Lean Six Sigma Quality Transformation Toolkit (LSSQTT)*
LSSQTT Tool #27 Courseware Content
“Information Technology, Maintenance And Safety:
Pivotal Manufacturing And Non-manufacturing Services”

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Basic Requirements For E-commerce, Information And Service

Maintenance and safety merge in tool 33 in a rather non-obtrusive manner since both are very much concerned with quality and productivity enhancements. Various functions and their roles will be explored relative to maintenance and safety, all via integrated information technology relationally. Basic requirements will be presented and addressed, all for the overall purpose of embracing E-commerce relationships inherent in maintenance and safety as prime service areas. This is aimed at helping the technologist better understand their role.

It is a foregone conclusion that technology must be maintained and that it must function in a safe manner. It also seems obvious that all persons in an organization must consider one another as customers to be serviced. If technology is properly maintained, it will be safe and therefore, more productive. The extent to which we consider all others, and all functions, to require our efficient and top quality services, will directly relate to how productive we can be.

Mechanical equipment, production tools, transportation systems, physical facilities, and all other aspects of the technological organization require proper maintenance and service functions. Perhaps nowhere besides maintenance and service functions are contingencies for others more noticeable. If maintenance services are not properly performed in a disciplined manner, no matter what other products may or may not be produced, the organization will not function. This is a safety issue since without properly maintained equipment it simply increases the likelihood for mechanical failure--possibly leading to lost time, non-value adding occurrences.

Consider how the floors or bathrooms will be cleaned? Or how will raw materials, components, new equipment and consumables, among others, be ordered and prepared for disposition? How will orders be processed, products packed and shipped, inventories maintained, bids let, contracts written, and so on? All functions in a technological organization are contingent upon maintenance, safety and other services being performed properly. E-commerce provides both opportunities and challenges to this.

Several basic requirements must be met if maintenance and safety functions are going to be done properly, particularly when information technology is factored in. These are all related and critical for one another, as well as to all other elements for conduct of E-commerce in value-adding ways. Several related requirements and elements are explored to help set the tone for the broader manufacturing and non-manufacturing discussion.

Attitude, Commitment And Knowledge. Like many facets of the industrial and technological organization, only a few short years minimal commitment was required for maintenance and/or safety, and virtually any service function. But as competition increased and the marketplace expanded, so has the need to properly maintain equipment in a safe and productive manner, and provide other services in a top quality and timely manner. In short, lean and mean technological organizations which wish to remain competitive must have productive equipment and other systems, largely connected with proper maintenance, safety and other service programs.

The attitude must be one of understanding that without properly functioning equipment, and other internal and external services, we simply cannot add value and provide useful outputs. All members of the technological organization must have the attitude which makes a commitment to maintain their environment in a manner which they all can be proud to be a part of, including housekeeping, cleanliness, tidiness and safety, and so on. This commitment, like many others
in the competitive organization, can not be taken for granted. All persons, at all levels and in all functions, must have this attitude and commitment. But more than ever before, attitude and commitment will only fall short if not accompanied with proper training and education. New systems and equipment will no longer be successfully learned by "fiddling around" on the job. Rather, the skills required to set up and operate, let alone properly maintain, new computerized numerically controlled or robotics systems, or any of the other high technology devices, will be far more advanced than ever before.

No longer can we simply use the least desirable persons in maintenance and many other service functions. In fact, for safety reasons as well as many others, it now appears that these functions require skills and knowledge at least equivalent to, if not greater than most other technological functions. If anything, perhaps more skill and knowledge is required since these persons must often deal with more types of systems, and of a greater diversity, within the organization. As will be noted in the remainder of this tool, the complexity of maintenance, safety and service functions requires that some of the sharpest individuals be involved. This is an expanding area since new technological systems require increasing numbers of individuals to maintain and service these systems--likely persons prepared in technological studies.

**Analysis, Diagnosis And Troubleshooting.**

Further expanding on the previous points, the new kinds of talent required in maintenance, safety and service functions are not of the "rum-dum" variety. The new types of skills and talents are related to analysis, diagnosis and troubleshooting. Broad and firm grounding in electromechanical, transportation, production processing, among others are required to be successful in these fields today. Broad cross functional knowledge will be essential, as well as specific knowledge in one or more areas--much as the technologist is currently prepared.

Being able to grasp relationships which are often not readily apparent, but rather generally ambiguous and certainly not always right out of the textbook, are pivotal in maintenance, safety and service functions. The analytical and diagnostic brain for these types of functions must be able to go beyond typical rudimentary memory work and other perfunctory levels of functioning, and be comfortable with novel technological circumstances for troubleshooting and other highly creative types of essential activities. Frequently ambiguous and different day to day, this is a very challenging and rewarding area in technology, one that technologists are well prepared to address.

**Discipline, Stick-to-it-ive-ness. Follow-through.**

Information technology changes which are upon individuals and organizations do not simply require that we be computer junkies. Yes, it is imperative that we be computer-literate and comfortable with our command of the tools and systems related to computers. Being able to control and apply the hardware and software today and in the future means that we are able to use and apply those tools which our organization values in ways which add value to the organization. We must be fairly disciplined as individuals, and then also engage with others of like mind to grow and maintain a culture which is disciplined as well. Dealing with day-to-day issues of how to move information, and solving technically related problems and issues related demands that we be self-disciplined, and that we work in an environment which is highly disciplined as well.

Discipline as used here means we can stay on a task until it is satisfactorily addressed. This will typically require us to gather data over time, document this data and other related findings, and interface with others to help resolve issues. These are basic “stick-to-it-ive-ness” type issues which are not traditional “punch the time clock” tasks and “forget what you did that day when you leave” type situations. The types of problems to be solved, infrastructure to be built, will require follow-through. Analysis and inherent discipline must be encouraged and serviced in ways which will become increasingly important. All of these behaviors are based on data gathering and documentation focused on issues and opportunities for improvement in technical work.

Persons engaged in maintenance, safety and information systems should want to learn, solve problems, and change. It is inherent in the service function in general, and these specific types of service certainly, that these characteristics can be anticipated. Moreover, particularly in the area of information systems, changes will occur infrastructurally and organizationally. The types of arenas being pursued with E-commerce will naturally lead to questions about why we need buildings, and what for, how to facilitate work teams from different locations, how to manage online activities, security and so on, all about massive changes in all that we do.

**E-commerce, information and service.** Whether manufacturing or non-manufacturing, part of the key to future competitiveness is to become proficient in the e-commerce venue. The ability to do various types of work at the web, using the internet to enhance and add value to other types of work, is critical to the future. But since this new technology is moving so quickly and evolving and defining itself as it is being built, it is fairly difficult to come to grips with just how to move forward. Yet this is one of the critical service areas for the future, tying much else together.

As a service area, information technology requires not only all of the technical attributes and
knowledges inherent in the hardware and software side, but much more. The information technology service area requires understanding much of the technology being used in the organization since this is essentially what we are networking. The information services group must be technically knowledgeable about the inner workings of the tools used in computer aided design, computer aided manufacturing, data gathering, building documentation systems at the web, how to ship large amounts of data as designs, and so on.

Servicing the future requires that we are able to use our organizational and infrastructural tools internally in proficient ways. We must be able to internally link all facets of the work to enable communications like were done face-to-face only a few short years ago. The concept of production and value adding have much to do with our ability to manipulate information in ways which enable outputs of a non-traditional nature. Value added is less related to changes in traditional materials, as in manufacturing, and is more to do with control and integrity of information to get sometimes simple yet important tasks done.

Value added in information technology functions may have more to do with consistency and reliability in systems than with actual changes in form. The ability to perform as specified, doing the tasks as described and required, to enable other functions may be the critical issue in information technology. But to build and service these systems, enabling other work and outputs as demanded by the customer, we must be able to build and maintain our information technology infrastructure. This is a hardware and software systems challenge and opportunity initially, but then beyond the initial systems, it is maintenance and safety as well.

E-commerce in the future will not only require our internal systems to be functioning at high levels, but we must link to sister facilities, suppliers, and certainly the customer. Most of the data and documentation-based tools described in the toolkit were designed as face-to-face tools to be used with people in the same room and at the same locations, physically. Now the reality is that most of these same tools and principles are needed to be used electronically in non-physical ways to do work on teams that do not see one another, and communicate primarily in emails, chats and by shipping important documents and files of information. The interactivity and transportable of systems is now a seamless infrastructure which demands a different set of requirements and characteristics for success.

The industrial technologist will need to be knowledgeable and proficient in various information-related areas. They will not need to be the designers of the hardware and software sub-systems which are used as the backbone of the broader systems. But they must be proficient in the use and application of the technologies required to make production happen, similar to many other areas to be managed in the organization. Managers in the future will need to see relationships in various technologies, relationships which represent opportunities for cost savings, improved quality, new contracts with existing customers, and others to better position organizations.

