Chapter 1

Identifying the Work

Most maintenance departments have developed workable methods to handle day-to-day work. However, the most complicated call for maintenance resources comes when the plant is shut down for maintenance. Some plant operations shut down just because inventory is high or because business activity is low. Others are in a sold-out situation, but they just can't run the plant in its current condition. Government organizations sometimes mandate annual shutdowns for inspections.

Whether it's called a *shutdown*, *shut-in*, *downturn*, *turnaround*, or *outage*, the down period affords the maintenance department opportunities that may not be available again for a long time. The most demanding aspect of these periods is fitting a large compliment of work into a short period of time. It can be a period where the maintenance department really shines, or, as is often the case, these down periods prove the inadequacy of the maintenance department.

Some companies leave shutdown planning up to one individual or a separate group of people at the plant. Sometimes the planning of a shutdown is taken completely away from site personnel and handed over to a corporate engineering department. Plant personnel are queried for their suggestions on jobs to be performed, but laying out the schedule is left to the specialized group.

Gearing up for a major shutdown does not necessarily have to be relegated to a special group. A novice with some insight can coordinate a good shutdown. Using modern project management computer programs can help. These programs enable maintenance professionals to staff and coordinate the effort of hundreds of workers along with support equipment while minimizing the downtime and the costs involved.

Project management is a science that has developed out of necessity. The increasing cost of labor and materials has required tight controls on these resources to maximize productivity and limit losses. The increased complexity of manufacturing plants and the high cost of downtime has necessitated tight control over the execution phase to ensure that total costs of the project and accumulated downtime do not get out of hand.

Although project management has historically been applied to engineering and construction work, the tool of project management is uniquely adaptable to maintenance work associated with a shutdown.

Project management begins with the inception of the project and includes all phases of development. Following are the five traditional phases of a shutdown, turnaround, or outage:

1. Identifying the work to be accomplished and the scope of work that can be completed with the time and money allotted. The application of project management techniques hinges on how well this has been done.
2. Planning the work included in the project. During this phase decisions must be made as to how long each job will take to perform, how many people are required, what materials are required, and what special tools or equipment may be needed. Included in this planning are economic decisions of make vs. buy and in-house vs. contract decisions.
3. Scheduling of the project work. This phase determines the order in which work will be performed. Such scheduling efforts usually include some application of CPM (Critical Path Methods) or PERT (Program Evaluation Review Technique). This phase can employ computer programs that assist in the scheduling process.
4. Execution of the project itself. During this phase, communication among the participants on the status of work is paramount. Also, the means by which contingencies and additional or new work will be handled must be determined.
5. Reporting and documenting the shutdown activity. Shutdowns of operations are usually not common events. It's a good idea to document the shutdown preparation and execution. Any discoveries or needs for future work made during the shutdown should be documented.

This chapter begins the examination of shutdowns, turnarounds, and outages by taking a closer look at the first phase: identifying the work. The chapter then delves into risk management before concluding with a discussion on defining and limiting the scope of work to be done during a shutdown, turnaround, or outage.

Identifying the Work

Don't restrict the shutdown scope in the beginning. Try to identify all the work in the affected area. Efficiencies through good project management may provide an opportunity to do more work than initially envisioned. Development of a critical path schedule and subsequent load leveling often identify periods of low labor requirements. Extra work on the schedule can be performed during these periods. Even if these jobs do not require downtime, they can be performed when personnel become available. Only the available downtime and the money that can be prudently expended should limit the shutdown scope.

Identifying the work in advance is prudent, even if the required resources will not be available to do the work during the upcoming shutdown. Some future shutdown will provide an opportunity to perform this work.

This section examines the following critical areas when identifying work to be performed during a shutdown, turnaround, or outage:

- *Reviewing the maintenance backlog*—This includes reviewing preventive maintenance (PM) jobs, jobs that do not require a shutdown, history of equipment that is being affected, and records of predictive maintenance (PDM) work.
- *Identifying the preliminary work*—This involves checking such things as infrared scans, preparing checklists of tasks to be performed, identifying specific areas for inspection, checking with individuals who have experienced similar shutdowns, reviewing shutdown files, preparing plans for start-up activities, and preparing checklists for tasks to be done during the shutdown.

Reviewing the Maintenance Backlog

The current maintenance backlog will most likely contain work that requires a shutdown in the affected area. Some computerized maintenance management systems (CMMSs) allow these jobs to be preclassified as shutdown, which makes them easier to find.

Utility equipment, outside the affected area, should also be considered during the search. Steam, compressed air, or electricity provided to the area can also be removed from service or curtailed to allow needed repairs to be performed.

Preventive Maintenance Jobs

Any search for preventive maintenance (PM) work to be performed during a shutdown should start with a search for overdue PM. Next, the planner should check all preventive maintenance work due to be performed before or after the shutdown date. It may be advisable to use the scheduled shutdown to change equipment oil rather than just add oil.

For example, assume the shutdown will take place on May 7 and the next major shutdown in this area will not occur for another three months. All PM work that will fall due during the three-month period after May 7 should also be considered for the May 7 shutdown. Also, some equipment lubrication can only be changed when the equipment is down. Be sure these jobs are on the shutdown schedule.

Jobs Not Requiring a Shutdown

Work in the backlog that may not require a shutdown should also be reviewed. As stated previously, resource load leveling may reveal idle periods for certain crews. Nonshutdown work can be performed for these crews.

Additionally, contract or specialized help not normally available may be present during the shutdown. An example of this could be an insulation contractor. If insulation work is required during the shutdown, the opportunity should be taken to do other insulating work while the contractor is on site.

Some nonshutdown jobs may require special preparation. Scaffolding, cranes, or other support equipment may be rented for the shutdown so this equipment won't have to be erected during a nonshutdown period.

