchant to the customers. Implied warranties are based upon the common law principle of "fair value for money spent." The law provides for two basic types of implied warranties that occur in consumer product transactions. They are the implied warranty of merchantability and the implied warranty of fitness for a particular purpose. The "implied warranty of merchantability" is a seller's basic promise that the goods sold will do what they are supposed to do and that there is nothing significantly wrong with them. In other words, it is an implied promise that the goods are fit to be sold. According to the law, merchants make this promise automatically every time they sell a product they are in business to sell. By contrast, the implied warranty of "fitness for a particular purpose" is a promise that a seller makes when the customer relies on the advice that a product can be used for some specific purpose. For example, suppose a woman comes to an office supply store and asks for a printer that is able to print 1,000 sheets of paper per hour. If the office supply company recommends a particular model, and the customer buys that model on the strength of this recommendation, the law says that the office supply company has made a warranty of fitness for a particular purpose. If the printer recommended proves unable to produce 1,000 pages per hour, even though it may effectively print 800 pages an hour, the implied warranty of fitness for a particular purpose is breached.

24.2.2 Express Warranty

Unlike implied warranties, express warranties are not automatically a part of the sales contract based on state law; rather, they are explicitly offered warranties. They are promises and statements, made voluntarily by the seller or manufacturer, about a product or service and about the commitment to remedy defects and/or malfunctions that the customer may experience. Express warranties can take a variety of forms, ranging from advertising claims to formal certificates. An express warranty can be made either orally or in writing. While oral warranties are important, only written warranties on consumer products are covered by the Warranty Act.

24.3 ELEMENTS OF A WARRANTY

The law requires that written warranties bestowed in connection with the sale of a product or service explicitly detail the following information:

- Who is covered under the warranty
- Length of warranty
- Description of the products, parts, properties, or characteristics covered by or excluded from the warranty
- Steps for customer in the event that warranty coverage comes into play
- Warrantor's response when confronted with product/service malfunctions, defects, or failures
- Any exclusions of or limitations on relief such as incidental or consequential damages
- Statement of consumer legal rights
- Any limitations on the length of implied warranties, if possible
- Description of the products, parts, properties, or characteristics covered by or excluded from the warranty
- Steps for customer in the event that warranty coverage comes into play
- Statement of consumer legal rights

24.4 FULL AND LIMITED WARRANTIES

The Act does not require businesses to provide warranties to customers. Indeed, some business owners decide that written warranties are not even necessary to enjoy success in their chosen field of endeavor. But other manufacturers and retailers are convinced that warranties help sell their products, pointing to the popularity of service contracts and the like.

- Businesses that choose to provide written warranties may choose from two types: full and limited. The regulations concerning full warranties are considerably more stringent than those that apply to limited warranties. According to the Act, "fully guaranteed" products or services must meet the following:

- Customer receives full money back or replacement or repair of any defective part of product in the event of a complaint
- Prompt and free repairs
- If repairs are not fully satisfactory to the buyer, a prompt refund is available
- Customer has no responsibility beyond reporting the defect to the company
- Acknowledgment of all implied warranties

Limited warranties, which must be prominently labeled as such, limit the liability of the manufacturer or service provider. A limited warranty may offer to replace defective parts free, but only do so for a limited length of time, or require that the consumer ship the product to a manufacturer-approved service center. The distinctions between full and limited warranties and the obligations of manufacturers to honor them vary from place to place, so it is up to the consumer to carefully read the literature and understand what is covered before the purchase.

24.4.1 Disclaimer

Vulnerability to express and/or implied warranties can be reduced somewhat through the use of disclaimers. A disclaimer is a means of denying that you are making one or more express or implied warranties. In the absence of a disclaimer, a breach of warranty will often give the purchaser of the faulty item the right to recover the cost of the item as well as additional damages caused by that breach of warranty.

Small business consultants note that warranties both express and implied can be negotiated with buyers, but they urge business owners to use specific language when adding such disclaimers to a sales contract. The term "exclusive remedy," for instance, can give a seller of products or services significant legal protection when it is used to explicitly limit a buyer's legal options in the event of complaints about product defects or workmanship. If, however, the customer is left without a working product, the seller may be sued no matter what agreement was signed, on the grounds that it's a remedy that "fails of its essential purpose." Obviously, the obligations imposed by law in the areas of warranty are extensive, so small business owners should make sure that they consult a legal expert so that they can develop the most effective disclaimer possible.