**Information Technology, Automated Electronic Push: Traditional Services**

Information technology involves everything from email to automation, and it is impacting everything in between. The concept of e-commerce is being defined as we do it, and in many cases is creating new relationships, or certainly changing many of the old one's in the process. The IT area combined with automatic or semi-automatic devices, and configured to accomplish specific tasks in a technological environment, are often referred to as a computer integrated automated production system. This relates to broader production systems and how we must service information technology and automated production.

**Organizations, automation and information.** As technological organizations have become increasingly reliant upon automation to accomplish productive work, many changes have occurred. It must be understood that this is not just about automation, although from a production standpoint, this may seem to be the basic issue. Automation is facilitated by service functions, all tied to information technology, requiring maintenance and having much to do with safety. This all relates to the computer and information technology and how we use the same to control information and devices for productive acts, but often in rather subtle ways:

1. Less manual labor is required, and manual labor still needed must have a higher level of thinking and intelligence to assist in managing and doing information technology.
2. Higher skill and knowledge levels are required for automation and information technology, and the traditional skilled craftsmen is generally in decreasing demand.
3. Automation provides enhanced repeatability and precision in production relative to manual methods, causing changes in quality systems, to be better aligned with information systems.
4. Increased energy and non-human resources are required for automation, with additional capitalization, and financial risk.
5. Higher output relative to input, or increased
productivity was realized. As higher volume and output have been realized, the overall cost per unit has been generally reduced.

6. Organizations are knowledge driven, not just requiring educated workers, but also information for "knowledge" functions.

7. Increased time all would have due to automation has back-fired, and many are more dedicated to the workplace, putting in more hours, not less. As the tempo of production has risen, perhaps all activities have become "efficiency driven".

8. Doing business is changing to be a computer and automated system of information movement for task accomplishment, including paychecks, work orders, design and manufacturing functions, among others, all now done at/by the computer.

But other, equally pervasive, changes related to computers and automation are occurring, and they will be at the core of what industrial and technological organizations are about in the future. Much of this relates to point 5 above--and education--changes driven by computers and automation will cause organizational shifts which provide many challenges in the future.

The electronic push. At the root of the computer and automation integration changes is electronics. The majority of computer and automation changes are fundamental electronic movement of information or signals, providing different ways of accomplishing tasks. Knowledge and related information are at the core of the electronic push, but clearly the technological vehicle for moving the information required is the computer. Computers provide key control and maintenance systemically for information and signals.

Considering how communication is occurring via telephone enhancements, voice mail, electronic mail, computer integrated video and animated training, and engineering design changes via computer networks, it is clear that communication and information flow are pivotal for competitiveness. Even more pervasive is the way process control data passing from floor level machining work station to engineering functions work station for experimentation will ultimately impact overall production functions. Eventually the entire function will likely occur at the work station on the plant floor or job site, perhaps requiring less movement of information, but enhanced personal computing power, or innovative networking of software from a server to the focused work area.

The electronic push for computer and automated integration must be kept in perspective--this is not the end product--only the vehicle. While acknowledging the importance of communication and information, the basic output must remain as some value added, production function, in an industrial or technological function. Virtually no technology is unscathed in this scenario--aviation, photography, training and education--all require additional inputs and outputs, tied directly and indirectly to computers and automation.

Computer aided design (CAD). Computer aided design permits a designer to work at the screen of an interactive graphics terminal to develop a geometric model which describes the size and shape of component to be produced. This model establishes a geometric data base that may be used to structurally analyze the component, to test various features such as fit and tolerance of the component, or to produce working drawings of the component. The shapes generated as part of the model can also be edited to conform to desired specifications--and in fact, to make changes and other engineering functions as required.

E-organizations may use this technique as a "desktop publishing" function for graphics preparation, while the construction organization may use it as a sales tool for enhancing a proposal for a contract--actually simulating much of what is being discussed via a graphics screen presentation. Other organizations concerned with health issues may use graphics tools for imaging and graphical analysis of health defects in an organ for diagnosis, or aviators may see graphic displays of weather information used to " automate" flight plans, and so on--all graphically presented at some point—based on shared information.

Computer aided production (CAP). Computer aided production (CAP), often referred to as CAM, standing for computer aided manufacturing, consists of using the computer to control various factors related to processing components. Many if not all of the inputs generated as part of the CAD data base typically can be used to produce a numerical control tape which can be cycled via the computer to control processing centers to produce the component generated earlier in CAD. Identified as generative programming, this CAD/CAM relationship is increasingly being used in industry to identify material to be machined, select tooling to be used, to aid in determining fabrication steps, and to sequence the tool path. Computer aided manufacturing typically uses machining centers consisting of a single (sometimes multiple) machine tools equipped with automatic tool changers and capable of performing a wide range of operations on a common workpiece. Operations performed at a CAM machining center might include milling, facing, slotting, boring, drilling and tapping on the same workpiece. Often the computer controls the tooling which is called up, the speed of cutting, application of cutting fluid, turning the machine on and off, sensing tool wear, measuring for quality and so on. Direct savings are provided to
producers with CAM due to increased productivity and reduced in-process inventory.

But in other technological functions the same logic applies. Massive automated photography and printing equipment uses "pre-designed" logic from early phases of customer input to provide graphic input media which started in a "CAD" type phase and was outputted in a CAP phase. Construction design information is first prints, later used to do "take offs" for estimating, scheduling and general construction applications.

**Robotics and handling.** Robots are operatorless devices which are programmable. The largest users of industrial robots in the U.S. have traditionally been automotive manufacturers, but this is changing to include a myriad of applications. Japan has traditionally had most of the robots which are in operation worldwide, and they have been a major producer of robots. In some situations robots have demonstrated that they can handle heavier loads more accurately at higher speeds than humans. The need to increase productivity and reduce cost in production has contributed to their increased application in recent years. Robots are available with handling capacities that range from minisized parts of a few ounces and a reach of a few inches to huge robots capable of payloads up to several hundred pounds. Robots can be programmed similar to other automated production machines.

Some robots have sophisticated memory systems with a capability of being able to take alternative actions under changing conditions, while other systems use the same overall utility, but with a limited work-handling flexibility. These are used for routine jobs involving simple put and take/place motions. It is possible to teach some robots to do a specified job by switching its control system to the teach mode and manually moving the robot through the various steps to complete the task. Ideally, these machines may also be "networked" with other electronic devices systemically.

Robots typically have a mechanical arm which can be moved in a variety of directions. A variety of hand-like fingers or grippers, vacuum cups, or a tool such as a welding gun or impact wrench can be attached and operated by the robot. These functions have become rather commonplace in many applications such as assembly operations, materials movement, large presses, injection and compression applications, spray coating/painting and heat treatment operations.

**Sensing, feedback and data acquisition.** Pivotal to industrial and technological competitiveness as related to computer integration and automation is sensing information in production and other technological functions, and feeding this information back to help correct and improve the system. Commonly called feedback loops, the strong application of electronic logic and hardware and software should be noted regarding sensing and feedback. This is a key function in the future since much automation, certainly electronic devices, requires instrumentation for control. Several of the previously discussed devices or sub components would frequently be part of the integrative feedback system—and ultimately this relates to data acquisition and quality issues.

Data collection may be of various types and for various purposes. But one key type of data collection which is important to industrial technologists is related to quality functions and systems. As automation and computer integration continue to proliferate into the technological environment, it stands to reason that systems for gaging, inspection and generally collecting data for processing control must be increasingly automated as well. This also strongly relates to the previous point since the ability to control any form of production relies upon data-collected and feedback through various instrumentation as indicated above.

Systems for data collection in process control may range from semi-automatic hand-held gages like micrometers which are electronically hard wired to a central processing unit, to a fully automatic system which automatically measures and transmits data to various analytical checkpoints or work stations. Information as data must increasingly be moved automatically to appropriate analytical locations, hopefully to/from workers on the line, for decision-making purposes. This may be for quality, cost, scheduling, inventory or other functions.

**Vision systems.** Machine vision systems have three primary elements. These are the camera, the computer video image analyzer, and an appropriate lighting scheme. The camera serves as the eye of the system, the computer houses reference shapes, positions or other data, and the lighting source provides appropriate image contrast for sufficient picture (vision) transmission. Although early systems were primarily two-dimensional, the more recent innovation is a three-dimensional system requiring multiple cameras and light positions, enabling variable shapes. The typical system has multiple lights and cameras focused toward the object being analyzed in production.