Equipment History

A quick review of equipment history when planning a shutdown is always advisable. Basically, this review is centered on finding the equipment in the affected area that has cost the most to maintain, or has the most work orders charged against them. This historical search should be limited to work performed in the last year or since the last shutdown.

Many maintenance professionals feel that they don't need a sophisticated system to identify high-cost areas. This may be true in very small plants, but it is definitely not the case in larger plants. A detailed review of completed work orders is usually required to identify problem equipment.

In the days before CMMSs, copies of completed work orders were filed three different ways: by work order number, chronologically, and by equipment number. A maintenance professional hoping to find the equipment in the plant that costs the most money to maintain would simply look for the fattest equipment file. This method would help identify equipment that had the most work orders charged against them. The fact that numerous work orders are charged to one piece of equipment may not, in itself, be an indication of a problem, unless the majority of the jobs are for breakdown or emergency work. A more detailed review of work order costs may also be necessary to find problem equipment.

Today, the search for work to perform during a shutdown is much simpler. CMMSs store all work order data in one computer file. This data can be sorted and reviewed in more ways than is possible with a manual system. The equipment history can be tabulated and sorted, not only by number of work orders but also by cost.

A shutdown planner should pick out equipment that seems to have been particularly troublesome because of the high cost of repetitive or emergency work. Engineering changes or detailed inspections should be scheduled for this equipment during the shutdown.

Predictive Maintenance Records

Many companies today have a formal predictive maintenance (PDM) program. PDM programs for rotating equipment concentrate on vibration measurement and oil analysis.

Even companies with no formal PDM programs can benefit from a quick check of equipment condition during operation. An inexpensive, handheld vibration meter is all that is needed to make this check. Instruments that measure vibration velocity provide the best indication of the severity of the problem.

The Vibration Institute (a not-for-profit organization) has established levels of equipment health as a function of vibration velocity. In general, equipment that exhibits vibration of .3 inches per second velocity is said to exceed an acceptable vibration limit. This limit holds true on most industrial equipment operating between 600 rpm and 3600 rpm. Most formal program limits are based on this value.

If a formal program exists, the planner should check the vibration records for all equipment in the affected area that exceeds an overall vibration of .3 inches per second. If no formal program exists, the planner should acquire a vibration meter and take the readings. This data is truly worth the time spent.

If few downtime opportunities are made available on the equipment, it may be advisable to include equipment with even lower vibration readings (such as .25 inches per second). The assumption is that this equipment may be approaching the limit and the time is right to shut it down for repair or inspection.

Spectrum and phase analysis of the equipment with high vibration can determine the root cause of the problem. The most common sources found for high vibration are misalignment, imbalance, or bad bearings.

Oil analysis is another predictive tool that can provide valuable information about the serviceability of the lubricant, as well as the condition of the equipment in general. A spectrographic oil analysis can be performed by many oil suppliers or through an independent laboratory.

Spectrographic tests can detect wear metals such as aluminum, iron, nickel, chromium, lead, silver, copper, tin, zinc, or silicon. Elevated levels of these metals in the oil may not only indicate a problem, but can also be helpful in discovering the source. High nickel can be the result of rolling-element bearing wear. High copper can be the result of plain bearing failure.

The same test can identify the additives in the oil. If the additive elements and quantities don't compare to the specified additives that should be in the oil, contamination of the oil is suspected.

The physical and chemical tests performed can detect contamination or dilution with other oils. The tests performed include the following:

- Water percent (moisture in oil)
- Carbon buildup (indicating oil breakdown)
- Viscosity (oil too thin or too thick)
- Silica (dirt contamination)
- Total Acid Number (TAN) (indicates acids in oil)

Prepare to take oil samples on rotating equipment while the equipment is down (even if the oil is to be changed). Oil tests can provide results that indicate a deteriorating condition in the equipment. Changing the oil destroys that record.

Identifying Preliminary Work

As much as 20 percent of the total cost of shutdown can be accumulated before the shutdown work even begins. A number of prefabrication and inspection jobs may be identified for work that requires a shutdown. Purchases with long lead times should also be made early. Engineering and design work should be identified and started early.

The start of the project begins the day the preliminary work starts. The shutdown cannot begin if the prefabrication work is not complete or parts are not received. Some planners mark the start of the project with the first purchase order. The lead time quoted by the vendor or the time to complete the prefabrication or design work can all affect the start and subsequent finish time of a project. Anything requiring time prior to the actual shutdown is part of the total project.

Infrared Scans

One preliminary activity that can yield detailed information for the shutdown is infrared scanning. An infrared scan of electrical equipment is performed for the purpose of detecting loose or corroded connections on electrical equipment. Electrical current flowing through copper or aluminum conductors generates heat. This heat is mainly caused by the resistance of the electrical current flow that exists in the metal conductors. If a loose or corroded connection should occur, the resistance to current flow through the connection increases, and so does the generated heat.

An infrared scanner can detect this heat and can indicate the relative temperature. For example, a three-phase motor should have equal current flowing to all three phases of the motor, so corresponding phase connections should have the same temperature. If one connection is hotter than another, it may be loose or corroded. A problem is said to exist if the temperature difference is greater than 5°C.

Because of the expense of required equipment, an infrared scan is usually performed by an outside service. An electrician will most likely have to be scheduled to work with the contractor to open equipment panels and then close them after the scan is complete.

Following are a few items that should be considered before the scan:

- Prepare all electrical equipment for safe energized access during the scan. An infrared scan can only detect a problem on equipment that is exposed and energized. Some equipment access points and covers may not include hinges or handles. Install this hardware during a convenient shutdown.
- Identify all connections and equipment to be scanned with a detailed list. This will help to more effectively use the time of a contract scanning service.
- Schedule the infrared scan for a period in which load in the plant is near maximum. This will allow the worst problems to better exhibit themselves.

