



MAINTENANCE PLANNING AND SCHEDULING HANDBOOK

DOC PALMER

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To Jesus and Nancy

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FOREWORD

We are witnessing a major change in maintenance. It is moving from an equipment repair service to a business process for increasing equipment reliability and ensuring plant capacity. Its practitioners are trading their reactive cost center mentality for a proactive equipment asset management philosophy.

As editor of a technical business magazine covering the maintenance and reliability field, I have had an opportunity to track maintenance during its move from craft to profession. I have had the pleasure of writing about its leaders, the people and organizations who are continually extending the benchmark for maintenance excellence. Many are well on their way to establishing themselves at a level where maintenance performance is measured not by simple efficiency, but by contributions to plant productivity and profitability.

One of my favorite jobs as an editor is the reporting of best practices to the maintenance community. I first met Doc Palmer during such an assignment—a magazine cover story on a plant maintenance improvement program. Since then, I have published some of his articles and heard his conference presentations, and found that he has a superb understanding of the practices leading to maintenance excellence.

One belief that the leading organizations hold in common is that maintenance is a business process and that formal planning and scheduling is key to its success. Yet, there is a dearth of practical references on the subject. Most articles and conference papers on planning and scheduling stress its strategic importance, but they do not delve into the practical details because of limitations imposed by article length or conference programming. Doc has leaped over this hurdle with his *Maintenance Planning and Scheduling Handbook*. There is now a ready reference to take the action oriented maintenance practitioner to the level of understanding needed to install a planning and scheduling function and make it work.

The book positions planning in maintenance operations and then proceeds logically to introduce the principles of planning and scheduling and explain how to make planning work. Additional sections cover the nuances of planning preventive maintenance, predictive maintenance, and project work. The book concludes with helpful information on how to get started.

Maintenance Planning and Scheduling Handbook is a welcome addition to the body of knowledge of maintenance excellence and how to achieve it.

Robert C. Baldwin
 Editor, *Maintenance Technology Magazine*
 Barrington, IL

PREFACE

The *Maintenance Planning and Scheduling Handbook* shows how to improve dramatically the productivity of maintenance. For example, a group of 25 maintenance technicians should be performing the work of 39 persons when aided by a single maintenance planner. This book clearly and simply sets forth the vision, principles, and techniques of maintenance planning to allow achievement of this type of improvement in any maintenance program.

When I began writing articles and publishing papers describing the success we had achieved in maintenance through maintenance planning, I was not surprised by the requests for help I received. We had revamped our existing planning organization and the result was a total clearance of a large backlog of work that had some work orders in it as old as 2 years. The clearing took less than 3 months thus freeing up in-house labor and allowing a scheduled major overhaul to commence without costly contractor assistance. We had been through a learning journey in the course of our success. Before we got planning "working" we had to unlearn about as many false notions about planning as we had to learn principles to support what it really was. Most of the requests for help I received primarily centered on a need just to get a handle on exactly what maintenance planning was. Eventually McGraw-Hill asked that I write this book.

I believe that maintenance planning has remained an undeveloped area of tremendous leverage for maintenance productivity for several reasons. The planning function is positioned down in the maintenance group and does not command the plant manager's attention, so it is "beneath the plant manager." The techniques require an increased degree of organization, coordination, and accountability as well as a loss of some control (which some maintenance supervisors might not find appealing), so it is "unnecessary to the maintenance manager." Finally, the principles of planning are not technical in nature, so it is "uninteresting to the plant engineer." Nevertheless, a company seeking to be more competitive would do well to exploit such an area of leverage. A common saying states that for any endeavor, 1 hour of planning will save 3 hours of work. Maintenance planning saves more. After a work order system, planning is the biggest improvement one can make to a maintenance program.

This book considers "planning" as the preparatory work given to individual maintenance work orders before assigning them to specific craft persons for work execution. This preparatory work, when properly done, greatly increases maintenance productivity. There exist few actual books in print for maintenance planning and most do not actually address planning the way the *Maintenance Planning and Scheduling Handbook* does. Each of these other books is excellent, but they portray maintenance planning as overall maintenance strategy or preventive maintenance instead of as preparatory work before work order execution. For example, one book focuses on planning maintenance management rather than planning work orders. That book emphasizes having detailed work plans for routine preventive maintenance, but the actual planning described in detail primarily shows how to schedule outage time for working on the equipment. Another book defines and presents planning as preventive maintenance or other work decided upon well in advance of execution. In other words, there exist two types of maintenance, planned versus reactive, so by definition there is no planning of reactive work. In contrast, my book presents planned

versus unplanned and reactive versus proactive as two separate considerations. Planning of reactive work is essential. A third book also addresses overall maintenance management with little distinction on what type of work is being planned. It compares the accuracy of different types of planner job time estimates, but without much comment on how using them affects crew productivity. So the few books available define "planning" in varying manners. Overall maintenance management and preventive maintenance are not the maintenance planning to which the *Maintenance Planning and Scheduling Handbook* speaks. Even though these areas are important and my book touches on them in several ways, they are not "work order planning." Maintenance management is using the right tools and using them correctly. Preventive maintenance is a tool involving some of the right jobs to do. Work order planning is a tool to get the right jobs "ready to go." *The Maintenance Planning and Scheduling Handbook*, authored by an actual practitioner, fills the gap in the literature for work order planning.

This book is also important because even when considering work order planning, industry has a significant problem with the concept. Most maintenance organizations do not have a planning function and many that do are frustrated and not getting anywhere near the improvement they should. Just like learning the computer, planning has been made needlessly over-complicated. Thomas Sowell (1993) said, "If driving an automobile were taught the way using a computer is taught, driving lessons would begin with an elaborate study of the internal combustion engine, then move on to the physics of the transmission system and the chemistry of rubber tires before finally getting around to explaining how to put the key in the ignition and start the car." People have not seen a clear vision of the work order planning function. Until now, most of the literature that targets the work order planning concept has presented merely the responsibilities of planning without actually defining planning in a practical, bottom-line manner. Because that literature does not know the vision, it fails to translate the responsibilities into exactly what a planner does. The few previous attempts illustrate this lack of clear vision: their ideas about everything a planner should do lead to a job description impossibly full, even for Superman. The great truth is that the Pareto Principle is alive and well. 20% of what planners should be doing contributes to 80% of the impact of planning. In actual practice, organizations have crowded this most important 20% out altogether with another group of activities imposed upon the planners. Some companies even mistakenly think of planning as simply a software project. Imagine the computer industry reinforcing this problem where there is an explosion of software to manage maintenance without a clear understanding of what maintenance planning is. As a result, the many companies who have not implemented a planning function miss a great opportunity and the companies frustrated with planning need to back up and relearn what planning should be. Because of insufficient understanding, maintenance planning remains an undeveloped area of intense leverage for maintenance productivity in industry.

The *Maintenance Planning and Scheduling Handbook* clearly sets forth both the vision and the how-to specifics of maintenance planning. The handbook carefully explains what maintenance planning is all about and then nails down what is expected from a planner and why. It also shows how to measure the success. The handbook includes specific directions for planners. Readers can grasp the fundamentals of planning and make an impact in their organizations.

Typically, maintenance managers and plant engineers have called me with questions after I make a presentation or write an article. One maintenance manager called me saying he had 38 craft persons and was going to hire 13 more for a major mill expansion. My opinion was that he should hire no one new (savings of over \$500,000 per year) and transform two of his existing craft persons into planners. His resulting productivity would be as if he had hired 20 more persons. I have also received a significant number of queries from computer system personnel and planners themselves. My favorite was from the planner who called from across the nation just to say I was "right on target and to keep up the good work." The book is primarily intended for maintenance managers (including plant engi-

neers responsible for maintenance) and for plant managers. It is equally valuable for maintenance planners themselves, as well as for management information personnel working with a CMMS (Computerized Maintenance Management System). Contractors and consultants helping others will benefit as well as risk management professionals interested in the care of physical assets. Corporate executives, of course, would benefit in learning what a difference planning can make as they play a role in getting the interest of these other persons.

The maintenance manager really determines whether planning will be successful, although to support planning, the plant manager must know what improvement can be expected, what impact will be made on production personnel, and what the maintenance manager must do. The maintenance manager will use this book to understand and believe the vision and to apply the principles to obtain the dramatic improvement. This maintenance manager is usually one of two persons: one is the degreed person, typically with an engineering background, who has been placed in charge. The other is the craft person who worked up into this latest promotion. This latter manager is many times the only nondegreed manager on site. (A third possibility, especially internationally where the distinction between engineering and maintenance is blurred, is the craft person who earns a technical degree while working. The resulting maintenance manager or plant engineer has much hands-on experience.) All of these persons need the concepts of maintenance planning very clearly expressed so that they can easily grasp them, apply them, and communicate them to others.