24.4.2 Extended Warranties

Extended warranties are somewhat controversial, but often profitable, warranty packages offered by manufacturers and service providers. Manufacturers sell these warranties, which are basically extensions of basic warranty packages, in hopes that the extended warranty will not be needed or used, thereby resulting in profits. Consumers buy them for peace of mind, reasoning that they are protecting their initial outlay of money. The controversy revolves around what the warranties cover. Some extended warranties are actually service agreements, resulting in higher charges than might be expected under a warranty. In other cases the fine prints in the warranties exclude the very things that the consumer assumes would be covered.

A warranty may be express or implied, depending on whether the warranty is explicitly provided (typically written) and the jurisdiction. Warranties may also state that a particular fact is true at one point in time or that the fact will continue into the future (a "promissory" or continuing warranty).

When you make a major purchase, the manufacturer or seller makes an important promise to stand behind the product. It's called a warranty. The law requires that warranties be available for you to read before you buy even when you're shopping by catalog or on the Internet. Coverage varies, so you can compare the extent of warranty coverage just as you compare the style, price, and other characteristics of products.

24.4.3 Written Warranties

Although not required by law, written warranties come with most major purchases. When comparing written warranties, keep the following in mind:

- How long does the warranty last? Check the warranty to see when it begins and when it expires, as well as any conditions that may void coverage.
- Who do you contact to get warranty service? It may be the seller or the manufacturer who provides you with service.
- What will the company do if the product fails? Read to see whether the company will repair the item, replace it, or refund your money.
- What parts and repair problems are covered? Check to see if any parts of the product or types of repair problems are excluded from coverage. For example, some warranties require you to pay for labor charges. Also, look for conditions that could prove expensive or inconvenient, such as a requirement that you ship a heavy object to a factory for service, or that you return the item in the original carton.
- Does the warranty cover "consequential damages?" Many warranties do not cover damages caused by the product, or your time and

expense in getting the damage repaired. For example, your freezer breaks and the food spoils, the company will not pay for the lost food.

- Are there any conditions or limitations on the warranty? Some warranties provide coverage only if you maintain or use the product as directed. For example, a warranty may cover only personal uses—as opposed to business uses—of the product. Make sure the warranty will meet your needs.

24.4.4 Spoken Warranties

If a salesperson makes a promise orally, such as that the company will provide free repairs, get it in writing. Otherwise, you may not be able to get the service that was promised.

24.5 SERVICE CONTRACT

When you buy a car or major appliance, you may be offered a service contract. Although often called "extended warranties," service contracts are not warranties. Service contracts, like warranties, provide repair and/or maintenance for a specific time. Warranties, however, are included in the price of the product; service contracts costs extra and are sold separately. To determine whether you need a service contract, consider:

- whether the warranty already covers the repairs and the time period of coverage that you would get under the service contract;
- whether the product is likely to need repairs and the potential costs of such repairs
- the duration of the service contract
- The reputation of the company offering the service contract.

24.6 PREVENTING PROBLEMS

24.6.1 To Minimize Problems

- Read the warranty before you buy. When online, look for hyperlinks to the full warranty or to an address where you can write to get a free copy. Understand exactly what protection the warranty gives you. If a copy of the warranty is available when shopping online, print it out when you make your purchase and keep it with your records.
- Consider the reputation of the company offering the warranty. Look for an address to write to or a phone number to call if you have questions or problems. If you're not familiar with the company, ask your local or state consumer protection office or Better Business

Bureau if they have any complaints against the company. A warranty is only as good as the company that stands behind it.

- Save your receipt and file it with the warranty. You may need it to document the date of your purchase or prove that you are the original owner in the case of a nontransferable warranty.
- Perform required maintenance and inspections.
- Use the product according to the manufacturer's instructions. Abuse or misuse may void your warranty coverage.

24.6.2 Resolving Disputes

If you have problems with a product or with getting warranty service:

- Read your product instructions and warranty carefully. Don't expect features or performance that your product wasn't designed for, or assume warranty coverage that was never promised in writing. A warranty doesn't mean that you'll automatically get a refund if the product is defective the company may be entitled to try to fix it first. On the other hand, if you reported a defect to the company during the warranty period and the product wasn't fixed properly, the company must correct the problem, even if your warranty expires before the product is fixed.
- Try to resolve the problem with the retailer. If you can't, write to the manufacturer. Your warranty should list the company's mailing address. Send all letters by certified mail, return receipt requested, and keep copies.