The electrical distribution system is not the only area where an infrared scanner can be used. Other problems that can be uncovered using an infrared scanner include the following:

- Kiln or furnace wall refractory failure
- Tube pluggage in a heat exchanger
- Insulation failure
- Leaks in roofing
- Other heating or cooling loss in buildings or machinery.

Identify Inspection Opportunities

Some work performed during the shutdown may not be immediately necessary but could provide some insight into future shutdown work. Exposed components provide opportunities for inspection and tests not normally available. High temperatures, chemical hazards, or radiation concerns may prevent inspection of equipment components and structures during operation. Once the equipment has cooled down or has been decontaminated, a more thorough inspection can be conducted. Consider the following examples:

- Collect dimensional information for future shutdowns
- Sketch up electrical wiring schemes that may be concealed while in operation
- Count exposed gear teeth in a gearbox (information that is very helpful in vibration programs)
- Perform nondestructive thickness tests on piping and vessels after the insulation is removed
- Perform eddy current tests on internal tubing
- Identify spare parts requirements on older equipment with no available manuals
- Take transformer or equipment oil reservoir samples that cannot be safely taken during operation
- Inspect and evaluate sleeve or bearing wear

Inspections such as the ones described here can uncover numerous problems. Shutdown personnel should guard against correcting each and every problem uncovered through a shutdown inspection. Unless the repairs can be accomplished very quickly during the shutdown or failure proves to be imminent, they should be left for future shutdowns. Making unplanned repairs as the problems are found diverts valuable time and labor that should be used for the planned jobs and could extend the shutdown period.

Solicit the Input of Others

When a problem arises during execution of a shutdown there is always someone around who predicted it or experienced the same problem before. These people just weren't heard early enough in the planning phase.

Success in shutdown planning lies in the details. Project or shutdown problems usually result from a lack of early information or responsibilities assigned to the wrong people. A shutdown planner would benefit greatly from the input of others in the plant.

Operations management can help identify additional needed work and potential problems by including engineering and maintenance supervisors. A major benefit can also be derived from soliciting the input from maintenance craftspeople, operators, line personnel, the storekeeper, purchasing, and other persons not normally included in the decision-making process. A structured group interview is one effective method of including these people.

The goal of a structured group interview is to document specific conditions and problems known to the attendees and to identify the solutions. These solutions are then prioritized.

Certain individuals may be stifled in a mixed group of management and hourly employees. Segregated groups should be considered, such as all operators or all maintenance mechanics. The group should contain a minimum of ten people and a maximum of twenty. The meeting should last no more than one to one-and-a-half hours.

Developing a question that best explains the problem to be solved starts the process. Questions such as "What can be done to make the next shutdown more successful?" usually elicit the most helpful responses. Avoid questions that may generate a laundry list of responses that will be difficult to prioritize. Questions such as "What jobs should be performed during the next shutdown?" should not be posed.

The rules for structured group interviews are very simple:

- *All responses must be presented in the form of a problem and a solution*—If a person has thought of a problem, he or she has most likely also thought of a solution to that problem.
- *All suggestions and solutions will be written down on a board or flip chart without rephrasing or debating them*—If people state only problems, explain to them, "It seems like you have thought a lot about this problem. Can you tell me of any solutions you have thought about?" It is alright to discuss the response after it is written down, but no one should be talked out of a response.

The steps to conducting a productive meeting are as follows:

1. Send out notices of the structured group interview and invite everyone. Provide a proposed schedule in the letter.
2. Everyone must be present before you start. When the meeting starts, no one else can be allowed to arrive in the middle of the session. Put a sign outside on the door stating, "Meeting already in progress—Please arrange to attend the next scheduled session."

3. Explain the purpose, goal, and rules to the group.
4. Write the question on a flip chart and post it in the front of the room.
5. Write down the responses (stated as a solution) to the question exactly as they are stated. Number them consecutively.
6. When a flip chart sheet is full, tear it off the pad and tape it on the wall.
7. When you reach 20 responses, stop listing responses.
8. Have everyone present vote for the ideas (posted on the wall around the room) by stating, "If you could vote for only five of these solutions, which five would it be?" Each attendee can go up to the posted sheets and vote by placing a mark next to the five responses.
9. Total the results for each item. Break ties between two or more items by asking for a show of hands, stating "If you had to choose 'A' or 'B', which one do you feel more strongly about?"

Individuals who have not been involved in brainstorming sessions in the past may be reluctant to be the first to talk. This is normal. After an initial response is given, group dynamics will take over and more responses will follow. Here are some tips that will help get that first response.

- Silence works wonders. After introducing the subject question, wait in silence. Fight your normal urge to break the silence. If you are talking, no one else can.
- If there is still no response, encourage attendees to consider a situation involving the subject question. "Think back over the last few weeks. Maybe you were in a situation that reminded you of our question. What was the situation and what kind of solution comes to mind?"
- Do not berate the group or put them on a guilt trip. Word will get around and any future sessions will be unproductive from the start.
- Do not coerce responses. Statements such as "We're not leaving this room until I have some responses" may get you a response or two, but the value of the session itself will be nil.

The result of a structured group interview will be a list of solutions to real and pressing problems in the affected area. These responses can only enhance the overall plan.

Reviewing Shutdown Files

Much of the work to be performed during an impending shutdown has been performed before. If the shutdown coordinator did a good job, the work performed in the past was well documented. Hopefully, a file of this work is available to the new coordinator.

The results of inspections or unfinished work are the most important information derived from this file. Any problems left or uncovered can be scheduled for rectification during the next shutdown. Any jobs that could not be started because of a lack of resources should also be considered for the new shutdown.