Maintenance managers and plant managers are not the only ones who will appreciate this book. The actual planners themselves will benefit from better understanding their mission and duties. Planners are typically maintenance personnel directly from the crafts or craft supervision, but sometimes they are engineers or construction technologists. In addition, computer system administrators and management information persons will better understand planning and be more able to help maintenance with a computerized maintenance management system. Companies that do maintenance for others and consultants that help improve programs will also use this book to establish superior maintenance performance. Finally, there is the risk management professional. Those persons in industrial insurance companies are taking a more active role spreading good ideas and asking pertinent questions. They have a vested interest in clients adequately protecting their assets; that is what maintenance is all about.

The *Maintenance Planning and Scheduling Handbook* is valuable to any person who wants to pick up a few good maintenance ideas. Nevertheless, the book is a handbook in its completeness of coverage and all readers will be able to use it to make their maintenance program dramatically more effective and productive. The readers will finally understand the simple truths about maintenance planning. Managers will be able to implement a new planning group or decisively redirect an existing one. Planners and supervisors will use this book as a training and reference tool. Because formalized planning can help any organization with more than ten maintenance persons, the resulting maintenance program can be a competitive edge for the company for utilization of labor and equipment assets.

Just after this Preface, and the Acknowledgments, the Prologue narrates several typical scenarios of maintenance, some with and some without planning. These scenarios all have significant problems which many readers will recognize in their own organizations. See if you recognize your own organization. After the book develops the planning function, the Epilogue describes these accounts again, but as the events should have transpired, flourishing with a properly executed maintenance planning effort, a tool leading to superior maintenance.

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January 1999

When writing the work order he knew he had taken more than the estimated 1 hour, but was reluctant to claim it took 5 hours so he wrote down two on the work order. The timesheet was more problematic for the technician because it had to total to 8 hours for the entire day and he only had one job. The technician therefore used the only work order assigned to allocate time on the required daily timesheet. Payroll required a timesheet from each technician every day. Did the job cost the company 1, 5, 2, or 8 hours? The company certainly paid the technician for 8 hours, but the experienced planner had determined that the job warranted only a single hour. Did the low productivity cost any time? Did the supervisor's method of assigning only a single job at a time cost any time? Would a methodology of scheduling enough work to fill up a technician's day help reduce the cost of individual jobs? These are some of the considerations one must make when dealing with actual work hours. The job actually cost the company an hour. The maintenance process cost the company 7 hours. The timesheet is the desirable reporting device for hours because it accounts for all paid hours. Maintenance planning aims at remedying this problem. Management desires to have more hours on planned and scheduled jobs as a means to reduce this discrepancy.

Maintenance metrics are another tool of the maintenance manager. The use of the maintenance metrics dictates their value. Is the quality of management decisions proportionately increased? The maintenance manager should work with the person who would be doing the compilation when deciding what to measure and how. This is because there are so many judgments and interpretations involved with even some of the most apparent straightforward measures. Maintenance planning makes use of several metrics in particular dealing with work hours.

SUMMARY

Planning is only a tool, but planning is a key coordinating tool that assembles, integrates, and helps manage many of the other tools of maintenance. These other tools include a work order system; equipment data and history; leadership, management, communication, and teamwork; qualified personnel; shops, tool rooms, and tools; store-rooms; continual process improvements; and maintenance metrics. In addition, management considers essential reliability maintenance composed of preventive maintenance, predictive maintenance, and project maintenance. On one hand, next to a work order system, maintenance planning is one of the most valuable tools maintenance management has. Yet on the other hand, maintenance planning is useless without the other tools. Maintenance management seeking to maintain high plant reliability places due emphasis on all the various aspects of maintenance. Nearly all of these areas present opportunities for management to improve their contribution to maintenance success.

CHAPTER 2

PLANNING PRINCIPLES

This chapter recaps the vision and mission of planning and then presents the principles of effective planning. Each principle identifies an important crossroads. At each crossroads, the company has to make a decision regarding alternative ways to conduct planning. The decision the company makes regarding each situation determines the ultimate success of planning. Each principle presents the recommended solution to the crossroads.

Six principles greatly contribute to the overall success of planning. First, the company organizes planners into a separate department. Second, planners concentrate on future work. Third, planners base their files on the component level of systems. Fourth, planner expertise dictates job estimates. Fifth, planners recognize the skill of the crafts. And sixth, work sampling for direct work time provides the primary measure of planning effectiveness. Figure 2.1 shows the entire text of these principles.

THE PLANNING VISION; THE MISSION

As presented in the Introduction, the mission of planning revolves around making the right jobs "ready to go." Maintenance management uses planning as a tool to reduce unnecessary job delays through advance preparation. To prepare a job in advance, a planner develops a work plan after receiving a work request. The work plan is nothing more than the assembled information that the planner makes ready for the technician who will later execute the work. Some organizations call the work plan a *work package* or a *planned package*. At a minimum, the work plan includes a job scope, identification of craft skill required, and schedule time estimates. The planner may also include a procedure for accomplishing the task and identify any parts and special tools required. The scheduling information produces the most help for the maintenance effort because it facilitates allocation of the personnel resources each week. The parts information and tool information follow in helpfulness. With the proper planning or preparation for each job, this effort sets the stage to increase the productivity of the maintenance force.

The vision of planning is simply to increase labor productivity. The mission of planning is simply to prepare the jobs to increase labor productivity. As simple as this sounds, when management implements planning, it becomes apparent that the planning system abounds with many subtleties. The inability of many companies to recognize or deal with these subtleties prevents their planning organizations from yielding productivity improvements. The following principles guide planning through these particular difficulties to be effective.

PRINCIPLE 1: SEPARATE DEPARTMENT

Planning Principle 1 (Fig. 2.2) states

The planners are organized into a separate department from the craft maintenance crews to facilitate specializing in planning techniques as well as focusing on future work.

The first principle dictates that planners are not members of the craft crew for which they plan. Planners report to a different supervisor than that of the craft crew. The company places planners into a separate crew of their own. They have their own supervisor. With a small number of planners, the planners might report to the same manager who holds authority over the crew supervisors. There may be a lead planner with some responsibility to provide direction and ensure consistency within the planning group.

The problem with giving the crew supervisors authority over their respective planners is that the crew focuses almost exclusively on executing assigned work. The crew members execute work; the planners do not. The planners must be engaged in preparing work that has not yet begun. In actual practice, the crew supervisor receives too much pressure for the supervisor not to use the planner to assist work that has already begun. The crew supervisor must have repairs completed. It is tempting to reassign a planner to a toolbox and say, "The planner is a qualified welder who can come help us." Even in a plant with few reactive jobs, the supervisor should still have significant motivation to keep actively completing an assigned backlog of work to keep the plant out of a reactive maintenance mode. The supervisor has an obligation to complete the assigned work in an expeditious manner with a minimum of interruptions or delays. Once any job encounters delays, the supervisor feels pressure to minimize them. With direct access to the superior craft skills of a maintenance planner, the supervisor would always have significant motivation to take a planner away from planning duties. To the crew supervisor, the present is always more urgent than the future. The work in progress is always more important than the job not yet begun.

Management may contribute to this problem when planners report to crew supervisors. The pressure is especially intense if the maintenance manager has given a specific direction to the crew supervisor, such as "Put that pump back on line today!" How does the supervisor balance this instruction against the manager's admonition last year, "Try

◆ Principle 1

Separate Department

◆ Planners not on craft crews

◆ Planners not pulling wrenches

FIGURE 2.2 Separation reduces temptation.