24.7 WARRANTY MAINTENANCE

24.7.1 Warranty Claim

Customers claim for repair or replacement of or compensation for non-performance or under-performance of an item as provided for in its warranty document. In order to have satisfied customers the manufacturer shall immediately understand the customer complaint in totality and take remedial measures to repair or replace the part or the whole equipment as the case may be.

From the manufacturer's side as far as the warranty claims are concerned it is not that the part or complete equipment is repaired and given back to the customer. It is the matter of how many such claims are coming and what is the root cause of such complaints is important. Let us now look at how to receive the warranty claims and how to handle the warranty claim so that the customer is satisfied and the reputation of the manufacturing company in the market place is taken care of.

24.7.2 Investigate the Warranty Claim

It is always prudent to have no warranty claims for a manufacturer however it may not be possible to achieve that goal all the time. Warranty claims are a loss to the company and so this key result is tracked so that the design team and manufacturing team have done their jobs properly and are as per specifications. Traceability and analysis to go to the root cause are key part of investigation. The failure of the part could be because of material failure due to poor design, overloading, stress concentration, lack of lubrication and many such reasons. Bad operation also could be a reason for early failures.

Reputed companies are following **8-D methodology** to receive the complaint, investigate it to the root cause, put some control system in place, see if the control system is giving results and finally, the communication of this case is closed to the satisfaction of the customer.

24.8 FUNDAMENTALS OF 8-D METHODOLOGY TO ADDRESS CUSTOMER COMPLAINTS AND WARRANTY CLAIMS AND RESOLVE THEM

- 8-D or 8-Discipline methodology is the analytical and informative way to understand, describe, analyze and resolve typical problems faced in the organization.
- It asks about why the process is operating outside of a target range and provides a mechanism for identifying the root cause and implementing appropriate corrective and preventive actions.
- Focus is on permanent solution to the problem and hence, through 8-D one can also change processes, procedures or systems, so that the problem and other similar to it are prevented from happening again.
- 8-D techniques require knowledge of basic quality tools, techniques and procedures to successfully resolve the problem.
- Quick and permanent elimination of internal and external customer complaints and warranty claims, using a systematic method of finding and eliminating the real defect cause.
- Preventive transfer (reapplication) of the knowledge gained to similar processes and products.
- Ongoing and final documentation of the problem solving process.

24.8.1 Purpose of 8-D Methodology

- Quick and permanent elimination of internal and external customer complaints, using a systematic method of finding and eliminating the real defect cause.

- Preventive transfer of the knowledge gained to similar processes and products.
- Ongoing and final documentation of the problem solving process.

24.8.2 D-0 Purpose

In response to a particular symptom, evaluate the need for the 8-D process. If necessary, provide emergency response action to insulate and protect the customer, and then initiate the 8-D process.

Symptom is a quantifiable event or effect experienced by the customer that may indicate existence of one or more problems.

Before initiating 8-D confirm whether it is a complex problem justifying approach according to 8-D? Also make sure that no earlier 8-D exists for the problem. Tasks and situation analysis is done satisfactorily. Ensure fault assessment is correct and reasons for customer complaint.

24.8.3 D-1 Purpose

To establish a small group of people with the process and or product knowledge, allocated time, authority and skills in the required technical disciplines to solve the problems and implement corrective actions. The group must have a designated champion and the team leader. The group initiates the team building process.

24.8.3.1 Team Membership

Members must have different technical skills required to resolve the problem. Necessary membership - person from the affected area/customer are needed. Team should be restricted between 4 to 10 members depending on the complexity of the symptom. Membership can change according to the stage within the process.

24.8.3.2 Role of the Champion

The champion needs to have ownership and control over the system or process under consideration and the team activity. He or she needs to have authority to make changes and provide necessary resources to the team. The person should provide high level support for team decisions and create an environment for empowerment of the team.

24.8.3.3 Role of the Team Leader

The team leader must be team's business manager, spokesman, decision maker and controller. He or she must synergize the team skills for problem solving. Also focus on meetings purpose and agenda. The person should be able to visualize the complaint on the shop floor. Explicitly give up the leadership role when participating in discussions.