**Information Shared For Work Cells, Analysis And Control, Flexible Services**

Computer integration is based on shared information, a form of electronic communication commonly called networks. This may be machine to machine, people to people, machine to people and so
on. Integrated information system is software and hardware driven, a critical electronic service for value added competitiveness. General characteristics include:

1. Networks use rather inexpensive transmission media and devices, yet the total system composed of both hardware and software may be rather expensive.
2. Rather high rates of data movement are possible in the network, contingent on overall design and components used.
3. Devices may be interconnected with other devices for "total" communication within an organization.
4. Networks do not require one central processor for all distribution (although this could be) but are commonly composed of numerous "on-site" processors or servers linked via networking.
5. Each user or device in the network must "listen" to all other users or devices regardless of whether each user or device desires communication at a given moment. Each component in the system may be aware of all others in the network, but will not act on each, only those targeted for that component.
6. Depending on numbers of times and types, data transfer occurs from device to device or system to system (i.e., CAD to CAM), quality and reliability of data, and broad integrity of data, can be questioned.

The network provides the ability to develop and dispatch the database which is necessary for complex production activities. Networking software and hardware give virtually total communication organizationally, regardless of device or task.

**Group technologies.** Part of the network of devices, another aspect of information technologies is using groups of technology which have parts or component processing similarities and relational efficiencies when grouped in work cells for various functions. Grouped technology could relate to having several different machining capabilities located in a workcell, all dedicated to a pre-selected series or type of processing. Similarity in group technologies does not necessarily lie only in the technologies themselves. Rather it may be components which will be machined or fabricated and are typically quite similar in this situation. Families of similar products or components can be organized for efficient production since all of the production requires the same machinery whenever possible. This technological principle, driven by automation, is relevant to all technologies. Examples could be groups of technology common to processing concretes or aggregates in construction, or various common technologies used for printing or graphics production applications. Where efficiencies may be gained by organizing broad groups of integrative technologies, this may help us add value.

Flexibility is a prime consideration in the overall mix of equipment issues for production. Part of the reasoning for grouping equipment in work cells is to have maximum potential for operations with minimal handling and setup in preparation as well as flexible production. A key element in competitiveness increasingly is our ability to reduce lead times and setup for production. Equipment and facilities must be grouped and organized in workcell configurations for flexibility. Other basic considerations include:

1. Handling, inventory, lead time and setup/changeover time are all reduced with enhanced flexibility in routing as well as virtually all related scheduling and management functions.
2. Even where shapes and dimensions are not identical, group technology can be employed since similar work cell equipment is used for processing. Production similarity and efficiency lie in ability to route similar groups or process needs through cells.
3. Bar coding systems are used to identify components, taking away the need to visually sort at each station/cell. Other machine vision systems for sorting and grouping, and inspection purposes, can be employed as related to group technology.
4. Since sizes, shapes and possibly other component characteristics can be more readily predicted based on groupings, quality and inspection functions can be more easily organized and controlled through the computer using vision systems or sensors for process control.
5. Work cells are specialized for group technologies, and due to specialization, has implications for types and volume of components to be processed. The major implication is that we must "lock in" to a specific type or group of products, focusing primarily on this group. Work cells can help enhance flexibility desired.
6. Group technology may be expensive, with debt incurred in acquisition. The implication for this is that equipment must be kept busy in order to achieve reasonable payback. If the work cell is not properly planned and utilized, it can reduce the overall positive impact of the investment.
7. Organizing and coding all components a plant produces is no simple task. It is a complex, time consuming and expensive task. This may be particularly true if the plant has put little effort into material requirement planning and particularly inventory planning and control. If this planning (MRP) has not already occurred, planning for group technology may be a good opportunity to accomplish some MRP objectives as well.
This type logic and approach is the heart of service based on information technologies. Enhanced manufacturing and non-manufacturing functions and operations requires considering this approach to improve quality and productivity.

Related to the previous discussions about group technologies, another example of information sharing is computer control for scheduling and routing. Scheduling and routing is aided by the computer by achieving an efficient balance of major inputs and desired outputs. As with many currently computerized functions, scheduling and routing was at one time done with pencil and paper or in the manager's head. With the advent of the computer, a more complex technological setting or work site involving perhaps thousands of machines, workers, materials, and several products can now accurately and efficiently be analyzed to provide optimum job-lot sizes, machines, numbers of workers and other key production inputs. Other business related functions and applications are described briefly—all based around the concept of shared information for services needed.

**Business and office functions.** Related to scheduling and routing, cost analysis and control uses the computer for cost accounting purposes to monitor and determine cash flow related to actual production. Cost accounting studies monetary activities related to processes, materials, products, departments and other general cost factors. Information supplied to the cost accounting division will aid in determining budgets, profits, production levels, which products are profitable and should be continued, general efficiency levels, expansion issues, and perhaps other production matters. Other business functions could include printing/controlling payroll checks, logging personnel benefits, and multiplicity's of traditional clerical functions. Often this information will be stored in the computer as a data base for future decisions.

**Operations analysis.** Operations analysis is another computer and information technology application area emerging as a service. Common technological operations analysis concerns for computer applications. For example, if a product can be made at more than one plant location, how much production should occur at each plant? Or if products can be shipped from more than one plant or warehouse, which plant or warehouse should service which customers? When and how often should materials be ordered from suppliers to keep inventory levels at a minimum without creating shortages of materials? Other business operations type questions which can be addressed with the computer to meet finished goods requirements include, how many machine hours should be scheduled for next week/month? How many labor hours? How many shifts? Is overtime necessary?

Computerized cost accounting activities subsume many specific cost analysis tools, including breakeven analysis, capital investment analysis, inventory analysis, and product cost analysis. While many cost activities may not be a direct function of cost accounting, most cost analysis tools are indirectly contingent on cost accounting for information necessary for their decision making input and day-to-day functioning. Related to cost accounting, another computer application which should be studied is data collection and processing. For example, in an order processing situation, quantity and types of products ordered are entered into the system against the actual inventory and the inventory record is reduced. The computer prepares a shipping order, invoice record and shipment schedule, based on quantity--all tracked for analytical and documentation purposes. Computer data collection and processing service applications in the technological organization could include salary and wage payments, income tax withholdings, payroll deductions, among others.

**Documentation, presentations and training.** The advent of computer integration brings significant change in the way documentation, presentations and training will be conducted in the future. This is because as technical problems and projects are being addressed, documentation will increasingly be on-going and carefully detailed to create a careful record for future reference. Documentation will increasingly occur as a standard procedure when various maintenance and non-standard technical situations are addressed--enabling us to efficiently accomplish this same activity in the future. When existing procedures are followed, on-line capability through the computer can permit quick and easy up-dates of existing service procedures.

Advantages of this are that up-to-date technical procedures can be readily available for various services. This type efficient documentation will facilitate ready-made training materials for new or existing persons. Procedures can be standardized organizationally based on documentation afforded by the computerized information system. Rapid preparation of presentation materials for various purposes can be accommodated via this computer documentation system. Assuming networking is on-line, technical solutions can be shared with various individuals or divisions, virtually as the solutions are documented. This same information, via computer networks or in other ways, can be packaged as engineering design changes, or other quality, engineering or production applications, providing efficient and accurate information. Key to this important service is ability to broaden the team, placing all on the same page in non-trivial ways.
**Artificial intelligence and expert systems.** Storing massive amounts of information in the computer and causing non-humans/other machines to communicate with one or another is partly the task of artificial intelligence. More significantly, with the data built up over time, the computer has the ability to provide innovative answers to novel questions. Properly programmed, computerized decision-making, problem solving, line balancing, and many other one-time human decisions can now be made (or assisted) through the artificial intelligence of the computer. Expert systems relate to artificial intelligence by providing a "shell" which can be programmed with existing knowledge or options, all based on pre-designed human inputs. Data documented electronically represents another digital opportunity for shared information to add value. Built in some type data base which can flexibly be modified and accessed to address various needs, the intelligence stored for future issues becomes a gold mine for harvesting.

**Computerized maintenance.** Maintenance systems are becoming significantly more sophisticated. Some industries are beginning to monitor maintenance needs through sensors and other process control technology, right into a central control room within the plant or from multiple work sites. Systems will define probable causes, display case histories, dispatch maintenance crews, and reroute material flows. The system could help show ways to solve problems by reconfiguring various elements based on available equipment, personnel, floorspace, and so on. To develop a maintenance system which is a computerized service, we must:

1. Define the requirements. What do we expect of the system? This provides a basis for the new system to be designed, selected and tested, called a requirements analysis.
2. Conduct a maintenance audit. Define the strengths and weaknesses of the system. Walk through it with various people who are involved to aid in effective communications.
3. Establish a project team. All departments affected will need representation. Also a data processing person is needed.
4. Collect maintenance costs and maintenance productivity data. This is necessary in order to sell any proposed improvements. Be sure to indicate production downtime due to maintenance, and estimate costs associated with unplanned breakdowns.
5. Keep management informed with brief, succinct, reports on a regular basis.

It is important to remember one of the key points relating to all information systems and technology in general applications. Automation will not solve problems that could not be, or were not, resolved prior to the new technology. We do not attempt to solve all the problems with information technology and computers, but we should be able to assist in having what is needed to solve the problems and improve.