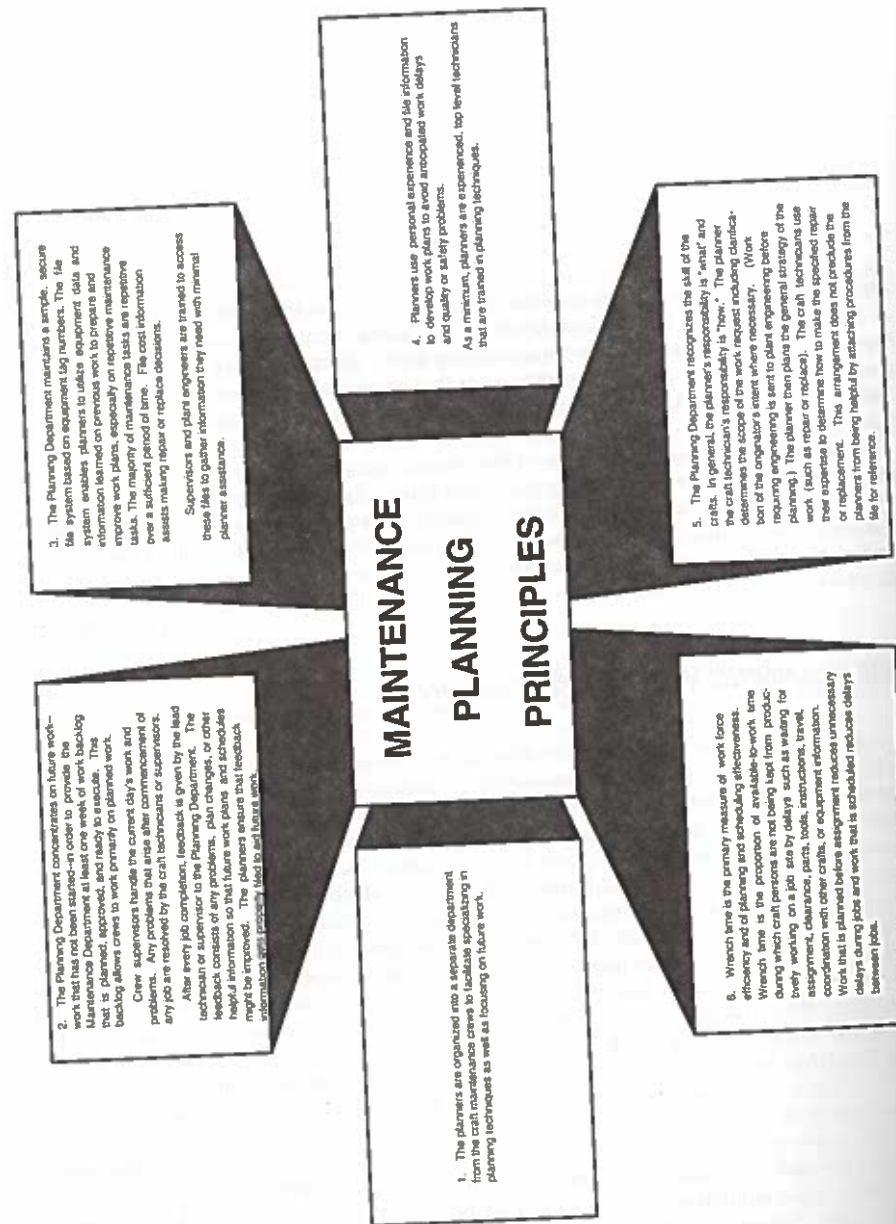


FIGURE 2.1 The six maintenance planning principles.

not to use the planner on field work unless necessary"? There will always be important work to complete today and the temptation to delay preparing for tomorrow's work.

Not only does the crew supervisor favor assigning craft work to the planner, the rest of the crew members as well place more relative importance on the work in progress than the paperwork of the planner. Such peer pressure encourages the planner to assist on jobs already begun or to take assignments directly for craft work willingly.

The natural inclination of the crew supervisor to place highest importance on assigned work, the unconscious pressure from management to encourage supervisors to give craft work to planners, and the peer pressure from fellow crew members all contribute to taking planners away from planning duties. In actual practice, planners on maintenance crews frequently work craft jobs and devote inadequate time to planning activities. As a result, crews have insufficient work to execute on a planned basis merely because planners do not have time to plan much work. This situation may also lead to another problem that manifests itself in an insidious fashion. Because planning contributes to scheduling, the lack of planning effort may decrease the number of work assignments to crews. The amount of work the company expects from each crew decreases. The work assigned becomes more reactive in nature because the plant executes less proactive work to head off problems. Gradually, the plant returns to a situation in which crews routinely repair equipment under urgent conditions and with little time remaining for maintenance to prevent equipment problems.

A self-fulfilling prophecy occurs for the manager who assigns planners to field crews. Supervisors frequently put planners on their tools to pull wrenches instead of plan. Planners plan less work. Less work is assigned. Work that is assigned is more reactive in nature, needing more on the job assistance. An apparent, but false, validation results showing that planners need to be on crews to help.

The problem is not managers, supervisors, or crew members with inadequate organizational discipline or inadequate understanding of the nature of planning. The problem is poor alignment of the company organization with the company vision. Simply removing the planners out from under the crew supervisors allows the planners to perform planning duties. The problem is not having persons who can resist the temptation to use a planner's craft skills. The problem is creating a situation where the temptation exists. The company avoids this situation by removing the planners from direct control of the maintenance crews. Then when the supervisor presumes it necessary to use a planner as a technician on an emergency job, the maintenance manager makes the call, not the supervisor.

If problems do arise where extra craft help is necessary, the supervisor has several options besides using a maintenance planner. The supervisor may assign more capable technicians to difficult jobs. The supervisor may decide overtime work is appropriate. The supervisor may decide to extend the job duration and not complete the job on schedule. The supervisor may decide to take advantage of an existing contract to provide contract labor assistance. The supervisor may decide to contract the job altogether. Perhaps the supervisor could increase productivity by personally supervising the work. The supervisor might request help from another crew. The labor contract might allow the supervisor to use another craft as a helper. For example, an electrician might be an adequate helper for a machinist on a particular task. Supervisors might also contribute their own hands to the execution of the work. Many options besides using the planner exist to expedite pressing field assignments.

Only after considering other avenues of help might the supervisor request using a planner as a technician through the maintenance manager who applied the job pressure in the first place. It is one thing for a manager to say "Fix that pump today!" and another thing for the maintenance manager consciously to redirect other resources to the task. Because a single planner helps leverage 30 technicians into 47, the planner in effect is

worth 17 persons. The planner is the last person the manager would want to pull away for a field assignment. Compare the cost of time and a half overtime paid to a mechanic versus 17 times straight time opportunity lost to the company for using a planner on a field assignment. Even triple overtime does not compare to the economic waste of using a planner for execution of work. Pulling a planner for a field assignment must be the absolute last resort for the manager who understands and believes in the leverage of planning. Making the manager involved in each case for such a decision helps prevent such reassignments.

The manager might expect the crew supervisor to complain that management took some of the best technicians from the work force to create the planner positions. The manager must understand that for each technician transformed into a planner, the work force receives the equivalent of 17 technicians in return. It is in everyone's best interest to make planning work. Time spent in explaining the leverage and benefit of planning to supervisors both at these times of questioning and at the outset of initiating planning is time well spent.

Another reason the company organizes planners into a separate group is to facilitate or help the planners become specialized in planning techniques. Planners need to work closely together to ensure proper execution and consistency of planning work itself. There are ample opportunities to conduct planning in different manners. Planners need the reinforcement of each other's help to plan jobs and follow the planning principles in a common fashion. Consider a school musical band with a trumpet section. The first and second trumpet parts follow the melody of the song exactly or very closely. However, the third trumpet part if played alone might not even be recognizable as the song being conducted. The third trumpet player greatly benefits when there are other third trumpet part players. This is especially helpful if the third trumpet player occasionally loses the place in the musical score. Listening to other third trumpets helps the player come back into place. Maintenance planning provides a similar situation. Preparing work to be accomplished in the future while the other technicians on crews scurry after jobs-in-progress is a new experience and is difficult to master alone.

Illustrations

The following illustrations demonstrate this principle of planning. The first section shows problems occurring as a result of not following the principle. The second section shows success through application of the principle.

Not This Way. Maintenance Manager Scott Smith walked over to the office of the mechanical crew supervisor. Each crew had its own planner who had a partitioned section of the supervisor's office with a desk and computer. Smith did not expect to see the planner necessarily because he knew that planners had to travel quite a bit to go to all the jobs for scoping. So it was not unexpected that the planner was not at the desk. The crew supervisor was not there either, which was appropriate, because Smith likewise expected supervisors to spend time in the field with their crews. However, on the way back to the front office, Smith happened to pass the fuel oil transfer pumps and saw the mechanical crew planner on a scaffolding assisting another mechanic hoist a valve into place. After questioning the planner, it appeared that the crew supervisor wanted to have the valve job completed today. He directed the planner to help the mechanic who was having trouble managing the bulky valve alone. Smith could understand that the planner was under the direction of the supervisor, but Smith had begun to notice an uncomfortable trend. At least half of the time when he saw a planner, the planner would be working on a crew. This probably contributed to the indicator Smith tracked showing

that the crews spent most labor hours on unplanned work. Last week Smith had even seen one of the planners working as a tool room attendant. The supervisor of the tool room had borrowed the planner from one of the crews because the tool room was suddenly short-handed that day. Smith was somewhat reluctant to counsel his supervisor because the supervisors took such great pride in managing their own work. However, in order for planning to work, obviously there had to be some planners doing planning. Smith decided to meet with his supervisors again regarding the matter.