24.8.3.4 Form the 8-D Team – Use the Plant Potential for Problem Solving

The problem owner has to act as leader or to nominate one representative. Each member has to know the roles and responsibilities. No hierarchy thinking in the team – only the contribution is important. The boss of team members should be informed about the participation. Need to have members in the team from manufacturing, process engineering, technical functions, quality and the customer.

24.8.3.5 D-2 Problem Description

Purpose: The purpose is to describe the internal/external problems by identifying "what is wrong with what" and detailing the problem in quantifiable terms, any vagueness or inaccuracy at D-2 can lead the team to the wrong cause, followed by the wrong corrective actions.

What is the deviation? What object/ which process is affected?

What is the problem's precise description and problem profile? Procure/ collect data as comprehensively as possible. Secure and collect sample parts and pieces of evidence.

Describe problem in detail — get full clarity about the defect

- Describe the problem as precisely as possible
- Define responsibilities and due date for data collection
- Use graphs and charts for data base, Pareto analysis, etc.
- Use simple questions like what, when, where, who?
- One time defect or repeated defect?
- Could a first inspection confirm the defect?

24.8.3.6 D-3 Containment Actions Purpose

To define, verify and implement the interim containment action (ICA) to isolate the effects of the problem from any internal/external customer until permanent corrective actions (PCA) are implemented. It is also the purpose of D-3 to validate the effectiveness of the containment action.

Containment action is totally temporary in nature. It must not create other problems in the subsequent process chain. PDCA principles may be used for deciding the CA. It has to be verified, may be through a trial run, empirical tests, comparison with similar proven actions or through review by cross-functional team. It has to be validated after implementation. How can the problem be tided over? What replacement measures are feasible? How can the process be sustained? How can it be prevented that defective parts are further processed or even reach to the customer? Stop delivery? Sort the manufactured parts/stores stock?

Containment actions –avoid further supply of defective parts

Find out stocks at customer's end, in transit, warehouse, and in factory. Arrange sorting out of available stocks and / or recall from outside if needed. Check if other types / customers are affected from same defect. Information and defect discussion with shop operators and setters. Display the defect and all actions on the shop floor. Implement additional test to ensure 100% detection. Firewall or special over checking (time limitation) is needed at this hour. Take first attempt to find out the source of defect and react immediately. Verify the effectiveness of containment actions—Zero defects to customer.

24.8.3.7 D-4 Identify Root cause(s)

D-4 is the core procedure. Success of 8-D lies on finding the real root cause.

Purpose: Isolate and verify the root cause by testing each possible cause against the problem description and test data. Isolate and verify the place in the process where the effect of the root cause should have been detected and contained but was not done.

- **Possible Cause:** Any cause identified on a cause and effect diagram that describes how an effect may occur.
- **Potential Root Cause:** Can be multiple. Will turn the problem on and off and cannot be eliminated based on available data. This requires D-7 prevention actions.
- **Root Cause:** The single verified reason that accounts for the problem.

Verification of the root cause is the proof that confirms proper identification of the root cause. It should be done in 2 steps — passive and active. Passive verification is done by observations.

Active verification is a process where the variable element which is thought to be the root cause is used to make the problem come and go. This is an important test for ensuring proper root cause.

Root cause analysis is to know why the defect can occur. Use analytical tools like Ishikawa diagram, FMEA, etc. Find out all changes in process, tools, material, organization, etc. Restrict the problem by grouping or defining margins. Go into the depth of problem by using the **"Why-why analysis"** method. Involve experts from other areas, other plants and third parties. Define further actions — how to continue and complete root cause analysis. Identify root causes for "defect not detected" organization, skills, technology etc.). Verify the probable root cause by tests, simulation, DOE, etc.

24.8.3.8 D-5 Establish Permanent Corrective Actions

- Select the best permanent corrective action to remove the root cause.
- Select the best permanent corrective action to address the escape point.
- Verify that both decisions are successful and implemented.
- Verify that both decisions do cause undesirable effects.

The decision making process should necessarily be by involvement of team members, with proper risk and benefit analysis and weighing of all the alternative choices. PCA developed thus, should be verified by actual trials (preferably) so as to ensure that the root cause and the symptom is totally eliminated.