**The broader service team for information sharing and integration.** As computer integration occurs, increasingly selected impacts and effects will be noted. The extent to which we can understand these and plan for their eventuality will determine tremendously to our ability to become and remain competitive. Effects on operators, supervisors and others will be explored, each individually. We must remember that the point of production becomes our primary focus, through the broader network of the team.

Operators will increasingly become more involved with monitoring, programming, setup, and troubleshooting, all pivotal tasks for improvement in the increasingly automated workplace. While functionally the task will still be a relatively straight forward take off and follow through of standard operating procedures, much change is occurring. Monitoring, while traditionally done by the operator, must now be done almost exclusively by operators. This includes data collection and analysis, tracking tooling wear, stock at production equipment, general WIP, and other pertinent information and systems issues. Like much else noted in other tools, this was, only a few short years ago, done by others, or at least better supported by various others.

One basic question will be who actually creates and maintains the computer program, run through the SOP at the workstation? As improvement, particularly in the form of parts, engineering design changes or others at the processing level occur, how is this translated into enhanced operation at the workstation level? And how is this change universally communicated to all who require knowing? While the simple solution may appear to be the operator doing the basic programming maintenance, and perhaps even creation, this can have substantial implications:

1. Assuming operators do programming, how much knowledge and education will they how prepared? Learning on the job in the broader team is clearly part of what must be done—but at minimum, an associate degree, and increasingly a BS degree may be needed.
2. What will be the span of control? Will we be able to continue only running one operation or workstation, as has been the tradition? Computer integration and servicing shared information,
provides for changes in cycle times, overall workloads, and other variables, necessitating a broader and different scope of work area.

3. What impact will there be on worker/management relations? Due to the operator increasingly becoming a manager, and the reality that a leaner work area will reduce traditional numbers of managers, relations may actually be less strained than traditionally true. Cross functionality of new work areas, driven by the computer and movement of information, will also inevitably cause traditional workload and service shifts.

4. Assuming time gains are made with the computer integrated information, how will we manage the time gains? Can they be expected to do some of the programming, as changes necessitate? The span of control, at least as measured in the number and type of operations they manage, should be considered as appropriate tasks and areas for change, all requiring more and different types of training. The basic question becomes, do we merely expect the operator to be a load and unload type person, or can they also do parts of the broader decision making and management?

5. Does integration apply primarily to maintaining islands of automation, or can we think in terms of moving product, information and general activity beyond the island or work area specific place, and get to the broader production site in total? This requires a different paradigm as part of service considerations, including cost.

6. Documentation must change along with all else. What used to be hard copy written information must become electronic at the terminal, throughout the collective organization internally and externally, for all on the team. This includes SOP's, FMEA's, OPCP's, 8-D's, and others in the form of data driven charts. We must go beyond simply writing things down and stashing them in a folder, to have "live" documentation upgraded regularly.

7. And what about the teaching and learning process and the team? As one group discovers information through solving a problem, interaction with customers or suppliers, we must have mechanisms available to routinely upgrade the documentation. This becomes the primary vehicle for "real time" education at every level, the actual sheet of music we use as our foundation for ongoing improvement.

We must change, and much of this is at the point of production, impacting first on the operator. Operators must accept much change, but others must also give up part of what has been their responsibility. The operator can only accept what the engineer and maintenance, as well as other technical support persons give up. New operators will become an empowered manager of their work area, and total operation, to the extent that others assist, support and empower them. This again speaks to teams--teams which require the same support and information as we have always had, but now in new electronic forms and more accessible at the point of production. This should include not only data from immediate production, but longer term data, maintenance information, general documentation and SOP's for reference and support, and so on. What used to be manuals in hard copy will now be at the terminal accessed by various persons on the team, but predominantly used to support the operator at the point of production.

Several final points should also be mentioned before closing off the section. These have to do with designing for production with automated equipment, thoughts on how to succeed in integration projects, and general thoughts on information technology.

**Designing for automation, shared information.** While automation and shared information will find many applications in production of the future, not all products lend themselves to enhanced processes or systems. It may be possible to increase the ease of production of a product with automated processes through use of several key design points. These are:

1. The product must be sufficiently large and stable to enable other components to be attached to the "base" of the product without disturbing the "base" orientation.
2. Rather than designing the product as one entity to be assembled simultaneously, the product should have numerous subassemblies preassembled individually through automated processes prior to final subassembly of the entire product.
3. Parts should be assembled in layers with guide pins or systems, connecting and guiding layers.
4. One gripper should be capable of handling and completing as many parts and functions as possible to help avoid changeover costs.
5. Screws, nuts and bolts should be avoided if possible, since they require significant manipulation. If these must be used the same shape and size should be used.
6. Parts should be self-aligning and easily inserted with a simple straight-line motion.
7. Ease of access, minimum adjustments, and totally standardized components should be fundamental in
design for automation.

Again it must be recognized that this is not only manufacturing related. Construction of modular systems in housing or other structures, packaging requiring print, graphics, folds, and so on, and numerous materials handling applications industries or in aviation and other transport can also relate.

**Succeeding with integration.** Careful study of computer integration for automation in the technological organization discloses the reality that several basic steps should be addressed in order to help achieve success. These steps are particularly important to help enhance competitiveness:

1. Make sure you really understand what is involved. It may involve unrealistic inventory and quality expectations, as well as unrealized costs to put the system on line, among other potentially "hidden" factors such as long term support contracts and additional software to make the system function.
2. Talk to people who actually have systems on line, to get feedback on the system directly from user's. Do not settle for only salespersons' view. Doing on-site evaluations of existing systems and talking eyeball to eyeball may also be extremely beneficial.
3. As the process moves forward, set meaningful goals. Before the organization has accepted a system and is going to move ahead, be sure to set goals and objectives that are realistic and obtainable. Look many years down the road. The basic question is "what do we expect computer integration and automation to do for us"? This is no different from how we would purchase a personal computer for our personal use.
4. It is important to involve the right people. This is a personnel and technical expertise type issue. Certainly you will tap programmers, engineers and vendors, but the most important sources will probably be the front line supervisors and workers on the line. Do not overlook your best sources for input and also remember who will actually be using the equipment--involve them to help avoid resistance to changes which are coming.
5. Carefully analyze your current process. Do not expect the computer to improve on an already faulty process. Study the process from a total quality control perspective, identifying each fault one at a time, and improving gradually by the use of statistical process control. The computer can help, but people must improve the process.
6. Think big but start small. Generally completely automated plants/systems designed right from the start work best because of the overall optimization of physical plant and being able to perform a "pure design" from the outset. Many organizations do not have the ability to do a complete design or redesign of systems due to cost and other and constraints. As we do integration projects we must develop a master plan and implement it a step at a time, integrating steps starting with steps/projects with the greatest potential returns and lowest risks.
7. Conduct careful and numerous "benchmarks". This is where you invite jobbers and vendors in to show what their equipment can really do. Possible buyers give vendors a component to produce, currently being produced. Comparison of existing method for processing and the new "vendor method" can be performed, and a decision whether to buy can also be made based on savings, quality issues, etc.
8. Information integration is a business decision and therefore it can only be accomplished if a sufficient ROI can be shown. Cost and profit are clearly identified as the bottom line, all with a payback.
9. Information and computer integration takes time. New acquisitions require much planning, design and implementation, training and education time. Be patient and plan up front to assure success.
10. Choose the right vendor. First ask how much they currently being produced. Comparison of existing method for processing and the new "vendor method" can be performed, and a decision whether to buy can also be made based on savings, quality issues, etc.
11. Success of information and computer integration depends extensively on quality people. All equipment is useless without people to run them.

One general point which has not been addressed is related to size and speed of computer. As we grow and expand we will need more and quicker machines relative to our current demands--plan ahead and allow for growth and future demands.

**General closing thoughts.** Information technology in virtually any form is capital intensive requiring significant capital outlays. It takes large volumes/lot sizes of production to make most forms of automation cost effective. However, with good planning, properly selected equipment can provide productivity increases needed by technological organizations. This means new jobs will be created to service the new equipment and systems. Programmers will be needed, as well as electronic technicians, computer managers, and so on, all being new types of workers in technological organizations. This all means working smarter since the wired work areas of tomorrow will require "brain intensive" workers. It requires more than just a high school diploma to be able to even work on the assembly line or job site in most cases. The gap between skilled and unskilled people is widened by information. Individuals without
the skills or knowledge, and perhaps without the ability/willingness to learn will be relegated to the unskilled tasks in the future—all of which are becoming in shorter supply, all indicating increased training.

Information used properly can raise skill levels of employees to that of a supervisor of sorts. This is particularly true since E-workers will quite likely be responsible for some extremely expensive equipment. As plant floor workers become increasingly knowledgeable, and more supervisory, they will also become a part of management in new ways. This is true too a large extent since group technologies, networking and other computer information related issues are driving increasing amounts of responsibility downward, with more immediate management access based on information shared and available.