This Way. Maintenance Manager Scott Smith walked over to the office area of the maintenance planners. Each planner had a partitioned office cubicle with a desk and computer. Smith did not expect to see all the planners necessarily because he knew that planners had to travel quite a bit to go to all the jobs for scoping. So it was not unexpected that only two of the four planners were at their desks. One of the planners present appeared to be attaching plan information to a work order and the other planner was going through a file to find equipment clearance information. On the way back to the front office, Smith happened to pass the fuel oil transfer pumps and saw two mechanics hoisting a valve into place. After questioning the mechanics, it appeared that the job plan was helping them expedite the job. The plan had given the valve weight so that the right straps could be checked out of the tool room before the job started. The plan had also advised the supervisor ahead of time that the job required two persons because of the valve's bulkiness. After talking to the mechanics, Smith started again back to his office. As he was crossing the pump yard he noticed one of the remaining planners carrying a clipboard with a stack of work order forms. This planner claimed to be in route from the power house where three jobs had been scoped and was heading toward the chemical waste treatment system to scope four more work orders. Smith was comfortable that the planners were engaged in planning activities as he wanted. Smith knew that the supervisors also knew the importance of completing the planning. This morning he had turned down a request for a crew supervisor to borrow a planner for a field assignment. After discussing the particular work order, Smith had advised that the crew supervisor would have to extend the schedule for its completion.

Managers need to place maintenance planners out from under the control of crew supervisors to prevent the planners from being assigned field work as technicians. The temptation to use planners as field technicians on current jobs is usually too strong to allow the planners time to do helpful planning for future work. A separation arrangement allows the planners to concentrate on planning future work.

PRINCIPLE 2: FOCUS ON FUTURE WORK

Planning Principle 2 states (Fig. 2.3)

The Planning Department concentrates on future work—work that has not been started—in order to provide the Maintenance Department at least one week of work backlog that is planned, approved, and ready to execute. This backlog allows crews to work primarily on planned work.

Crew supervisors handle the current day's work and problems. Any problems that arise after the commencement of any job are resolved by the craft technicians or supervisors.

After every job completion, feedback is given by the lead technician or supervisor to the Planning Department. The feedback consists of any problems, plan changes, or other helpful information so that future work plans and schedules might be improved. The planners ensure that feedback information gets properly filed to aid future work.

◆ Principle 2

Focus on Future Work

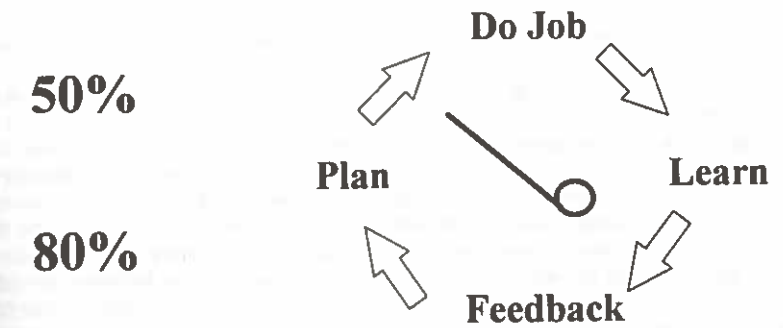


FIGURE 2.3 The snowball of improvement.

The reason the planners need to be separate is they need to focus on future work. Planners do not become involved in work that is already ongoing. A simple definition of future work is the crew has not yet been assigned to start on the work order. Once a crew has started working on a job and they find out they need more information, they do not come to the planner for assistance, but work it out themselves. Then after the crew successfully completes the current job, feedback to planning helps avoid similar problems in the future.

The problem with the planner having the duty to help technicians find file information for jobs already under way is that the planner soon has no time left to plan or gather job information to help future work. A vicious cycle is then in place. No jobs receive the benefit of advance planning because there is no time to refer to past feedback or otherwise anticipate problems ahead of time. The question at the crossroad is whether planners are really in the business of planning or are they in place to help technicians quickly find information to help resolve problems for work that has already started. The planners are most knowledgeable about the plant technical documents, and jobs that are under way need help fast when problems arise. Nevertheless, this use of planning is almost as short-sighted as using planners as field technicians.

Think of the circle in Fig. 2.3 as a repeated cycle of maintenance over the life of a piece of equipment. Maintenance does a job to maintain the equipment. During the course of the work the field technicians learn about the equipment or task. For example, they may learn that a certain pump bearing can only be removed from the inboard side because of an almost imperceptible taper in the design. The technicians learned this fact from trial and error and spent most of a morning doing it the wrong way. After the job the technicians give feedback on the work order form about the design and delay. Then the next time that particular pump needs maintenance, the planner can refer to the previous problems and the resolution because the planner filed the previous feedback. The planner reports this information as part of the job plan before the crew starts the task. As a result, previously encountered delays might be avoided on the subsequent maintenance operations. In the example of the tapered bearing, the second time the crew

replaces the bearing, they should not have to waste time trying to insert the bearing from the wrong side. The crew avoids an entire morning of wasted time. Each time the crew works on a particular piece of equipment, they might learn something new that could help future jobs.

This cycle of maintenance and planning concept carries some important implicit presumptions. The first and most important presumption is that a planner is available to review feedback from previous jobs and otherwise plan for new work. Another presumption is that feedback is not only obtained, but kept after each job. The final presumption is that equipment is worked on repetitively. These presumptions are not taken lightly.

The first presumption is that a planner is not only willing, but available to plan new work. As planning recognizes the need not to be on the tools (Principle 1), they are still frequently hindered from focusing on future work. As the planners leave their tools and arrive in the office to focus on future work, they meet a new challenge. The problem that arises is that if a planner is planning for 20 to 30 technicians, how many of those technicians are going to want some additional information? Probably at least two or three will do so. So these two or three technicians come to the planning office and ask the planner for help; after all, the technician regards the planner as the information finding expert. With this constant interruption, the planner does not have the time for the filing or work necessary to focus on future work. The planner helps with work-in-progress, not future work. Figure 2.4, Chasing Parts, illustrates what happens.

Figure 2.4 presents a variation of the common product life cycle that illustrates the planning effectiveness challenge. As management takes good technicians out of the work force (Principle 1) to be planners, the work force's effectiveness initially suffers. Then as the planners become proficient at finding file information (albeit on work-in-progress), there is overall improvement for the work force. However, the first curved line shows an upper limit to how much help this practice can deliver. The second curved line shows when planners turn away from constantly helping work-in-progress and focus on future work that maintenance effectiveness can improve further. Opportunity

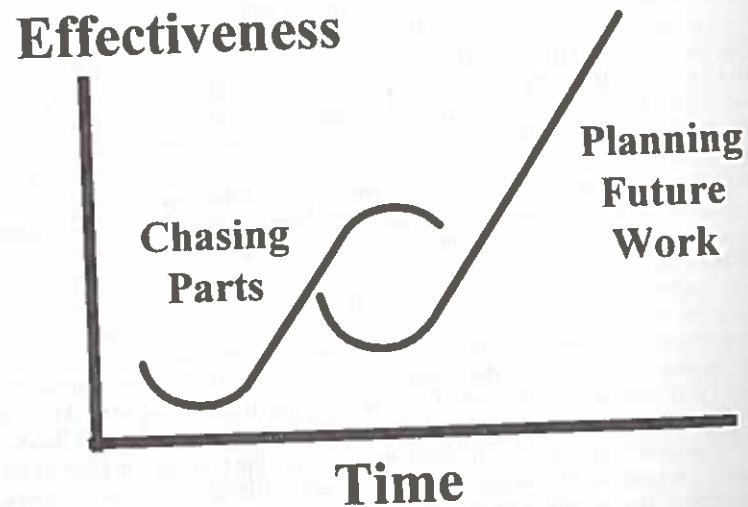


FIGURE 2.4 Chasing parts for today's jobs cannot help as much as focusing on future work in the long run.

for further improvement exists because when the planners only help work-in-progress, they are not helping the crews avoid previously encountered delays. Every job becomes a new job without any history advantage. No wonder so many techs need help with work-in-progress; they have no opportunity to avoid what has happened in the past. It is no wonder the planner cannot focus on future work. Every job in progress runs into problems creating another vicious cycle. The planners become known as "parts chasers" excitedly helping technicians find parts information or solve other problems on most jobs. Every job is urgent once it starts.

This is a very sensitive area for existing planning departments. Management may have started the planning department with the published intent of helping everyone with obtaining information at any time. A planner soon learns the impracticality of planning in advance for 20 persons while at the same time helping with work-in-progress. The best alternative at this point is to try to designate one of the planners for helping all jobs-in-progress to shield the other planners.

It is best to start out with the understanding that "planners will not replace the need for a tech (or supervisor) to find technical information." However, once a technician has found information the planner will save and reissue all job feedback on future work. This arrangement is also necessary for the crew supervisors to maintain their familiarity with the files and also encourages feedback from the technicians. Once technicians have to find technical information for a job, knowing that they will have to find the information again themselves the next time unless the planner can extract the data from the files, encourages feedback.