It should be ensured that no "side-effects" or other problems crop up while implementing the PCA. What measures prevent appearance of the cause which led to the deviation complained? Is it modification of the product? Or is it modification of the production process? Or it is modification in the organization, quality system, etc? Evaluate the effectiveness of these permanent corrective actions & decide further.

24.8.3.9 D-6 Occur Permanent Corrective action(s)

Purpose: To plan and implement selected PCA, remove the ICA, validate the PCA and monitor long-term results.

Key Concepts

- Plan steps necessary to implement and validate the PCA
- Planning and problem prevention is applied to each step of the plan to implement the PCA
- What potential problems are conceivable in connection with the modifications?
- How can the modifications decided in D-5 be implemented as far as possible without problems?
- Action plan
- Potential problem analysis
- Critical areas (risks + side effects)
- Preventive measures
- Protection actions
- Information to all concerned (work instructions)

24.8.3.10 D-7 Preventive actions to avoid recurrence

Purpose: Modify the necessary systems—including the policies, practices and procedures — to prevent recurrence of this and similar problems.

Make recommendations for systematic improvements, as necessary. Establish rationale for completing D-7. Fix the root cause of the root cause of the problem. Address the systems, practices, policies and procedures that allowed the problem to occur and escape. How can it be ensured that disturbing influences are permanently prevented, detected and reported and at an early stage eliminated? Is it constructional training, organizational measures, work instructions, information and or Poka- Yoke?

Transfer the knowledge/experience to other areas.

24.8.3.11 D-8 Team and Individual Recognition

Purpose: Complete and document the team experience. Sincerely recognize both team and individual contributions. This is where the documentation ends and is archived. Feedback is given to the affected persons / departments / organizations. Completing unfinished team business—finalizing and archiving documentation. Recognizing technical lessons learnt.

Making the final presentation to the champion.

Submit to the internal/external customer who has raised the 8-D by raising warning signs through the symptoms observed by him.

Review process success. What have we learnt? What was good and what should we improve during solving problems in future? How can we acknowledge the persons involved?

Close the 8-D and report the findings to the internal/external customers; congratulate the team and seek new avenues for improvements.

Herein, there are a few things to be noted down from the experience of team members. These are known as Do's and Don'ts.

24.8.3.12 Do's

- Involvement of all the team members during the process.
- Ensure defect-free supplies in the meanwhile (fool-proof containment actions)
- Visualization on the shop floor.
- Systematic review of each step against the set time frame and the effectiveness of the actions and the yield thereof.
- Regular information exchange within the team, to and from the customer, to and from the champion, to and from the management.
- 8-D closed only when all the actions are effectively completed, and the symptoms/problems raised are totally resolved.
- Presentation by the team to the customer/initiator of the 8-D.

24.8.3.13 Don'ts

- Do not initiate a fresh 8-D if any 8-D is initiated for the same/similar problem. The old 8-D is to be revived and accordingly addressed for preventing recurrence.
- Do not develop the process on only one person's knowledge and experience. Check and recheck all possible hypotheses generated in the brainstorming process. Synergizing the skills of all guarantees success.
- Do not start the next step unless the earlier steps are properly analyzed and reviewed. Success of 8-D lies in proper review.
- Do not believe in what is obvious, unless it is properly tested and confirmed.
- Do not exceed the deadlines set. In case of contingencies, if it happens, keep the customer and all the concerned informed , with proper justification

24.9 WARRANTY REPAIR OR REPLACEMENT

There are two types of repair or replacement. The first one would be to conduct the repair in the field. This is generally done when the equipment or item under warranty is big and also transporting that item is expensive. Also it is done when the item under discussion is part of a big system and repair to the item in consideration is better done at site. If it is clearly understood that it requires a spare part and by fixing the spare part trials can be taken there at site, then the repair can be done at site instead of moving the whole system to the manufacturing plant.

The second type is generally a warranty claim where the part is definitely needed to be brought to the plant so that the whole investigation work is done at the plant or service station. A thorough investigation by going to the root cause as explained in the 8-D methodology can be done at site. In such cases the manufacturing plant or the seller needs to identify the root cause and may do corrective maintenance or design changes so that the failure of the part or equipment is finally stopped.