Types Of Maintenance: Service Underpinnings For Waste Reduction

Several types of maintenance will be presented, including preventive, breakdown, corrective, predictive, remedial, plant engineering and computerized functions. It must be understood at the outset that preventive maintenance is a basic goal of good management practices. Too much emphasis placed on prevention can outweigh the cost of remedial maintenance.

**Preventive.** Preventive maintenance is a philosophic attitude which says the technological organization can, and should, take action to keep a currently operating piece of equipment functioning at an appropriate level of quality. Traditionally, preventive maintenance activities involved inspection, detection and prevention of problems. Problems could be mechanical, electrical, or people oriented, among others, but in all cases, if uncorrected, problems will almost always lead to breakdowns or rejects.

The basic reason for preventive maintenance is to save money by reducing operating costs, and thus, to enhance competitiveness. If maintenance problems go undetected or are ignored rather than corrected, the likelihood increases that a critical breakdown will occur, particularly when pressure is on to be most productive. At the very point in production when we need equipment to be most functional—when extreme pressure is on to meet consumer demand—this is the most likely point where maintenance problems will surface and lead to ultimate and costly breakdowns.

But preventive maintenance is also important for quality reasons. Capability in production quality refers to equipment capability to produce to specification. If the technology is not well maintained, it simply will not produce the proper quality levels in product. This leads to rejected product, missed production schedules and lost contracts, among other undesirables. Quality provides the second major reason for preventive maintenance—quality can only be optimized if equipment is functioning properly. Maintenance and quality in production share a definite relationship, ultimately both being cost and competition oriented.

A third and somewhat different reason for proper maintenance is safety. Note that without proper maintenance it is almost certain that the likelihood of increased opportunities for unsafe operating conditions will result. By conducting routine maintenance inspections, the likelihood increases that unsafe conditions will be detected and presumably corrected. Similarly, seemingly insignificant matters such as good work habits and proper housekeeping are "musts" if the technological organization wishes to become or remain competitive. Positive work attitudes toward safety, quality, and maintenance, will likely be directly related to the way we all do our housekeeping.

Preventive maintenance, while merely a fundamental management approach, or philosophy, is also important in broad ways as noted above. Cross functionally, good preventive maintenance ties in to collecting good data in quality, use of good documentation in all that we do, scheduling product in production, and so on. All are aimed at preventing breakdowns and unsafe conditions.

**Predictive.** Predictive maintenance tends to be of two types, both related to preventive maintenance. Predictive is both scheduled and monitored, being done to prevent potentially more costly unplanned remedial maintenance due to an unplanned breakdown. Predictive also indicates that planning, further defined as good management practices, is well established and in place. The key is proactive rather than reactive management of technological maintenance.

Scheduled maintenance includes changing bulbs, liquids, belts, batteries, sharpening or adjusting critical components, cleaning, and so on. The schedule is generally based on past data and experience, suppliers' recommendations, or other inputs. The maintenance schedule may also be based on computer generated service life modeling, using sophisticated finite element analysis and statistical software to predict when a critical part or component in a system will likely fail, although this is generally only true in potentially life threatening, or other, extenuating circumstances.

Contrasted slightly with scheduled maintenance, monitored maintenance is based on periodic extenuating circumstances. Disciplined activities such as inspections or other regular observations will typically be a part of these systems. Monitored maintenance is based on diagnostic testing and analysis, mostly non-destructive. A monitored type circumstance would result because an operator detected something
unusual during routine operations, control charts showed consistent irregularities, or some similar reason. The monitored approach is observing and studying for further analytical input, a good opportunity for data and documentation to be used.

**Remedial.** Remedial maintenance is the type maintenance that preventive maintenance is trying to combat. Regardless of how well designed the preventive maintenance system is, technology does misbehave and break due to improper uses, operator error, misunderstandings due to miscommunications, aging and so on. Remedial maintenance may not necessarily be due to a breakdown. Remedial may be related to equipment which is still functional but functioning inappropriately. Effects would be noted in production, requiring corrective action.

Initially it is less likely that we will worry about what caused the problem relative to getting the equipment back in order and operating. But ultimately, we must determine the cause and correct the causes as well as the symptoms which surfaced. Note that much of the logic and approach discussed throughout the toolkit is applicable in this. Problem solving tools, team approaches, corrective actions, SOP's and so on, are pivotal in remedial processes.

**Breakdown.** When breakdowns do occur, it is critical that properly planned systems be in place to enable efficient and thorough addressing of the problem, the actual breakdown. Issues to be dealt with relating to breakdowns might include numbers and types of stand-by equipment, components/parts inventories to be kept on hand, cost of having a given piece of equipment out of commission, and so on. In all of the above circumstances it should be clear that costs related to the various options provide the key to decision making. If a machine or component has never broken down, we do not keep replacement equipment or components on hand, particularly given the cost.

If a piece of equipment is critical to our operation, the likelihood increases that we will have alternative means for production and/or replacement components on hand--possibly to the point of standby equipment. Frequently, this is why organizations have multiple sites for accomplishing production, storing equipment and so on. Rather than having all equipment housed at one site, alternative sites may be located strategically to facilitate added capacity.

**Corrective.** Corrective maintenance relates to problems discovered in routine inspections, during monitoring or testing of equipment, or after a breakdown when it is clear what caused a problem leading to the breakdown. Some form of correction was deemed necessary to avert additional problems, and corrective maintenance could be of many forms. For example if during routine changing of lubrication fluids it is discovered that a seal is leaking, it would seem reasonable to consider replacing the seal. Or if during routine maintenance of cutting tools on a machining center it was discovered that the spindle had too much end play, it is appropriate to consider correcting this. If while performing routine service on an auto exhaust system the service person notes a worn brake line, needing replacement, it is important to correct this rather than ignore it. Inspection and corrective documentation systems must be in place.

Perhaps more important, if after a breakdown, and necessary repairs have been made, it may be important to evaluate the possibility that some design change, or other significant corrective change, must be performed. For example, in the cutting tool situation cited above, what if, due to wear over time, the entire spindle assembly needed replacement, rebuilt or redesigned? This requires substantial evaluation and analysis, perhaps beyond internal technical skill levels.

**Plant Engineering.** Plant engineering may deal with multiple functions related to maintenance. One in particular which is useful to be knowledgeable of is the renovation function. Assuming the technological organization is competitive, it will be on the move. Part of what this means is that changes to the physical plant will need to occur periodically. That is, new equipment, changes in production systems, new physical structures, environmental changes, and so on, must occur from time to time if an organization wishes to remain or become competitive. It is important that renovations be articulated with production to eliminate possible down time, safety hazards, and so on.

This is frequently a fairly straight forward project management issue. When it has been determined that an upgrade in physical plant must occur, the physical plant group would evaluate circumstances and plan for required changes, either as a sub-contractor function, or simply as a maintenance group. This all must be done within the context of getting product out the door.

**Housekeeping.** Housekeeping has an obvious role in all of the above. The overall role of the housekeeping function must not be downplayed or taken less than seriously. Increasingly, as indicated earlier, organizations are recognizing that a direct relationship exists between attitude of workers and the general environment they work in. Everything should have a place and purpose in the work environment. Tools and rags should not be helter-skelter. Lunch buckets, leisure reading materials and other non-work related items do not belong on benches, or in the work area. Housekeeping becomes the responsibility of workers in the general work area as much as anyone else--keeping the job site orderly, safe and productive.

Housekeeping involves a heavy emphasis on
Both begin with some pretty basic assumptions about the workplace, related to maximizing technological capacity. A clean, well-organized, cooperative work area will be more productive relative to a messy and disorganized work area. Relying heavily on preventive maintenance principles, as discussed earlier, TPM aims to maximize equipment usage through the efforts of all employees, but organized at a local level with small group efforts drawing on broader expertise as needed. TPM is an organization-wide effort, supported at all levels and requiring total participation of all employees, which pursues total effectiveness for profitability through total maintenance systems.

Additional TPM features are that it requires each piece of equipment to have a maintenance plan for the entire life of the equipment. The maintenance plan includes a maintenance prevention emphasis during design, even before the equipment is built (or purchased). TPM requires maintainability improvement efforts to help prevent breakdowns and to assist in efficient maintenance during the equipment's useful life. A final TPM feature is the on-going, day-to-day, maintenance function by operators at the production site as part of their regular duties. Documentation is pivotal, providing a history to draw upon for improvements.

TPM is an equipment intensive maintenance effort. This is not to say that people are less important in TPM than in some other maintenance approach. But it does acknowledge that as production continues to become increasingly technologically based, even to the point of near total automation and mechanization, the equipment is becoming of paramount importance. TPM allows and requires increasing numbers and types of human input via the team participatory element.