The future work concept is important. If a crew has already started working on something and they find out they need some more parts, they do not come to the planner to help find those parts. One would think the planner is the one most familiar with the files, parts, and the computer system. One would think the planner is the person to whom to turn. But that is counterproductive overall. Think back to before the company had planning; then the crew supervisors knew how to obtain parts. The crew supervisors knew how to find file information. That previous familiarity should be maintained. Management wants the "added value" of looking at future work. Therefore, after the job starts, the techs or crew supervisors must find any additional information just as they did before planning existed. That lets the planner focus on getting all the jobs planned. Principle 3 does not accept planning being a highly efficient department of persons to help crews look for parts once jobs start. The craftperson who changes the plan or has problems should write that information down after she finishes the job and give it back to planning for filing. The next time that piece of equipment needs work the planner will take the filed information and insert it for an improved job plan.

Management needs to monitor the time planners spend planning future work versus helping jobs-in-progress. If using a timesheet system, management may consider planners using a one time accounting number when planning and another number when providing technical assistance. A balance should be struck between the use of separate numbers legitimizing "chasing parts" and showing that "chasing parts" is not planning.

The second implicit presumption is that feedback will be received and used. Many companies almost hopelessly damage their planning effort with misconceptions regarding this point. These organizations start their planning groups with the expectations that field technicians would never have to look for information and that planners would always plan jobs from scratch. In other words, their concept is that each planner would pick through the technical manuals every time a job came up to support the planner's 20 to 30 technicians. The field technicians thereby never have to find information because the planner always has it ready. This approach fails for two reasons. The first is that a planner cannot keep up with the work load researching each job from scratch. This is why planning organizations have a difficult time in their first 6 months of existence. In effect, every job is being built from

square one before the files slowly become built up and useful. The second reason is that the most valuable information needed on plans is not available from equipment manuals. Information such as potential work permitting problems, the probability that certain parts will be needed, and corrected local inventory stocking numbers are learned from past jobs. A planner must be able to find the helpful feedback on those last three work orders from the last three years to help the crew avoid previous problems. For example, if the planner finds that the last time the crew worked on this job they did not have a certain part, the planner makes sure they have that part this time. Each and every job is on a learning curve. Looking to the files helps achieve that improvement opportunity. The correct concept is that the planner to a large degree is essentially a file clerk for their technician. The planner promises that if the technician reports any information, the planner will have that information available for next time. The field technicians must be willing to research and resolve problems as they come up on jobs in progress and report feedback to their file clerk. The technicians must not have the false impression that because certain information was unknown that the planner failed to adequately plan the job. On the other hand, the planner must understand the importance of saving and referring to this important feedback. The planner does not plan each job from scratch. By using feedback in the plant files, the planner not only has the opportunity of continuously improving job plans, but has time to plan all the work orders.

The last presumption concerns doing work repetitively. Working on equipment repetitively is a reality. One typically thinks of preventive maintenance as the only repetitive work in the plant. Yet the 50% rule says that if a piece of equipment requires work, there is a 50% chance it will require similar, if not the same, work on it again within a year's time. Moreover, the 80% rule says that there is an 80% chance the equipment will be worked on again within a 5-year period. These percentages are not for preventive maintenance. Why are these percentages so high? One reason is "infant mortality." After any work on any equipment, there exists an increased chance of additional maintenance soon being required. Problems from the initial job might include faulty materials or maintenance practices. The feedback from these jobs is especially important for the planner to scrutinize for opportunities to avoid repeated problems. Another reason is that some equipment simply requires more attention than others. Out of 10,000 different pieces of equipment, 300 might continuously need attention while the other 9000 or so never seem to need work. On the other hand, there is a common perception that "Nothing is ever the same" or "It is always something different." These statements reflect a perception that none of the equipment receives repetitive maintenance attention. This perception is false, but understandable. For one thing, the exact same technician might not be involved each time. For another thing, working on a piece of equipment only once or twice a year just does not seem to be very repetitive, especially if the exact same task is not involved. Nonetheless, one must move beyond the horizon of a crew thinking of one week at a time. The 30 plus years of a plant's life mean that the vast majority of maintenance tasks will be executed repetitively. And if the vast majority of jobs are repetitive, each presents the potential opportunity of contributing to increased labor productivity through heeding the lessons of the past. That means there is a tremendous opportunity to improve through avoiding past delays. There is a cycle and a snowball effect. As maintenance crews work jobs, they learn helpful information about delays. Then they give that information to planning as feedback at the end of a job. Planning references this information when the next job comes up for that equipment and the snowball picks up momentum as repeated jobs avoid past delays.

A final comment is appropriate regarding future work. Even without regarding the repetitive nature of maintenance work, there is a serious problem when the plant overfocuses on helping jobs-in-progress. When technicians run into a problem, there is generally a job delay while they resolve the matter. Unless these technicians can quickly move to

other work, there will be several technicians standing around wasting time even if the planner rapidly resolves the problem. It is undeniably much better to have the planner anticipate problems ahead of time and spend time resolving them while no one is waiting.

Illustrations

The following illustrations demonstrate this principle of planning. The first section shows problems occurring as a result of not following the principle. The second section shows success through application of the principle.

Not This Way. Sally Johnson was the planner for the mechanical work for Crew A's ten mechanics and ten welders. Since it was Monday, she planned to scope and compile plans for all the jobs that the weekend operating crews had reported. In addition, there were a number of jobs completed last week for which she needed to file the work orders. Before she could complete checking her email, however, two welders came into the office requesting her help to run pick tickets for them to receive a valve out of inventory. Soon after she provided this help, a mechanic called her on the radio for assistance obtaining bearing clearances for the forced draft fans. She knew this would be a problem and she spent the better part of the morning locating and talking to the manufacturer. By midafternoon, the interruptions had kept coming and Johnson still had not scoped the first job. At least she felt a sense of accomplishment that she kept important jobs going through her efforts.

This Way. Sally Johnson was the planner for the mechanical work for Crew A's ten mechanics and ten welders. Since it was Monday, she planned to scope and compile plans for all the jobs that the weekend operating crews had reported. In addition, there were a number of jobs completed last week for which she needed to file the work orders. After checking her email, she began filing. Then as she started to assemble information for the new jobs, she first made a field inspection, then again returned to the files. Good, she thought, here is a list of parts for the air compressor job. That will help the mechanics when they start that job. On about half the jobs, she found useful information from previous work orders. After compiling the information, she finished the required planning by about midafternoon. That left part of the day to talk to one of the plant engineers from whom she had asked some material selection advice. She felt a sense of accomplishment that she was part of a new service for maintenance that boosted productivity and ultimately company profits. She could feel that her efforts were part of a better process than the old "Just work harder" mind set.

As one can see, the repetitive nature of equipment maintenance provides great opportunity for planners to give technicians a head start in avoiding past problems. Technicians need to be mindful to resolve problems without planner assistance and provide feedback on circumstances encountered and information gained. Planners need to be heedful to their task of keeping and utilizing past work order information to improve jobs being planned. To make the cycle of job improvement work through avoiding past delays, planners must be allowed to focus on future work. Nevertheless, past delays can only be avoided if they are remembered, which leads to the next principle.

PRINCIPLE 3: COMPONENT LEVEL FILES

Planning Principle 3 (Fig. 2.5) states

The Planning Department maintains a simple, secure file system based on equipment tag numbers. The file system enables planners to utilize equipment data and information learned on previous work to prepare and improve work plans, especially on repetitive maintenance tasks. The majority of maintenance tasks are repetitive over a sufficient period of time. File cost information assists making repair or replace decisions.

Supervisors and plant engineers are trained to access these files to gather information they need with minimal planner assistance.

The concept of component level files or "minifiles" is a vital key for successful planning. Principle 3 dictates that planners do not file on a system level or basis, but on an individual component one. A minifile is a file made exclusively for an individual piece of equipment the first time it is maintained. The term minifile helps convey the understanding that the file does not keep information for multiple pieces of equipment together. Planners make new equipment a minifile when it is purchased. Planners label the file with the exact same component tag number attached to the equipment in the field. Planners consult the minifile for each new job to take advantage of the lessons and information gained on previous jobs. This principle takes advantage of the fact that equipment requires repetitive attention over the life of the plant. In particular, cost information available through the files helps planners and others make important decisions on replacing or modifying troublesome equipment. The files are arranged in a secure fashion to keep data from being taken away unadvisedly and lost, but are arranged simply enough for other plant personnel to be able to access their information. Engineers and supervisors directly use the files for obtaining information for projects or jobs-in-progress rather than interrupt the planners from planning future work.