Additionally, mistakes of the past should not be repeated. Logistical errors and unexpected work stoppages can be eliminated in the next shutdown, as long as someone remembers these problems occurred. This information is often reported in a final shutdown report.

Identify Start-Up Activity

Make a list of activities that will occur at the end of the shutdown period. Cleanup, painting, touch-up, insulating, and start-up should be added to the list of shutdown work.

Sometimes unknown charges continue to accumulate against the shutdown after it is completed. Add a step to return rental equipment and compressed gas cylinders when the project is complete.

Shutdown Meetings

Meetings should be held throughout the planning phase of the shutdown. These meetings should be large at first (such as the structured group interviews described previously). Other brainstorming sessions may be helpful in the early stages.

Eventually, the project meetings should be restricted to a select group of people with a direct stake in the shutdown. Always publish an agenda before the meetings. Someone should be assigned to take the minutes of the meeting. These minutes should be published and distributed to all attendees and other stakeholders.

General Shutdown Checklist

Knowledgeable individuals should perform inspections of the affected area with the shutdown in mind. A checklist should be developed for this purpose if the shutdown is not a unique occurrence. All equipment and supporting structures should be inspected for the following:

- Missing guards
- Safety hazards

- Seal leaks
- Cleanliness
- Gage readings (compared to a limit)
- Oil levels
- Unusual sounds or smells (emanating from equipment)
- Deteriorating supports

Using a strobe light can enhance many inspections and checks. First, the condition of moving parts can be discovered. Additionally, the strobe light can be used to collect data from moving parts on rotating equipment. Finally, belt, coupling, sprocket, or sheave markings become visible under the strobe light.

The following items are common to many shutdowns and should be part of every shutdown manager's checklist:

- *Barricades*—Barricades should be considered to restrict movement of personnel for any of the following situations:
  - To limit entrance to, or egress from, any particular area of the plant or facility.
  - To restrict travel for contractors to and from their parking lot.
  - To protect all personnel from hazardous areas (or to minimize access to such areas) and to limit right-to-know training for all temporary personnel.
- *Building permits*—New construction or major improvements made during a shutdown may require permitting in some locales. Ensuring such legalities are covered in advance of the actual work should eliminate unnecessary and time-consuming delays.
- *Contractors' insurance certificates*—Most companies require minimum liability protection as well as proof of Worker's Compensation coverage for on-site contractors or other outside services. A file should be maintained for such certificates to minimize third-party litigation in the event of injury, death, or major damage.
- *Dust control*—The extra activity during a large shutdown can also be the source of excessive dust when unpaved areas are utilized as parking, staging, or even fabrication areas. Contracting a water truck service to regularly dampen down the areas can keep this problem in check, as well as improve relations with temporary personnel and the quality of work they

provide. Providing a temporary wash-down site for automobiles and trucks is also a recommended nicety.

- *Emergency showers and eye baths*—Extra emergency showers and eye baths should always be considered when the number of working personnel increases. These units are available on a rental basis with pressurized water supplies. The rental company can also be contracted to provide regular, documented inspection and testing. Request copies of such inspections for your own records.
- *Flag person or traffic control*—Services or individuals to control traffic or personnel flow should be investigated for large shutdowns. Consideration should be given to covering the following situations:
  - Exit to and from temporary parking areas onto local streets during shift changes.
  - Traffic control at heavily traveled or centrally located intersections within the plant or facility.
  - Special occasions for the movement of heavy machinery, cranes, arrivals of large shipments, or any extraordinary circumstance.
- *Liquid waste handling*—Liquid waste from certain cleaning operations may not qualify for handling within the in-plant industrial sewer. These materials need to be identified ahead of time for proper handling. If such handling is to be the responsibility of a vendor or contractor, review in detail the method of spill control, containment, and disposal.
- *Noise control*—Some shutdown operations may generate noise levels that are excessive. These operations must be identified ahead of time so that proper barricading or posting can be done.
- *Repairs of other damage*—Damage to existing structures or equipment should be assumed and accounted for when a large number of people are working in the same area. Additionally, all contracts with outside vendors and contractors should include repair clauses for damage to property fences, temporary facilities set up for such personnel, or other plant properties or facilities used by temporary workers.
- *Repairs of pavement*—Potential damage to pavement areas should be discussed with heavy equipment contractors ahead of time. If load-bearing capacity is unknown, plant roadways should be tested. Contractors should be advised of areas

where damage is probable and kept from movement in such areas.

- *Scaffolding*—Be sure to put up all scaffolding beforehand. If several contractors or scaffold rental agencies are to be used at the same time, require that each mark their own scaffolding so that it is not confused with others. Scaffolding is often moved from site to site during a shutdown, and the probability of mixing is fairly high. Requiring a different color marking from each supplier will help to keep it all identifiable.
- *Solid waste handling*—As with liquid wastes, potential handling problems can exist for solid wastes, especially when hazardous classifications are involved.
- *Supervisory coverage* (dark shifts and weekends)—There should always be a company representative any time temporary personnel (not employees) are in the plant. This individual is responsible for adherence to safety rules and represents the company in the event of an injury or incident.
- *Temporary buildings and enclosures*—Temporary buildings and enclosures are often the direct responsibility and cost of vendors and contractors. It is advisable to review with each supplier of temporary structures the following areas of coverage:
  - *Temporary cafeteria or eating facility*—Ensure that some provision is made, including vending equipment. Work through the logistics of restocking vending equipment (when it will be done, which supplier will be used, and so forth).
  - *Temporary first aid*—Large contractors should provide their own licensed Emergency Medical Technician (EMT) or First-Aid Technician along with a facility for primary care.
  - *Temporary heat and light*—Temporary parking areas used during 24-hour shutdowns should be provided with adequate lighting. Test the lighting before starting the shutdown.
  - *Temporary showers and change rooms*—Some shutdown work may necessitate the need for clean and dirty change rooms and shower facilities. The need for (and provision of) such services should be handled before the shutdown begins.
  - *Temporary storage*—Storage for material, tools, and equipment should be the responsibility of the vendor or contractor. Security for such storage and liability if theft or damage

occurs should be determined before any material, tools, or equipment comes on site.