Maximizing technological capacity through zero defects and minimal equipment breakdowns requires TPM systems and strategies for waste elimination and reduction. Zero defects and minimal equipment breakdowns also compliments the current quality movement and just-in-time production methods. Maximum technological capacity, or full equipment utilization for profitability, will come only with throughput times that are not hampered by quality rejects and nonconforming product. But from a TPM perspective, it is important to recognize that this also assumes clearly understood product specifications, with parallel equipment requirements. Equipment breakdown reduction can only be successful if the right equipment was designed and implemented for a given task in the first place. Equipment changeover setup time must be minimal if capacity is to be maximized. Time spent in changeover setup, like maintenance, is not productive.

Successful equipment maximization will be
Based, in part, on accurate data kept over time. Accurate records should be kept on time the equipment is actually used on a dedicated production job, time spent in breakdown during a job, time spent on predictive and remedial maintenance not associated with a job, downtime for any reason (not in another category), changeover and setup times, performance efficiency based on operating speeds, feeds and outputs, among others as appropriate. Various documentation form examples are provided throughout the toolkit, helping to build the maintenance system.

Reducing Deterioration. Deterioration over time is part of what detracts from maximum performance in technology, further pointing to the need for TPM. When surfaces are pitted, gears develop too much backlash, and pumps have insufficient pressure, performance begins to slump and possibilities multiply for defects in product and breakdowns, increasing the likelihood of decreased competitiveness. The goal becomes detection and correction of deteriorating circumstances.

Operators should perform daily maintenance and work area inspections, along with maintenance personnel who are responsible for periodic (monthly, quarterly, etc.) tests and inspections, to determine if problems, either visible or hidden, may exist. During inspections performed by both operators and maintenance personnel it is critical that such seemingly mundane items as loose bolts, dust and grime, leaks, and so on be detected and corrected. These may be symptomatic of other, bigger, maintenance issues. Noises and conditions, once detected, can form the basis for a TPM local team problem solving focus to determine cause and effect, and corrective action.

It is particularly important that the equipment operators be carefully "tuned in" to changes in behavior of machinery. Chatter, moaning, clicking, whistling, abrasive sounds, and other uncharacteristic noises above and beyond the normal operating behaviors would likely constitute sufficient concern for investigation. This underscores the important role of line operators and need for industrial technology persons to provide leadership and training.

Selected Troubleshooting Fundamentals

But what are some of the particular behaviors and problems to be on the lookout for as services to others? What types of circumstances might be built into maintenance procedures as "likely conditions to service"? Several conditions are sufficiently commonplace, deserving to be presented and further discussed within the scope of service. These include mechanical, electrical, fluidics and general housekeeping, all at an introductory level. These are generally consistent with the services information. It is significant to point out, for safety reasons, that only based on further study and with much practice should these types of information be acted upon. Specific safe work practices must be researched and developed as part of proper work conditions procedurally.

Mechanical. Mechanical troubleshooting falls into categories related to components in mechanical systems. These systems rely on drives such as belts, chains, gears, clutches, and they involve shafts which require bearings, seals, gaskets and lubricants. Obvious inspection points include overheating in bearings and shafts, as well as other components. Misalignment in drives will contribute to unwanted heat which can be counter-productive. Lack of lubrication can be a heat generator leading to wear and damage.

In the absence of motion (generally due to work stoppage), heat will not be generated for detection. But other tell-tale signs may be noted such as surfaces on components appearing cracked indicating fatigue, pitted, scoured areas, or become otherwise irregularly shaped over time in the case of misalignment, lack of lubrication, overload, or other abuses. Other signals of problems could include loose or "too tight" components, incorrect direction of rotation, and need for adjustments per specifications. Another good signal regarding seals may be drips, leaks, streams and pools if lubricants are not properly contained.

Belts and chains must be observed for proper tension, and if undetected on the loose side can lead to slippage in belts or "jumping" on sprockets. By contrast, if too tight, belts and chains can be stretched and damaged and over time can lead to other components' damage in the system. Drives often exhibit signs of trauma or other wear at the "key" or tightening screws due to mis-adjustment, incorrect installation or other maintenance factors and issues.

Electrical. Electrical troubleshooting considerations include wiring, switches, contacts and relays, and motors and generators. Wiring, as well as other components must be checked for insulation. Over time insulation on wires can become cracked or barred, due in part to heat cracks and abrasive types of wear, leading to possible "shorts" in the system. Other possible wiring concerns are connectors and terminals where wiring is hooked up to various components in the system. Due to expansion and contraction in the system, as well as other mechanical vibration and motion, electrical connectors should be routinely observed, guarding against disconnects or shorts.

Switches, relays and other types of contacts all rely upon physical mechanical contact between two or more metallic materials' surfaces to conduct electricity. Obviously, if dirt, lubricants or other foreign particles become associated with the contact points this could be
a less than desirable situation. Periodic tests or observations may need to be conducted to analyze the pressure at the contact points, particularly if arcing is noted. If inordinate heat is detected in relays or contacts it is generally a good sign of trouble to be followed up on. Mechanical contacts used with rather large amounts of electricity have many mechanical components which must be checked periodically.

Motors and generators comprise a significant amount of equipment used in industrial and technological circumstances. Once again there are some rather standard types of symptoms to be studied with these applications. Commutators and slip rings, and armatures and brushes, comprise typical conducting mechanisms where problems occur. Brushes are made of carbon materials, and thus, over time do wear out. Commutators and armatures may become worn and pitted, or depending on circumstance, may have other types of wear patterns. Motors and generators also rely on bearing and shafting principles discussed earlier, and require typical rotating machinery care and observation.

**Fluidics.** Fluidic systems were discussed briefly in a previous tool. Many of the components and principles already discussed in general mechanical circumstances also apply. But fluidic systems also have many particularly unique circumstances to be on the lookout for. Pumps and compressors should be studied for unusual noises or heat levels. Sometimes pumps are installed, or run, with incorrect direction of rotation, or other variables lead to overworked conditions which are noted by inordinate noises and heat. Air leaks at the pump can cause unwanted noise indicators of weak seals or weak connections. Dirt and other contaminants, and clogged filters or other components not allowing flow at appropriate rates, can also give "noise" conditions, indicating problems. Some other rather obvious signals may be worthy of note. Loose or worn components increase the likelihood of leakage or other weaknesses in the system. These will often result in accumulations of fluid in pools on the floor, or other undesirable conditions. Vibrations and heat in the systems, while expected at some level, must be monitored as possible indicators of problems. Fluids in the system may become contaminated over time, or condensation may lead to water in the system. Valves and actuators may stick due to wear or dirt, requiring replacement, adjustment or cleaning. Hoses or lines may become damaged over time due to abrasions caused by rubbing on other items. Hoses must be studied for fatigue due to twisting, improper original fit, or general wear.

**General Housekeeping.** General housekeeping is at the center of the overall maintenance effort. This involves taking care of the place where we spend at least one third of our lives, and easily more than this. General housekeeping relates to virtually all that we do, including appearance and aesthetics, things being clean and in their place, and proper organization for maximum productivity. General housekeeping also relates in very significant ways to safety.

General housekeeping speaks to the overall quality of an organization, its management and planning systems, and certain basic maintenance functions. If an organization does not have its maintenance act together, it will show up in equipment downtime and work stoppages, messy/disorganized work areas, tools/supplies not being where/when needed, or not being of the proper type and/or condition.

**Safety Services**

Maintenance ties directly to safety, and a significant part of servicing technology has to do with safety. People and technology in combination will eventually result in some form of safety related issues. Safety is a primary concern since safe people will be productive. Conversely, people who do not feel safe will be preoccupied with hazards, and less productive.

**Safety Objectives.** Four major safety objectives are identified in this section. While these are not necessarily always the case, they will generally hold true in technological organizations and industries.

**Accident reduction.** A major safety objective is reducing lost time accidents, those which result in people losing time from work, or worse yet, those accidents which result in death or dismemberment.

**Cost reductions.** Accidents cost money to replace that which was lost. This includes workers, products, equipment, and so on--all costing the organization.

**Morale, productivity and quality.** The third objective is improving intangible items such as worker morale, productivity and quality. Safe workers will likely have better morale, productivity and quality.

**Frequency and severity.** Although the major objective is to reduce accidents, they will occur. Therefore, the objective is to reduce the frequency and severity of those situations which do occur.

**Safety Management.** Technological safety, like quality and productivity, is a concern of all people in the organization. This includes management and labor alike. Clearly, safety particularly does require top management support if it is to be successful. It is only through visible (and financial) support from the top of the organization that safety programming will be taken seriously. A specific safety program is tailored for each organization based on issues such as are shown below.

**Clear responsibility.** It is important that all
people, labor and management alike, understand what their responsibilities are. Who will document hazards? Who will request repairs or upgrades? Who will report unsafe people and/or circumstances?

**Absolute accountability.** Not only must people be given clear safety responsibilities, but they must also be held accountable. If people know they will be evaluated based on their responsibilities, meaning they will be held accountable, they are increasingly likely to assist in facilitating safe working conditions.