The crossroads, so to speak, in this instance is whether to file information by systems or by individual equipment. A simple few files make it easy to put certain information in, but later difficult to find and take out that information. A complex, multiple file arrangement would require more time to find the right file in which to put the information. On the other hand, later it would be easier to find the information again. Starting from the extreme, the easiest arrangement into which to place information would be a single repository or file for the whole plant. Planners would have no trouble filing infor-

◆ Principle 3

Component Level Files

◆ Paper and Computer

◆ Work Order and Equipment

Databases

FIGURE 2.5 Filing so that information can be used.

mation because it all goes into one place together. However, later if a planner wanted information saved last year for the clarifier drain valve, it would be impractical to find it amidst the mass of other saved data. Moving to a slightly less simple arrangement, the plant could file information by building or plant area. A planner would file all the waste treatment information together and later might have a less difficult time finding the clarifier drain valve data. Continuing to how many plants do actually file data, a plant could file by equipment system such as the liquid waste system, the high pressure steam turbine system, and the polisher system. This makes the planner have to take a little more care filing the information to place it in the right place. Later the planner has a much easier time finding the information if needed. The next less simple filing system would be filing information by the equipment itself such as the clarifier drain valve. Obviously, the planner would have little trouble later retrieving information, but to begin with the planner would also have to exercise considerable care filing information. The extreme case would be to file information separately even by nearly every discrete subcomponent such as a valve body, a valve actuator, a pump, or a pump bearing. These arrangements become too complicated for filing or retrieving information. Alternately, the plant may file equipment information by manufacturer or vendor. Filing by manufacturer or vendor is common, but generally not favored because manufacturers and vendors change over time for particular pieces of equipment.

Consider a road or street address system in a town or city. Persons might take a multiple lane highway to arrive at the town. They turn off the highway onto a major road to go to the neighborhood. Then they look for particular side streets leading to the street of interest. Once at the specific address of the home of interest, they turn onto a specific narrow driveway. The seekers can locate all of the occupants of this home because they are at a specifically numbered address within the city. One cannot find any of the occupants of the home by simply arriving in the city. Planners likewise cannot find any of the work orders for a piece of equipment if the population of total work orders is significant at all.

Consider a doctor's office. Many physicians have a paper file system directly behind the receptionist. There is a separate paper file for each patient or, at most, family. The physician can easily determine the patient's medical history by looking at the filed information. A patient would also be uncomfortable if the physician did not think any past history was ever important. A patient would also be uncomfortable if the physician filed all history by single neighborhood files. Similarly, planners know that history is important for all equipment and there is not too much trouble in filing by equipment.

The conventional wisdom is threefold for filing. Do not file information that one knows will not be needed in the future. File in fat files what probably will not be needed in the future, but if needed must be found. File in skinny files what will be needed and used in the future.

Maintenance work orders decidedly fall into the last category considering that the majority of equipment maintenance is repetitive over the years.

It turns out that once management takes the planners off their tools (Principle 1) and actually ready to focus on future work (Principle 2), a new situation arises. The files where everything has been put for years are not useful unless information is filed by individual pieces of equipment. Say a planner is planning a job on the polisher cation regeneration valve. According to the 50% rule, there should be at least one or two previous work orders from the past couple of years that would help. The problem is that the plant used a single file to place *all* the work orders from the polishers; there must be 250 work orders. The planner does not have time to dig through them looking for the several cation regeneration valve ones if this situation is the norm encountered for every piece of equipment and job planned.

As planning is implemented, it soon becomes evident that it is not feasible to check individual equipment history and technical information if they are kept in system files.

System files have too much information to allow quick reference for individual equipment. Once the planner receives job feedback for future reference, it cannot go into a system file. A system might have 20 to 100 or more different components along with multiple work orders for each. When a file is that large, planners cannot practically find information on a single piece of equipment. Therefore planners use a component level file for each piece of equipment. When the planner receives a work order, the planner consults the specific file to find the previous work orders for that equipment. The filing mirrors the obvious work order arrangement. Normally, planners plan work orders for discrete pieces of equipment. It makes sense to file information in the same manner.

Consider a simple, paper file system. This file system is the equipment database complete with work order history for each piece of equipment. With a minifile, the first thing a planner does when a job comes in is go to the minifile, pull it out and find the previous work orders for the equipment. If the planner finds that the last time the crew worked this job they did not have a certain part, the planner makes sure they have that part this time. The job is on a learning curve.

As discussed in the previous principle, many persons think a crew never works on the same thing over again, that it is always something different. Yet in reality they work on the same things over and over again, just not every day. It might be 9 months to over a year before a crew works on it again and even then with a different technician. So persons just have a feeling that they are working on different things all the time. Notwithstanding popular opinion, if a planner can find those last three work orders over the last 3 years, the planner can help the crew avoid previous problems. Furthermore, if a planner can tabulate the previous cost, the planner can make better repair or replace decisions. For example, "The last two times we worked on that, it cost \$1000. I know I can buy a completely different valve for \$500 that probably will not need as much maintenance." Looking to the files helps the planner reach that improvement opportunity. In addition, since the majority of jobs have been worked on before, most of the jobs currently in the plant would benefit from a planner being able to review past information through an adequate file system. Filing information by the individual equipment allows that opportunity.

Experience has shown that after only 6 months of conscientious feedback and planning, most jobs in the plant receive a benefit from feedback learned on previous jobs.

The next issue concerns how the planners should physically arrange and number the files.

First, an intelligent numbering system of some sort is preferred. Many plants might have the equipment files labeled by the written names of the equipment. For example, one file might have Polisher Cation Regeneration Valve as its label. The plant may order these files within systems alphabetically or by process location. However, using the filing system becomes somewhat cumbersome as the quantity of equipment rises. For one thing, not everyone may refer to the equipment by the same name. On the other hand, a plant-wide coding system allows better file arrangement through intelligent numbering. For example, from the number N01-CP-005, one could tell that the equipment is a part of the Condensate Polisher system of North Unit #1. This number allows not only a unique, file reference number, but also the grouping of all polisher equipment together. This system is preferred although some thought will have to be spent on developing an appropriate numbering system. Some companies have already tagged their equipment with unique numbers just for the benefit of ensuring maintenance does their work on the correct machines. Planning should use these existing numbers as the basis for the filing system whenever possible. Appendices J and K give practical advice on setting up a numbering and tagging system.

Second, when using a numbering system, the company must make sure to follow through on one action. Not only must they label the files, but it is almost imperative that

they hang matching equipment tags on the field equipment. This simple step greatly assists the operators and other writers of work orders tie the equipment number to the work order. This tie helps the planner find the correct equipment files. Some filing programs have failed not because the filing system was somewhat complex, but because there were no corresponding equipment tags.

Third, the planners must set up the files so that the supervisors and plant engineers do not ask the planner to look in the files; they look in the files themselves. The planners intend for these persons still to work with files and information. For this reason, paper files should be open and easy to see with side labels on individual folders. Files that are enclosed within closing file cabinet drawers tend not to be inviting or as user friendly as possible. Large labels should clearly declare the contents of different shelf areas. For this same reason, planning should keep all the files in a common area, not within individual planner cubicles.

Fourth, if other persons have access to the files, management may have some concern for security. Generally, having the file area located so that persons must first pass through the planner area is acceptable. This arrangement strikes a balance between making the files accessible and making the files less prone to wander off by knowing who is there. Supervisors may want to designate that only certain individual technicians may access the files depending on the competence of the technicians in this regard.

The objective of this principle is to create a file system that delivers useful information to the planner and the rest of the plant personnel.

Illustrations

The following illustrations demonstrate this principle of planning. The first section shows problems occurring as a result of not following the principle. The second section shows success through application of the principle.

Not This Way. David needed to plan two jobs. One job required a simple filter change and the other required stopping a drip on the hypochlorite discharge piping. Both jobs were fairly routine. The filter was not on a PM route because varying operating modes caused the filter to plug at different intervals. The operators monitored the pressure differential and wrote a work order whenever the filter was beginning to show signs of clogging. David first skimmed through the thick system files behind his desk for past work orders, FC for Fuel Oil Service System and IR for Intake Chemical Treatment System. He was sure there were at least some for the filter. After several minutes he was able to find one for the filter, but not the piping. David copied down the filter and gasket inventory numbers off the previous work order plan. From his field inspection of the discharge piping, he determined that maintenance needed to cut away and replace the PVC piping. David included PVC piping inventory numbers and a statement to obtain PVC glue from the tool room in the job plan.

As David was finishing up the job plans, Supervisor Juan asked where the equipment information was for the hypochlorite pumps. David explained that all the information from past work orders was together in the system file and waited patiently as Juan shared his cubicle looking through the file.