  - *Temporary telephone*—Temporary telephones should be brought into the plant. These should be located in the normal temporary break areas. It is the responsibility of the vendor or contractor to ensure that abuse of this equipment does not occur.
  - *Temporary toilets and water*—Portable toilets and potable water stations should be brought into the temporary structure area. If these facilities are to be staged within the plant or facility proper, it is advisable to arrange ahead of time how and when they will be serviced.
  - *Temporary power*—If an unusually large contracted work force is expected, the utilities to such a camp town may tax existing capacity. Identifying the potential need and providing a temporary source from the local utility is advisable.
  - *Smoking areas*—Set up smoking areas ahead of time or else contractors will be smoking on the job (which may be against plant rules).
- *Temporary construction protection*—Temporary protection of equipment undergoing maintenance or construction in progress should be addressed. Following are typical areas to be considered:
  - *Large machinery in overhaul*—Protection of bearings, machined surfaces, and tolerance items must be considered.
  - *Areas requiring special attention*—Protection of concrete forms, flange faces of prefabricated piping, and delicate instruments are just a sampling of items that should receive specific attention.
- *Gang locks and shift locks*—The Occupational Safety and Health Administration (OSHA) allows the use of gang locks and shift locks as long as adequate procedures and controls are in place to ensure that such locking devices really provide the necessary protection. It is strongly advised that lockout procedures be reviewed in advance, especially where large numbers of workers are involved or many different outside companies are on site at one time.
- *Make up a blind list*—Know where every blind is installed, and make sure that each is removed prior to start-up.

Work Lists versus Work Orders

The result of the many meetings and inspections will be work lists. Many companies start a shutdown with just these lists and then realize there is no document for charging labor and/or withdrawing materials from the storeroom.

Work lists should be converted to work orders so costs associated with the work can be accumulated. Any purchases that may not be directly associated to labor costs should also be covered on a work order as well as a purchase order. Relating all purchases to a work order streamlines the final accounting of the project. Define any engineering required by assigning a work order for this activity as well.

Any remaining activities that cannot be converted into work orders (such as operations decontamination or safety inspections) should be clearly listed for inclusion in the total project schedule.

Once a solid work list has been developed and finalized, we need to address *what can go wrong* with these jobs. Even the best-planned job can go awry during shutdown execution, and unforeseen situations can occur that must be addressed. These situations can be mitigated once the shutdown team goes through a risk management process.

Risk Management

All projects include some element of risk. It's natural to be optimistic that you will overcome any unplanned event during the execution of a project. It's also normal to be anxious that all things that can go wrong will go wrong. The adage "optimism blinds, pessimism paralyzes," applies very well to projects. Project risk management strives to achieve a balance between optimism and pessimism by confronting potential risks during the planning phase of a project.

The Project Management Institute (PMI) defines risk management as a subset of project management with the following four basic components:

- Risk identification
- Risk quantification
- Risk response development
- Risk response control

This section examines each of these four components in detail.

Risk Identification

A process should be set up to identify the risks that exist with a project. The development of a list of risk situations is a good team exercise. Often, the insights of one member will stimulate the thinking of others. The following items can be explored to stimulate discussion and flesh out hidden risk:

- *Staffing assumptions*—Some important activities may depend on the attendance of essential personnel. Identify people who will be indispensable during project execution because of their special skills or knowledge. Next, determine whether or not the project can proceed without these people. Also consider the potential for work stoppages or slowdowns.
- *Estimate risks*—Identify time and cost estimates that were developed with minimal information.
- *Procurement problems*—Any deliveries expected during the project execution should be reviewed for potential delays or even cancellation. Items from sole source suppliers represent the highest risk.
- *Project files*—Review previous project results. Even shutdowns performed in a different area can provide some insight into potential problems.
- *Commercial data*—Review trade articles for insight into some problems that others have encountered. The American Society of Professional Estimators (ASPE) has published articles on shutdowns and major modifications performed in industry.
- *Project team knowledge*—Query the project team. Team member recollections of previous projects are useful, yet less reliable than documented results.
- *Possible weather conditions*—Major storms (or just rain and snow) can affect the schedule of a project or shutdown.
- *Nature of the project*—Sometimes the magnitude of internal damage is an unknown. Corrosion, abrasion, or wear may be higher than expected. A similar risk exists when primary activities of a project will be performed for the first time. Application of new technologies or methods falls into this category.

Risk Quantification

The list developed from the risk identification process will most likely exceed the capability to mitigate all potential problems. The items on the list must be quantified to temper any response plan. The following two questions should be asked of the project team for each item on the list:

- Is the probability that this risk will be encountered high or low?
- Would an occurrence of the event significantly lengthen the project?

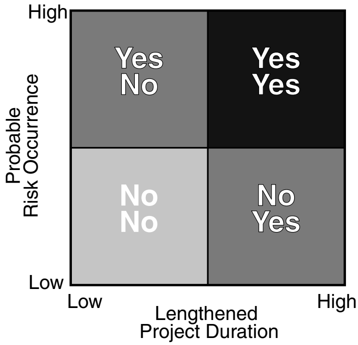

Figure 1-1 Quantifying the Risk.

Figure 1-1 can be used to weight your reaction to these two questions.