**Develop goals and objectives.** Safety goals and objectives can, and should, be requested from people. If this is done on a regular basis we will help ensure safety since people will be "thinking safety".

**Safety dollars savings.** One way to help keep a safety program going is to be able to show actual cost savings due to safety activities. Documentation should disclose the effects of training, committees, and other efforts to assist in improving safety. Some of the costs which can be discussed as safety related, to help build the case for safety, could be training costs for replacement workers; increased workers compensation payments; costs of reduced output by returned injured workers; costs to repair damaged machinery; and, costs for clerical activities to complete forms.

**Safe procedures.** Safety should be built in to all procedures. Identified in the procedures, safety should be the standard working and operating procedure. No matter the job, there are safe methods which should be identified, documented, trained for, and used.

**Design/build-in safety.** When possible in original design or redesign, plant layouts, work areas, machinery and related items should apply an attitude of safety, also related to controlling physical conditions.

**Front line supervision.** It must be recognized that one of the most important people in the management team, for safety, is the front line supervisor. If this person is effective, many safety problems will be eliminated or reduced.

**Be persistent.** Safety is an issue which must be continually repeated. This is accomplished with posters, newsletters, Friday meetings, safety fairs, family outings sponsored by the company and perhaps in other ways. Safety can not be presented too much.

**Do it right the first time.** One of the best occasions for creating a safe working environment is when new employees are being prepared. Sometimes called "new employee indoctrination", this must be carefully planned, organized and executed to ensure that proper procedures are given and followed. This is true since many accidents happen during the first few days of work, with new employees. Other concerns include:

1. Where lockers, restrooms, cafeteria, showers and other facilities are located.
2. Where first aid is located.
3. Where exits for emergencies are located, and provisions for an emergency or disaster plan.
4. Information about benefit programs (insurance, health, medical, vacation, etc.).
5. Medical examinations for determining "base-line" health conditions for employees. This is important to the organization since the employee may attempt to blame the organization for any number of medical/health maladies. Document their condition early, and then presumed hearing loss or back pain ten years later can be more carefully determined.
6. When people transfer from one job to another, internal, they may think they do not need "new employee" treatment. They should be given proper training and work procedures for the new job. This may help avoid the accusation, later, that every precaution was not provided.
7. Provision to ask questions and learn the proper approach early--we want to avoid situations where people learn wrong behaviors.
8. Provisions for proper job placement, providing:
   -Clear policy on selection and placement with general skills and qualities needed.
   -Determining organizational requirements, emphasizing physiological and psychological needs, including job descriptions.
   -Knowing applicant capabilities, experiences, aptitudes.
   -Knowing physical limitations, safety concerns on the job, including visual, hearing, nervous or emotional disorders, epilepsy, and others.
   -Analyzing, matching job needs with applicants.
   -Providing training in new positions after placement.
   -Follow-up procedures to assess placement.

**Use job safety analysis.** One clear safety method which should be used by management is job safety analysis (JSA). This method helps analyze and list procedures to complete a job in one column and the possible accident concerns to be avoided in an adjacent column, on the same sheet. Example accident terms are:

-Struck by, struck against.
-Caught in or between.
-Contact with electrical current.
-Fall on same level, fall on different level.
-Inhalation, absorption, ingestion.
-Burn, thermal or chemical.
-Overexertion, strains and/or sprains.
-Abraded, punctured, scratched.
The JSA makes an excellent training tool, providing a standard procedure for tasks. If accidents occur, a point of reference is available since workers should be following the prescribed method or procedure (SOP)

*Keep effective records.* Managing the record keeping function is a major task in technological activities today. This is important for various reasons:

- Over time, with documentation, hazards are known.
- Scope of safety problems will be clearer.
- Records on employee performance can assist in evaluation and effective placement of people.
- Records serve as a baseline, to show improvements.

*Accident investigation.* Another management issue is accident investigation. Since accidents are costly, they are sometimes dealt with in terms of accident investigation costs on forms for collecting data. There are four classes of accidents:

1. Permanent partial, temporary total disability.
2. Temporary partial disability, medical treatment case requiring an outside physician.
3. Medical treatment requiring local dispensary care.
4. No injury.

Most investigation concerns are self-evident, but not all accidents result in injuries. Accidents may result in damaged product, people talking and "losing time", and so on. When investigating accident situations it is important to observe several points which should aid in netting accurate information for the report:

- Get several points of view. Do not rely on one perspective, and get eye witness accounts.
- Get reports and input as soon as possible, directly at the scene, if possible.
- Let emotions clear in initial investigations. Compare second versions with initial reports.
- Be tactful with injured persons, be diplomatic.
- Listen rather than talk. Best reports come by listening carefully based on key questions.
- Take pictures for clear documentation at the scene. These are difficult to argue with.
- When interviewing use a tape recorder, acknowledged to the people being interviewed.

*Conduct inspections.* Another helpful management tool for gaining and maintaining safe technological working conditions is the routine inspection of the plant operations and job site. This can be conducted in a variety of ways, but the intent remains the same. Inspections help discover safety issues and unsafe practices before they are problems. This is a key piece of documentation to substantiate that the safety issues were identified for correcting. Due to costs and other factors it may be that problems are not corrected as quickly as they should be. If an accident results from the identified safety problem after the inspection process documented the hazard, but before it was corrected, it was documented, and management may not be accused of being negligent. Different inspection methods are generally used depending on need, contingent on the nature of the technologies (i.e., nuclear versus general construction).

People doing inspections may be a significant issue as well. This is since management may have their own motivation for inspecting, related to much that has previously been stated. Consistent with the movement to place responsibilities at the lowest level possible, for empowerment purposes, it may also be highly advisable to engage line workers and operators in a self audit for safety purposes, on a regular routine/systematic basis.

*Build off the job safety programs.* When the company begins to be concerned about the health and safety of the employee away from the job, this is termed "off the job safety". Since a significant percentage of accidents occur away from the workplace, it is often true that technological organizations are concerned about non-work related circumstances. When we recognize the investment the organization makes in it's people, and the costs required to replace people, we know it pays to worry about health and safety off the job as well as on the job.

Typical off the job concerns are alcoholism and drug rehabilitation; stress management and general counseling; vacation safety programs; general physicals; and, driving safety. The entire family is included, since an employee who's family is well cared for is more productive.

*OSHA compliance.* Another area of concern is related to the Occupational Safety and Health Act (OSHA). This act, if used properly, should be a positive influence. While specific OSHA regulations are far beyond the scope of the current section, several key points can be adequately introduced. These points include OSHA inspection procedures, general record keeping. The procedure which is generally followed in OSHA inspections is outlined in the following steps--all shifting to states from federal jurisdiction.

The inspection is announced or unannounced, requested by a worker or by management. After the inspector arrives and is identified a pre-inspection conference is held to determine the nature of the overall safety issue and if immediate threats exist:

1. Serious, substantial probability exists that an accident will result.
2. Willful, problems exist and the employer knows it, yet continues to operate.
3. Repeated, organization was cited for a violation, no correction was made.
4. Immediate danger, needing immediate attention due to such a serious hazard.
5. Fines, up to $10,000 and if serious enough facilities closed.

Another important aspect of OSHA procedures relate to record keeping. All organizations with more than 10 employees must keep records. Records must be kept for 5 years, including information pertaining to work related injuries, illnesses, deaths and associated losses requiring medical treatment. Various OSHA forms and log summaries are used for these purposes.

Controlling Physical Conditions. Physical conditions in the technological environment are concerned with all aspects of where people work. The interest here, of course, is in keeping the workplace as safe as possible. Specific physical conditions are:

1. Plant layout and general physical design.
2. Mechanical devices, equipment guarding.
3. Electrical devices and equipment.
4. Hand tools.
5. Material handling.
6. Housekeeping and general maintenance.
7. Fire control.
8. Pollution in and out of plant.

Each of the above physical conditions will be explored in greater detail in the following section, beginning with plant layout and general physical design. Several specific guiding principles are identified:

1. Sufficient space for aisles, storage, equipment must be allowed. Isolate/contain hazardous operations.
2. Exits/stairs need doors/locks which permit rapid exit, doors swinging outward and not directly onto stairs, consistent handrail design, and lighting with auxiliary battery powered lights.
3. Floor openings and platforms require covers, railings and foot guards, one inch angle iron (minimum), to keep people from slipping under.
4. Flammables must be stored and handled with care, in approved cabinets and containers, isolated from igniters like motors and furnaces.
5. Lighting in work areas is ten feet over workers, well distributed. Special operations may require high intensity lamps. Amount, brightness, glare, intensity and uniformity of light are important.
6. Pipes are color coded with dangerous materials as yellow, safe materials green, protective materials blue and costly materials purple.