This Way. David needed to plan two jobs. One job required a simple filter change and the other required stopping a drip on the hypochlorite discharge piping. Both jobs were fairly routine. The filter was not on a PM route because varying operating modes caused the filter to plug at different intervals. The operators monitored the pressure differential and wrote a work order whenever the filter was beginning to show signs of clogging.

The operators had written the equipment tag numbers on the work orders so David was able to walk over to the planner file area and immediately locate the two pertinent file folders, N02-FC-003 and N00-IR-008. (David could have found the specific folders even if the operators had not written the tag numbers on the work orders. The plant schematics, the computer drill down, or a field inspection could have shown him the specific number. He could also have simply looked in the file area under N02-FC for specific folders for fuel oil filters and under N00-IR for specific folders for chemical treatment piping.) As he had suspected there were several work orders for the filter and one for the piping.

David noticed that out of the three times the plant had changed the filter, two times the technician had reported having to redo the job because the assembly had leaked upon pressurization. David decided to change the work plan and include a reminder to tighten the strainer cover in a criss-cross pattern. David also included a step to request the operators to pressure test the line before the technicians packed up and left because of past trouble with the lid. David also copied down the filter and gasket inventory numbers off the previous work order plans. From his field inspection of the discharge piping, he determined that maintenance needed to cut away and replace the PVC piping. David included PVC piping inventory numbers and a statement to obtain PVC glue from the tool room in the job plan. David also noticed that the previous job in the file for this piping had recorded a job delay to wait on the operators to drain the pipe. Apparently the pipe was not self-draining as previously thought. David included a note in the plan for the supervisor to remind operations about the potential clearance problem.

As David was finishing up the job plans, Supervisor Juan asked where the equipment information was for the hypochlorite pumps. David pointed to the file area and explained that any information they had from past work orders was in the N00-IR section in several specific pump files. If Juan could not find what he wanted there, Juan might want to try the O&M manuals on another shelf area in the same room. David asked that if Juan found anything useful, to make David a copy and he would file it in an equipment specific minifile.

Caution on Computerization

A computer certainly gives more capability to the maintenance effort. For instance, a CMMS (Computerized Maintenance Management System) might allow accessing work order information away from the planning shop (by operators, engineers, and managers). It might allow sorting work orders (such as for specific types of outages). A computer might be able instantly to tabulate previous work order histories with costs and even eliminate a paper file system altogether. However, these benefits are not the specific leverage of planning. They are either additional points of leverage or acceleration of the manual planning operation. Planning itself is not the use of a computer. First one must learn to add, subtract, multiply, and divide before employing a calculator. The calculator simply helps the existing process.

Be cautious in thinking that having a computer system is itself planning. Planning multiplies a work force by 157%; it transforms 30 technicians into 47. Is management properly thinking that the computer system may help reach the top of this percentage increase or is management only thinking in terms of replacing two clerks currently entering work orders or typing PMs? Management needs a sense of perspective. Do not be unnecessarily eager to abandon a paper file system.

Figure 2.6 declares that computerizing a poor maintenance process will not help maintenance. This is especially true of the planning process.

When Using a Computer

1. If you do not know how to do something without a computer, doing it with a computer will not help.
2. Doing something wrong is faster with a computer.

FIGURE 2.6 First learn planning, then computerize.

As one can see, having unique numbers for equipment and then filing equipment work orders and information by those numbers make it possible for the planner to file and retrieve information as needed. Planners serve as file clerks to a large degree and need an accurate filing process.

PRINCIPLE 4: ESTIMATES BASED ON PLANNER EXPERTISE

Planning Principle 4 (Fig. 2.7) states

Planners use personal experience and file information to develop work plans to avoid anticipated work delays and quality or safety problems.

As a minimum, planners are experienced, top level technicians that are trained in planning techniques.

◆ Principle 4

Plans with Estimates Based on Planner Expertise

FIGURE 2.7 Estimates are easy for planners that are accomplished craftpersons.

Principle 4 dictates that the plant must choose from among its best craftpersons to be planners. These planners rely greatly upon their personal skill and experience in addition to file information to develop job plans.

The crossroads that this principle addresses is twofold. First, the plant has to decide what level of skill planning requires. The choices range from using relatively lower paid clerical skill all the way up to higher paid engineering skill. Second, the plant must decide the appropriate method of estimating job time requirements. A wide range of choices also exists for this issue.

It would seem that with the feedback and file system in place, clerks might be utilized as planners. However, as a minimum, planners need to be top level, skilled technicians so that they can best scope a job or inspect the information in a file for its applicability to the current job being planned. One issue at stake is in whether to have (hopefully) good execution on an excellent job scope or have excellent execution of perhaps the wrong job scope. Identifying the correct job scope is of primary importance. One of the best persons to scope a job is the skilled craftperson who has successfully worked the job or ones similar many times in the past. Even if the planner has not worked the particular task, a skilled craftperson can research or make an intelligent estimate for what the task might require. A second issue involves the files. Planners cannot simply be clerks or librarians in this regard, either. Again as a minimum they need to be skilled craftpersons so that when they review information in a file, they can gather all possible help for the current job. They can look and see if a part used on a previous job was a "one in a million" type of part or whether it really needs to be a part used on most future jobs.

Companies have considered apprentices for planner positions. These appointments run into two problems. First, an apprentice rarely has the experience to scope jobs properly simply from a lack of experience. An apprentice has also not had the opportunity to develop a top level of skill. The second problem is that experienced craftpersons receiving a job plan from an apprentice tend to cast doubt not only about the job plan, but management's support of planning as well.

A newly promoted technician rising from the apprentice class has essentially the same weaknesses in the planner position as an apprentice. There is more possibility that an experienced technician may make a good planner, but consider that the planner will be dictating certain job requirements to all of the field technicians. If an existing technician is not a star performer, the technician may not have the skill desired to be scoping all the plant work. The rest of the technicians also have some reason to doubt the specifics of any job plan based upon their perception of the talent of the planner as a technician.

Companies have also used engineers and technologists as planners. However, they typically do not possess the skill to plan most maintenance jobs. Most maintenance jobs consist of routine valve replacements, filter changes, or equipment adjustments that the technical experience of the engineer or technologist does not encompass. Each of these seemingly simple tasks is laden with potential job problems and delays beyond their experience. On the other hand, even if these personnel have actually risen through the ranks of the maintenance force while earning their degrees, they are not cost effective to utilize as planners for routine maintenance. Routine maintenance offers the highest potential for planner contribution to company success because more intricate or unusual maintenance tasks normally already receive help from plant engineering.

Supervisors make excellent choices for maintenance planners because they were typically experienced, top level technicians before promotion. Because planners also must have a high degree of self-initiative, they possess another of the qualities mandatory for supervisors, but possibly lacking in some technicians. Existing company guidelines for selecting supervisors frequently are satisfactory for selecting the best planners. Because

companies realize that they must attract the best technicians to make planning work, many companies pay planners at or above the first-line supervisor level. A recent survey indicates this is the case for over half of the electric utilities with maintenance planning. A company might want to consider moving an existing supervisor into a planner role or providing an additional promotion opportunity for its existing technicians. Making the planner position a step toward supervisor may also increase support in maintenance for planning. Another argument for paying planners at the level of supervisors is that the planners deal with the crew supervisors, not the technicians, at a peer level.

Companies not accepting that planners should be supervisor level might have one or two other considerations in mind. The company might feel that responsibility over personnel is more difficult than responsibility over a process. This thought has some merit, but consider that companies typically pay engineers higher than crew supervisors because of market demand. The market might also attract away some of the companies' best technicians if there is not ample room for growth. Paying planners as supervisors offers one solution to keep company strength in technical talent. Another consideration might be that the company does not support planning all the way. The company is keeping open an option to revert the planners back into the work force if planning does not work. The company might also be leaving an avenue to replace one or two planners that do not do well. The company so inclined must be very careful that it is not holding back the support a planning organization must have to succeed. The company might also have a weakness in not being able to remove unqualified supervisors. If the company's strategy does not select the best planners, the company does not follow this principle at the peril of planning.

Appendix M, Setting up a Planning Group, gives more guidance on selecting maintenance planners.

Another issue is the development of time estimates. The opinion of the skilled technician-planner is preferred over strict file information, pigeon holing, or other buildup time estimates.

File information yields historical data about past jobs, but can only offer general guidelines for current estimates. For example, the same job to clean an oil burner gun showed the following actual time requirements. One time the job took one person 20 hours. The next time the job took two persons 4 hours each. The last time took two persons 6 hours each. A planner might be tempted to average the times and plan for two persons at about 7 hours each. However, it is difficult to understand why the past jobs were so different especially if feedback was minimal as in these cases. The longest job might have had an inexperienced technician assigned or the person assigned was given no other jobs or schedule pressure. In the latter case, the person may have simply taken all of two 10-hour days to complete the work. If this was the case the planner might be more inclined to average only the two shorter jobs and plan for two persons at 5 hours each. Alternately why might not the planner insist that the target should be two persons at 4 hours each since that rate had been achieved once? On the other hand, what if the technician feels that from personal experience that, if done properly, the job should take two persons an entire day, 10 hours each?