24.10 PRODUCT RECALL

A **product recall** is a request to return to the maker a batch or an entire production run of a product, usually due to the discovery of safety issues or a product defect. The recall is an effort to limit liability for corporate negligence (which can cause costly legal penalties) and to improve or avoid damage to publicity. Recalls are costly to a company because they often entail replacing the recalled product or paying for damage caused by use, although possibly less costly than consequential costs caused by damage to brand name and reduced trust in the manufacturer.

A country's consumer protection laws will have specific requirements in regard to product recalls. Such regulations may include how much of the cost the maker will have to bear, situations in which a recall is compulsory (usually because the risk is big enough), or penalties for failure to recall. The firm may also initiate a recall voluntarily, perhaps subject to the same regulations as if the recall were compulsory.

It is a big effort and depending on the resources available the scale of operation is decided. It also depends on the urgency in which these recalls have to be completed. There are many examples of product recalls in the world history. A number of cars, mobile phones and other consumer durables have gone through these types of product calls.

24.11 INSURANCE CLAIMS

In some cases there will be a third party or an insurance surveyor who will try to understand the customer's complaint in details and shall decide about the repairs or replacements. In situations where a third party surveyor or insurance surveyor is involved the cost of total repairs and replacements may not be borne by the manufacturing company. How much compensation is due from the insurance is decided by the insurance company and how much will have to be paid by the buyer is decided by the insurance company.

24.12 AFTER-SALES SERVICE

Periodic or as required maintenance or repair of equipment by its manufacturer or supplier during and after a warranty period.

What is After-Sales Service?

After-sales service refers to various processes which make sure customers are satisfied with the products and services of the organization.

The needs and demands of the customers must be fulfilled for them to spread a positive word of mouth. In the current scenario, positive word of mouth plays an important role in promoting brands and products.

After-sales service makes sure products and services meet or surpass the expectations of the customers.

After-sales service includes various activities to find out whether or not the customer is happy with the products? After-sales service is a crucial aspect of sales management and must not be ignored.

24.12.1 Why After-Sales Service?

After-sales service plays an important role in customer satisfaction and customer retention. It generates loyal customers.

Customers start believing in the brand and get associated with the organization for a longer duration. They speak well about the organization and its products.

A satisfied and happy customer brings more individuals and eventually more revenues for the organization.

After-sales service plays a pivotal role in strengthening the bond between the organization and customers.

24.12.2 After-Sales Service Techniques

Sales professionals need to stay in touch with the customers even after the deal. Never ignore their calls. Call them once in a while to exchange pleasantries.

24.12.3 Give Them the Necessary Support

Help them install, maintain or operate a particular product. Sales professionals selling laptops must ensure Windows are configured in the system and customers are able to use the Net Without any difficulty. Similarly, organizations selling mobile sim cards must ensure the number is activated immediately once the customer submits the necessary documents.

Any product found broken or damaged must be exchanged immediately by the sales professional. Don't harass the customers. Listen to their grievances and make them feel comfortable.

Create a section in your organization's website where the customers can register their complaints. Every organization should have a toll free number where the customers can call and discuss their queries. The customer service officers should take a prompt action on the customer's queries. The problems must be resolved immediately.

Take feedback of the products and services from the customers. Feedback helps the organization to know the customers better and incorporate the necessary changes for better customer satisfaction.

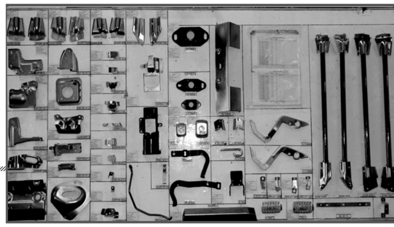
Ask the customers to sign annual maintenance contract (AMC) with your organization. AMC is an agreement signed between the organization and the customer where the organization promises to provide after-sales services to the second party for certain duration at nominal costs.

The exchange policies must be transparent and in favor of the customer. The customer who comes for an exchange should be given the same treatment as was given to him when he came for the first time. Speak to him properly and suggest him the best alternative.

24.13 WARRANTY MAINTENANCE

So, finally there are three types of maintenance work either during warranty period and after the warranty period is over.

1. There are warranty claims: The warranty claims are analyzed by going to the root cause and maintenance, repair and replacements are done during the warranty period.
2. There are customer complaints and these are analyzed by going to the root cause and maintenance, repair and replacements are done during the warranty period and later.
3. There are service contracts and as a part of service contract maintenance, repair or replacements are done in the tenure of service contracts.



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