- *The Yes-Yes Quadrant*—The risk situations that fall into the Yes-Yes quadrant are too high to be ignored. Necessary steps and associated costs to minimize the risk should be built into the project plan.
- *The No-No Quadrant*—The risk situations that fall into the No-No quadrant should be ignored. The potential of occurrence is minimal and, even if the situation develops, the impact on the project schedule is negligible.
- *The Yes-No and No-Yes Quadrants*—The remaining two quadrants are economic issues. An assessment must be made of the cost to mitigate the risk situation to quantify these situations. If the cost is minimal, including the solution into the project plans would be good insurance.

Risk Response Development

Responses to a potential risk event fall into the following three categories:

- *Avoidance*—Eliminate the possibility of an occurrence
- *Mitigation*—Reduce the monetary expense of the occurrence
- *Acceptance*—Live with the consequences of an occurrence

Avoidance of problem usually costs money and can extend the project duration. For example, the use of a backhoe to dig a trench may damage buried piping. Consider paying the extra money and taking the extra time to hand-dig the trench.

Mitigation is the same as taking out insurance against the problem. For example, the simple act of opening or testing a component can damage it. An A-C high potential test of electrical cable can destroy the cable if it is in poor (but still operable) condition. Plans should be made to replace any cable that fails because of this test.

Acceptance of a problem means living with the extra down time and higher project execution costs. This is reasonable if the cost to mitigate the problem is about the same as the cost of the occurrence.

Risk Response Control

Executing the risk management plan will obviously begin when an identified risk event occurs. However, even the most thorough review of potential events cannot identify all risks, so a plan of action may have to be implemented on the fly. This plan must include the cycle of identification, quantification, and response. The key is in data collection, as shown here:

- Determine the information contained in the data that team members are reporting.
- Don't play hunches. Get the facts, and then act accordingly.
- Delegate (but monitor) action steps to reduce the effects of the event.

Defining and Limiting the Scope

Definition of the scope should begin with a statement about the purpose of the project. It is best if this statement is put in terms of a problem to be solved. A couple of good examples are "This shutdown will resolve questions about the condition of the #5 Boiler" or "This shutdown should build back capacity into the #2 Packaging Line."

Identify the stakeholder in the project. Who wants the shutdown and who will benefit from it?

- The maintenance department may want the shutdown to perform needed repairs.
- The operations department may want the shutdown because inventory levels are low or product quality has dropped noticeably.
- The engineering department may want the shutdown to make a modification or new installation.
- The plant may have to be shut down because of operating license requirements (such as boiler inspections).

Defining the Constraints of the Shutdown

Most projects have three basic constraints: elapsed time, resources, and money. A goal for the project coordinator is to determine which constraints are most important. *Elapsed time* is usually the most important constraint for industrial shutdowns. A specific amount of production downtime may be allotted for the work to be performed. If the work cannot be performed within the designated period of time it may have to be scaled back.

A *resource* refers to materials, tools, and equipment, but mostly labor. There is an upper limit to the labor hours available at any time. Even though the work force can be augmented with contracted help, this resource may not be adequate for all work to be performed. Particular jobs may require specialized skills that are in limited supply. Also, there is a limit to the number of people who can be working in close proximity to each other.

Money is usually the last constraint considered. The assumption is that most of the work must be done eventually, so why not now. The cost is inconsequential. However, if this attitude persists, the costs could run away because of overtime and penalty charges, putting the continued operation of the plant in jeopardy.

An old saying states, "Time is money." There is a cost of downtime that must be considered. For example, electric utilities must balance the cost of downtime against project costs. Staffing levels and the scope of work to be performed must be considered together with the lost revenue from not generating. Some utilities must pay a penalty for not being connected to the grid.

Quality may be a fourth constraint that is often overlooked. The quality of the work performed is directly related to the long-term success of the shutdown. If workmanship is poor, the shutdown will have to be repeated sooner. Usually, the quality of the work performed depends on the time provided to perform the work. However, experience and skill play a big part as well. Assigning the right people to the right job at the right time is one key to getting the best job possible.

Prioritizing the Proposed Work

After the initial scope of work has been defined, some prioritization is necessary. Most project management software programs allow you to establish a relative priority (along with the precedent activities) for each job. For example, one program initially sets the priority of every job at 500, with a possible range of 0 to 1000. The higher the number, the higher the priority. This prioritization should take into account the following factors:

- The future impact on capacity if the job is not performed
- The probability the problem will worsen before the next shutdown
- The increased cost of the job if it is delayed until a future date

All potential jobs should be entered into the project management program—even the ones with the lowest priority. Once the priorities are set and precedent activities are determined, the three project constraints (elapsed time, resources, and money) should be evaluated. A lower priority job should be dropped if any of the constraints are exceeded.

Preliminary Estimates of Proposed Work

After the initial activity of defining the scope of work is completed, you must develop preliminary cost estimates of the proposed work. These estimates are necessarily rough, attempting only to assign raw labor and material costs. Often, historical records of similar work performed on prior shutdowns will provide quick estimates at this stage. On other jobs (for which no historical records relate), an armchair analysis is the best means for establishing preliminary cost estimates.

Establishing a meaningful estimate for material costs may be difficult for some jobs. A typical ratio of labor to material costs is often used in this case. The assumption is made that any job would be typical of other maintenance work and would require an average amount of material. For example, assume a particular job requires an estimated 120 hours of maintenance labor to complete at the going internal rate of $35.00/hour. The Labor costs would be $4200 (120 hours × $35.00). If the ratio of labor to material costs has historically been 1:1.2, then the material costs can be estimated to be $5040 ($4200 × 1.2). The total job cost would be $9240 ($4200 + $5040).