Hazards can be eliminated, re-engineered, isolated or guarded. People can be trained to properly interact and function in hazardous situations. After training has occurred or other steps have been taken, enforcement and discipline is paramount. This includes use of checklists or other operational guides.

Guarding is another important physical condition which must be addressed. The key factor with guarding is "fail-safe". This simply means when a worker goes wrong, rather than crushing or losing fingers, they should fail-safe, without hurting the worker. Types of action to be guarded are shearing, rotating, in-running nips (rollers), and smashing. Guards used to address these types of concerns are a) barriers to keep the worker from getting into machinery, b) interlocking which keeps the machine from functioning until various components are in proper and safe positions, and c) automatic guards which automatically assist the operator by providing a guard in various work positions, simply by not allowing the machine to function without the guard.

Further guarding information is noted in the following "guard criteria". Guards should:

1. Enclose moving parts and components.
2. Be sufficiently strong to hold together.
3. Use materials such as transparent, perforated, or expanded, and which are thermally and chemically inert as well as electrically resistive.
4. Maximum protection, minimum inconvenience, not a hazard itself by the condition corrected.
5. Be a permanent part of equipment, not removed because it is perceived as a removable item.
6. Enable maintenance and inspection.

Several benefits from guarding are identified for workers. Guarding should reduce injuries, fear, complaints, noise levels, and training needs.

Technological safety can be improved through the use of lockouts. Lockout means a machine can be totally and safely powered down to a zero energy state. Lockouts are locks placed on or near switches or other power control mechanisms. Typically, the lockout principle applies when cleaning or maintaining a machine. Any time workers or others wish to ensure that the machine is truly off, this may be a lockout application. Lockout bars provide a place for several workers and/or maintenance people from the same or different shifts to "down power" equipment and be assured when working it will not be turned on, endangering them. This is important where many people are involved. Each lock is separately placed, or the control of operation must have a different combination so all can only remove their own lock, but not another's lock, helping ensure credibility in the system. Lockout procedures include:
1. Agreement is reached regarding units which are to be taken out of service.
2. Point of operation controls are turned off, followed by main power being turned off.
3. People who will be servicing the machine then place their locks on the control lever.
4. A tag is placed on the lockout explaining who is involved, how long the job takes, and so on.
5. Double check the switch or valve prior to starting, with no chance of machine startup.
6. After each worker completes servicing, they should remove their lock, one at a time.
7. The last person's lock to be removed should sign the tag indicating the job is done.

It is often important in locking out power to make sure all sources are dormant. This includes electrical, pneumatic, hydraulic, flywheels, and other types.

Manual lifting can contribute to accidents and injuries. Often loads are improperly lifted, too heavy, not gripped securely, or personal protection equipment such as gloves or proper shoes are not used. Much of this can be avoided by simply inspecting the load prior to beginning to lift. The load should be inspected for stability, determining if any rough edges or irregularities of shape will cause injury, and to make sure a place is open to put the item down once a destination is reached. Other procedures are:

1. Feet should be comfortably spread for balance.
2. Keep the back straight. This enables better leverage and helps minimize back damage.
3. Keep the chin tucked to minimize back damage.
4. Use the entire palm and fingers to help ensure a positive power grip.
6. Keep arms close to body to multiply leverage.
7. Bending should occur only in the knees.
8. Work on signal where two or more are teaming.
9. Do not twist the body in various shapes-try to work in straight line motions.
10. The same people should do lifting regularly.

People unaccustomed to lifting may have "weak backs", muscles increasingly likely to be pulled.

Several other lifting or handling devices are identified. One example could be pallet trucks which can run over feet, while the powered type can actually "get away from you" and strike people, product or equipment. In the case of fork lifts, the OSHA requires specific annual training and other considerations for their proper use. Among fork lift considerations are eight hours of training annually, in-plant licensing for operators, periodic maintenance checks which are generally done prior to each running, physical exam, and documentation of operator's vision, reaction time and coordination. Commonly, organizations will have a fork lift safety training course which is offered periodically to help address these considerations.

Conveyor hazards include making certain all guards are properly installed and actually used, and checking sensors to ensure they can be triggered to shut the conveyor off if needed. Conveyors should also have manual shut off safety switches at periodic locations to enable shutting the conveyor down if needed. Lockouts should be used for servicing conveyors, and overload devices should be installed on the conveyor to indicate when the load is too heavy.

Regarding chains, ropes and cables, it is important to use them in a straight-ahead load circumstance whenever possible, rather than, at angles. Simply stated, when loaded at angles, strength diminishes. Periodic inspections should be conducted to determine when the useful service life is concluding for cables, chains, ropes, and so on. Often after pre-determined lengths of service, these devices are phased out and replaced with new, fresh, units. Stretching, bending, twisting, corroding and cracking all diminish strength in these types of lifting devices.

Control of physical conditions should include concern for electrical safety as follows:

1. Tools and machines should be checked after each use at the tool crib, including a tagging system for any item rendered needing repaired.
2. Metal appliances/devices should have the three wire ground built in. Shorts automatically ground at the third wire rather than operator.
3. Electrical devices should be double insulated with cases/bodies of plastic, insuring safety.
4. Electrical inspections include circuit and continuity...
tests to determine shorts or breaks, often done as tools are checked at the tool crib.

5. Ground fault interrupters can be placed into power lines of equipment to accept shorts in circuits rather than reaching the operator.

Another physical condition to be controlled in technological organizations is fire. Fire is defined as a rapid, self-sustaining oxidation process accompanied by the evolution of heat and light of varying intensity. There are six major sources of fire identified as electrical, incendiaryism (arson), smoking, hot surfaces, cutting and welding, and, friction. Several methods can be used to help prevent and/or keep fires from occurring or from becoming a serious threat:

1. Provide appropriate fire extinguishers, maintenance and training for their use.
2. Eliminate or confine hazardous processes.
3. Install water sprinkling systems.
4. Use fire doors to contain fire.
5. Use spark-free motors and devices.
6. Provide marshalling areas where people can be directed to safety and calmed.
7. Identify escape routes and practice using.
8. Know what rescue and medical services are available--and how to access.
9. Conduct regular fire hazard inspections.

Fire occurs in four stages, a function of heat, oxygen and fuel. Stages are identified as incipient, smoldering, flame, and heat. Incipient stage is the fire in its initial stage, often with very little visible smoke. Smoldering is the second stage, with visible smoke clearly occurring. Flame stage is where ignition actually occurs, with flames clearly visible. The final stage is heat. In this stage heat, smoke, flame, and toxic gasses combine to provide the deadliest stage. The heat stage is deadliest primarily due to toxic gasses making it virtually impossible for people to breathe.

One of the key problems related to fire is liquids which give off vapors. Gasoline is a prime example. If not properly stored, some liquids can create an explosive fire hazard. Although specific safety and storage guidelines should be available from manufacturers of vaporous materials, some general storage/handling pointers are offered:

1. Do not use glass containers, these can break.
2. Do not store vaporous materials near motors or other potential igniters.
3. Watch "flash point" in liquid/vaporous materials. Some liquids can ignite by being changed to a sufficient ambient temperature.

Hygiene is another physical condition further identified as chemical, physical, and biological. Chemical is further defined as atmospheric and could include fumes such as welding, gasses such as carbon monoxide, vapors and mists in plating operations, water pollution, and dust and smoke. Physical hygiene issues are heat, noise and radiation from various sources. Biological sources are any natural organism which attack humans (poison ivy or bee stings).

Common entry points for the three hygiene circumstances are inhalation, skin absorption, and ingestion. Inhalation is related to breathing, skin absorption is actual contact with an undesirable substance, and ingestion is contacted by drinking or swallowing. The most serious is inhalation since they can be chronic, such as lung/respiratory illnesses.

Control of chemical hygiene comes through air or water samples as tested under controlled conditions such as colormetric tubes for air quality or chemical reactions for water contaminants. Physical hygiene as related to heat is typically controlled through personal protection equipment. Noise can be controlled by using personal protection equipment (ear plugs), by isolating the equipment, or by engineering approaches:

1. Reduce driving force or vibrational surface.
2. Reduce response of the vibrating surface.
3. Reduce size of the responding component.
4. Change the direction of the sound waves.

Biological hygiene can be controlled through proper precautions such as personal protection equipment to help avoid contact with the biological source.

Personal protection equipment is a final area to be studied with physical conditions. This area of concern places primary responsibility for personal safety squarely on the shoulders of the worker by requiring the individual to personally protect themselves. Various parts of the body require numerous types of protection. Examples follow:

1. Head - hard hats, helmets, hoods, eye goggles, earplugs, respirators, etc.
2. Main torso - thermal suits, life preservers, visible vests, harnesses, life lines, straps/belts/nets, chest protectors/bullet proof vests, lead shields, etc.
3. Arms/legs/feet - gloves, arm/leg rawhide covers, safety shoes, etc.

Personal protection equipment is a cost-effective investment which can be made technologically.