Maintenance Shift Efficiencies and Cost Factors

In developing shift schedules, some planners erroneously assume that shifts of differing durations will return comparable hours of real work time to the project. This is not necessarily true. In many plants or facilities, some additional loss occurs when 10-hour shifts are scheduled. Even though 2 hours have been added to the workday, only 1½ hours are available for additional work. For twelve-hour shifts, the loss can be even greater. In many labor contracts, the 12-hour shift allows the maintenance worker to request a meal break after 10 consecutive hours have been worked. This meal break, though contractually limited to a half hour, can easily increase to an hour in length, as the workers at this point are exhausted. In reality, the two additional hours added to the workday from the 10-hour schedule only add one half hour of real work time to the day. This breakdown can be seen in Table 1-1, which shows a single workday as it compares to various schedules.

Table 1-1 Single Workday Compared to Various Schedules

Shift Duration (Hours)	*Days per Week*	*Schedule Hours*	*Available Hours*	*Available/Schedule Ratio*
8	5	40	40	1.0
8	6	48	48	1.0
10	5	50	47.5	.95
10	6	60	56	.93
12	5	60	50	.83
12	6	72	60	.83

The effectiveness of the maintenance work force on continuous schedules (7-day weeks) should be considered when developing work schedules. The physical demands of a continuous work schedule become very apparent after the first week of the shutdown. Fatigue takes its toll as the second week progresses. Many plants apply the factors shown in Table 1-2 to the available work hours as the shutdown moves into subsequent weeks.

Table 1-2 Availability Factors

Shift Duration	*Second Week*	*Third Week*	*Fourth Week*
8	.9	.8	.73
10	.85	.73	.61
12	.80	.64	.51

In applying the factors, the labor hours that are projected to be scheduled are derated by the factor, and those hours are the hours that are, in fact, scheduled for execution. For example, if there were 1000 hours per week available on an 8-hour shift schedule, only 900 hours would be scheduled for the second week, 800 hours scheduled for the third week, and 730 hours scheduled for the fourth week.

Cost factors should also be taken into account when developing shutdown schedules. Work hours after 8 hours in any given day, or work hours in excess of 40 hours in a given week, are paid at a premium of $1\frac{1}{2}$ times the base hourly rate. Many plants also pay a double-time premium for work performed on a seventh consecutive day. Table 1-3 shows the relative hourly rate for varying work schedules over one week.

On the basis of the previous data, most plants utilize 10-hour shifts scheduled over 6 day workweeks. For work that must proceed

Table 1-3 Relative Hourly Rate for Varying Work Schedules over One Week

Shift Duration (Hours)	*Days per Week*	*Available Hours*	*Straight Time Hours*	*Hourly Cost Ratio*
8	5	40	40	1.00
8	6	48	52	1.08
10	5	47.5	55	1.16
10	6	56	70	1.25
12	5	50	70	1.40
12	6	60	88	1.46
8	7	56	68	1.21
10	7	59.5	90	1.51
12	7	70	112	1.60

continuously, a staggered shift schedule is arranged, with a portion of the work force working a Monday through Saturday schedule, and the rest of the work force scheduled on a Tuesday through Sunday schedule. The importance of communication from shift to shift is critical in such a schedule.

Comparing Preliminary Estimates to Budget

After preliminary estimates have been made and, if necessary, massaged to reflect shift efficiencies and costs, the costs can be totaled and compared to the budget that has been approved for the shutdown. Shutdown costs are usually a major expense in any plants' operating budget. An early indication of what these costs might be is vital.

Hopefully, the estimated total cost of anticipated work does not exceed the budgeted amount. If this is true, more formal planning can now be done to more clearly define the resource requirements and cost of the jobs.

The total of the preliminary estimates may exceed the approved budget amount. In such instances, the early prioritization of the proposed work can be used to consider candidates to be dropped from the project scope. Since preliminary estimates will now be available on major jobs, an economic analysis can now be made in which the preliminary cost can be weighed against the potential benefit to the plant.

If the total of preliminary estimates cannot be reduced to within budget allowances, upper management must be made aware of the dilemma and brought into the decision-making process. Maintenance planners should not attempt to make these decisions alone, nor should they blithely proceed with project development hoping that preliminary estimates are overstated. The idea that all the proposed work can be accomplished at or under budget allowances must also be looked out for.

Determining Contract Work

In considering the amount of work to be performed in a typical shutdown, it is usually a given fact that the internal maintenance resources will be greatly overtaxed if they are the only considered work force. It is inevitable that some (if not a major portion) of the planned work will have to be performed by outside contractors or vendors. Contract or vendor supplied work is often the best alternative for the following situations:

- *Technical support*—Work that is very technical or specific to a manufacturer or special machine is often best contracted out. The unique skills, tools, or methods are often outside the technical scope of the maintenance personnel, or the skills are used so infrequently that retention is difficult. Typical of such work would be turbine/generator inspections and repairs during a unit overhaul for an electric utility. Industrial masonry work (such as refractory linings) is often contracted to experienced brick-laying companies.
- *Nontechnical support*—Work that is mundane (or requires relatively low skill levels) is often contracted out. In such instances, the skill levels of the maintenance personnel are much better applied to shutdown work requiring their knowledge. Typical of such jobs would be labor-intensive tasks of cleaning operations, catalyst removal and addition, or removal of abandoned equipment and systems.
- *Work that can be performed off-site*—Work that can be performed off-site is best contracted out. Such work will not place additional burden on plant parking, facilities, or other ancillary plant services. Fabrication, overhauls, testing and calibrations are examples of off-site work.
- *Work requiring special equipment*—Work requiring special equipment is almost always contracted. Since the special equipment is needed only during the shutdown period, it does not make sense for a plant or facility to own such equipment for the infrequent usage. Pressure blasting, nondestructive testing, and aerial painting are typical of contracted work.

Determining Internal Labor Demands

After considering work that can be contracted out, the remaining work in the initial scope must be performed by the internal labor resource. Using the initial preliminary estimates and proposed work schedules, an estimate can be made to determine if the existing maintenance work force can perform the work. If the existing work force is fully scheduled, some additional scope must be considered for performance by an outside contracted resource. It is well advised to schedule the existing work force to no more than 90 percent of the available maintenance hours. Some contingency must remain to allow for emergency situations elsewhere in the plant and possible reductions in the work force because of sickness, absenteeism, or other factors.

Job Input Cut-Off Date

Job input must have a cut-off date. This is usually a minimum of two weeks before the start of a small shutdown but could be as much as one or two months for a very large shutdown. The remainder of time before the projected start of the shutdown is needed to develop preliminary estimates, compare projected work to the approved budget, decide which work will not be done if the preliminary estimates exceed budget allowances, determine which work will be contracted, and finalize the project schedule.

It is imperative that management support the cut-off date. Even upper management should not have the ability to submit additional work after the cut-off date unless there are mitigating circumstances.

Prioritizing Last Minute Requests

It is also a good idea to decide how new work will be handled. New work consists of repairs identified after the start of the shutdown. Some thought must be put into qualifying this work. What criteria will be used to justify new work displacing work originally included in the shutdown? What will justify the displacing of work from the original scope of work? These issues are usually handled by the economics of the shutdown.

Maintenance should guard against giving undue preference to new work identified in the course of the actual shutdown. It is the tendency of many managers to overreact to this work and give it more that its due. In return, critical work first considered in the original scope is displaced from the schedule and subsequently causes reduction in capacity or additional downtime before the next scheduled shutdown.

Summary

The most complicated call for maintenance resources comes when the plant is shut down for maintenance. The most demanding aspects of these periods are fitting a large complement of work into a short period of time. It can be a period where the maintenance department really shines, or, as is often the case, these down periods prove the inadequacy of the maintenance department.

Project management is a science that has developed out of the realities of increasing cost of labor and materials. Although project management has historically been applied to engineering and construction work, the tool of project management is uniquely adaptable to maintenance work associated with a shutdown. Shutdown steps include identifying the work, planning the work, scheduling the work, execution, and reporting/documenting activity.

We should not restrict the shutdown scope while identifying the work. Development of a critical-path schedule and subsequent load leveling often identify periods of low labor requirements. Extra work on the schedule can be performed during these periods.

Identifying the work involves reviewing the maintenance backlog, preventive maintenance jobs, as well as jobs not requiring a shutdown to take advantage of resources and equipment available during the shutdown. Additionally, equipment history stored in a computerized maintenance management system (CMMS) should be checked for hidden problems that can be remedied with scheduled shutdown work. Predictive maintenance records (such as oil analysis and vibration monitoring results) will pinpoint equipment that would benefit from shutdown work.

It is also necessary to prepare for the shutdown period by performing some preliminary work. As much as 20 percent of the total cost of shutdown can be accumulated before the shutdown work even begins. Prefabrication and inspection jobs may be identified for work that requires a shutdown. Purchases with long lead times should also be made early. Engineering and design work should be identified and started early.

An infrared scan of electrical equipment is one preliminary activity that can yield detailed information. Prepare to perform the scan by ensuring safe access to the equipment while it is energized. Identify all the connections and equipment to be scanned with a detailed list. Schedule the scan for a period in which load in the plant is near maximum.

Other problems that can be uncovered using an infrared scanner include kiln refractory, furnace refractory, tube on equipment (such as heat exchangers), thermal insulation, building heating loss (roofs, walls, and so on), and machinery components (such as bearings).

Inspection opportunities during the shutdown should also be identified. Collecting dimensional data, electrical circuit sketches, gearbox inspections, nondestructive tests on empty insulated tanks, eddy current tests, hard to get oil samples, as well as evaluating sleeve or bearing wear all are important.

Solicit input for the upcoming shutdown from maintenance workers and operations personnel. A structured group interview is the best forum to get this input. Try to mine solutions from the interviews rather than a list of potential problems.

Mistakes of the past should not be repeated. Develop a regimen of established shutdown files. These files can be reviewed prior to the next shutdown to reveal the results of inspections or unfinished work. Make a list of activities that will occur at the end of the shutdown period. Cleanup, painting, touch-up, insulating, and start-up should be added to the list of shutdown work.

Meetings should be held throughout the planning phase of the shutdown. Shutdown meetings should start out large and include many people but should eventually be restricted to a select group of people with a direct stake in the shutdown.

Build a shutdown checklist, specific to your site. Facility walk-throughs should be organized to find obvious problems (such as missing guards, hazards, and leaks). A detailed list of items that may create a problem during shutdown execution should also be developed. The need for barricades, building permits, insurance certificates, dust control, and so on should be listed for the current shutdown and future use.

All work lists should be converted to work orders. Costs associated with the work can be accumulated in a CMMS only when this occurs. Work such as operations decontamination or safety inspections should also be converted to a work order, even though hours may not be charged against this work.

Risk management as defined by the Project Management Institute includes risk identification, risk quantification, risk response development, and risk response control. The project manager will have clear plans on how (or whether) to mitigate potential problem that may come up during a shutdown once a risk management process has been completed.

Defining the constraints of the shutdown involves reviewing elapsed time, resources, and money. A fourth constraint of quality (that is, workmanship) can also be considered. These constraints should be used to start prioritizing the proposed work. Preliminary estimates of proposed work should also be developed to determine the scope of the shutdown.

How and when to use a contractor is always a question prior to a shutdown. Contractors can be used for technical support, general labor, off-site work, or work requiring special equipment.

A cut-off date should be established for all work that may be added to the shutdown schedule. This is usually a minimum of two weeks before the start of a small shutdown but could be as much as one or two months for a very large shutdown.

Chapter 2 discusses the methods to plan shutdown work, the idea of work packages, and how to deal with contracts for services.