Perhaps the planner could use the historical time estimates to create job standards for certain repeated tasks. The problem with this approach is first that historical time estimates might not reflect the appropriate time to do the job right. Second, other than for routine PMs, the day-to-day maintenance tasks are typically not repeated often enough or with enough similarity for studied measurements. In addition, management might be reluctant to press for early PM completion where one of the objectives of PM is to take care of all necessary minor adjustments.

Pigeon-holing offers another option for estimating jobs. Pigeon-holing involves estimating a job's time requirements by referring to a table or index of similar jobs and

making adjustments for particular job differences. For example, if the job at hand is to rebuild a 25-GPM pump, the planner might refer to a table for pump work. The planner finds a suitable chart showing overhauls for 20-, 50-, 100-, and 200-GPM pumps. The planner figures that a rebuild is probably about the same as an overhaul and adds a little time to the estimate offered for the 20-GPM pump. The problem with this effort is the time consumed finding and using the correct tables even if they are available.

There are industrial engineering estimates available for minute portions of tasks that are generic to many jobs the planner is planning. Times for taking off individual bolts of various sizes, walking certain distances, and particular hand or body motions are given. The planner could build up a time estimate for different maintenance operations using these standards. It is doubtful that the estimates these buildup estimates would yield would be worth the planner's time in creating them.

In certain industries such as maintenance of automobiles, auto shops have available books of standards for almost any maintenance task regarding almost any car. The great numbers of identical cars make these books possible.

The jobs in many industrial plants do not yield themselves as well to such universal standards. These plants use a variety of equipment in a host of different applications. The plants also have unique spatial or geographic layouts and unique maintenance facilities and personnel skills.

The objective in planning is to help boost labor productivity, not create perfect time estimates or meet standards. On the bottom line, maintenance supervisors need estimates to help schedule and control work assignments. In practical application, the estimates that a qualified planner can make based on personal experience supplemented by file information are entirely adequate. The planners' estimates are therefore considered the plant's standards for jobs even though they are not "engineered standards."

This need for an easily determined time estimate that the field technicians will respect is one of the reasons a planner must possess the skills of a top level technician.

Two issues arise after accepting how the planner determines the job estimate. Should the planner plan for a certain skill level and should the planner allow time for delays? The resolution to both of these concerns is that the planner estimates how long the job should take a good technician without *unanticipated* delays.

These concerns are discussed briefly here and more thoroughly in the Chap. 5 section on estimating work hours and job duration. First, the planner wants to set a standard for performance through the estimate. The planner does not want to set an ambitious target or goal. The planner wants the standard to be met, but at the same time provide for proper maintenance execution of the work. The planner does this by deciding that every job will be done by a good technician. This methodology encourages most technicians on most jobs although it requires the supervisor to shore up weaker technicians on certain jobs. Second, the planner does not allow extra time for delays that the planner does not expect. This keeps the estimate accurate when the technicians encounter no delays, and provides the supervisor a reference time for controlling the work when unexpected delays do occur. The supervisor can judge the appropriateness of the performance taking into account the specific delays dealt with and the time estimated for the job without those delays. Setting time estimates for jobs not to include extra time for unanticipated delays also sets forth the expectation that maintenance should proceed as expeditiously as possible under normal conditions.

Another issue regarding the expertise of the planner involves skills outside the normal experience of the planner. Some jobs require crafts outside the background of the planner. An example might be a requirement of electrical work on a mostly mechanical job. The mechanical planner has several options. The planner might ask an electrical planner for input. If there is no established planner for electrical work, the planner might also consult an electrical technician or leave it up to the electrical craft supervisor to

coordinate the electrical input at the time of work assignment. The planner might also be able to provide basic file information from previous jobs that might be helpful to the electricians. A mechanical planner might even have difficulty planning certain mechanical tasks. Many pieces of equipment have become so specialized that not all technicians within the same craft might be familiar with them. In these cases the planner simply consults with the specialists who have knowledge. The planner attempts to provide useful information regarding scope, schedule, and file data even on these jobs to help the later scheduling and execution efforts. In certain plants planners may become specialists in planning different work and do not attempt to plan all the jobs. Jobs requiring the expertise of another planner are referred appropriately.

Two final issues regarding planner training include maintaining a planner's craft skills and developing skills in specialized planning techniques. First, experience has shown that a planner retains practical knowledge of craft skills even when not applying them in the field. This is because of the close association to the actual maintenance through the planning duties. These planning duties allow the planner continually to develop strategies for jobs and review feedback from actual execution. The planner also spends significant time in the field talking to technicians and supervisors. Second, there are formal courses available for training planners in planning techniques, but on-the-job training provides the most effective training of planners. An experienced planner guides the new planner through the processes. The first planning principle to keep the planners in a separate group together facilitates this learning.

Illustrations

The following illustrations demonstrate this principle of planning. The first section shows problems occurring as a result of not following the principle. The second section shows success through application of the principle.

Not This Way. The planner sat down to estimate ten jobs. Lynn was by classification an apprentice who had completed all of the requirements necessary for promotion to technician and was waiting for a technician job to become available. He had been one of the few persons interested in the job as planner when it became available. The first job was a pump alignment. He had been trained and done several alignments, but never on a pump of this size. He looked in the file and was able to find a previous alignment work order for this very pump. The previous work order had estimated 10 hours for the task and the actual field technician had reported taking 10 hours. Lynn therefore used 10 hours as the job estimate. The second job required rebuilding a fan and there was no previous information available. Fortunately, Lynn had personally been involved in two rebuilds of either this same fan or its redundant spare nearby in the same service. He felt very confident that the job should take two persons a total of two days. However, just in case something came up, Lynn put an extra half day into the estimate. Lynn continued to estimate times for the remainder of the jobs.

Later the mechanical supervisor who was about to assign several of the jobs looked at the pump alignment and fan rebuild work orders. Brittany had not had a chance to see the jobs in the field and was inclined to accept the estimate of the planner who had. Still she wondered why the alignment procedure should take so long.

The technician received the pump alignment work order and knew right away that the alignment would only take 4 or 5 hours. Dana decided she would spend the morning setting up for the job and complete it in the afternoon. That would ensure a quality job. After completing the alignment, she reported to her supervisor an hour before the shift ended. The job had only taken 9 hours instead of the estimated 10.

Meanwhile, Scott and Fred had received the fan rebuild assignment. Surprisingly, the total job lasted exactly two and one half days as estimated even though there had been several unexpected delays. Fred had been temporarily reassigned for several hours at one point. One bearing had also been damaged beyond repair and a new one had been obtained from inventory.

Several days later Lynn received the completed work orders for both jobs for filing. The alignment had only taken 9 hours Lynn observed and the fan rebuild had apparently gone off exactly as planned since no unusual feedback was reported.

This Way. The planner sat down to estimate ten jobs. Lynn had been a certified mechanic with over 15 years of experience. He had competed for the job of planner when it became available since it was a promotion. Lynn had been able to pass the test and interviews successfully. The first job was a pump alignment. He had aligned most of the pumps in the plant in his 15 years including this one. He looked in the file and was able to find a previous alignment work order for this very pump. The previous work order had estimated 10 hours for the task and the actual field technician had reported taking 10 hours. There did not seem to be any unusual reasons the alignment had taken so long for the last person. Lynn thought that most good mechanics ought to be able to align the pump in about 5 hours. Lynn used 5 hours for the estimate. The second job required rebuilding a fan and there was no previous information available. Fortunately, Lynn had personally been involved in two rebuilds of either this same fan or its redundant spare nearby in the same service. He felt very confident that the job should take two persons a total of two days. Lynn used that for the estimate. Lynn continued to estimate times for the remainder of the jobs.

Later the mechanical supervisor who later was about to assign several of the jobs looked at the pump alignment and fan rebuild work orders. Brittany had not had a chance to see the jobs in the field and was inclined to accept the estimate of the planner who had. She had confidence in Lynn's ability to estimate the jobs.

The technician received the pump alignment work order and knew right away that the alignment would take 4 or 5 hours. Dana spent the morning setting up and aligning the pump. No unusual delays came up and she reported to her supervisor an hour after lunch. The job had taken 6 hours instead of the estimated 5.

Meanwhile, Scott and Fred had received the fan rebuild assignment. The total job had run over about a half day because there had been several unexpected delays. Fred had been temporarily reassigned for several hours at one point. One bearing had also been damaged beyond repair and a new one had been obtained from inventory. Scott, the lead technician, carefully explained the delays on the work order after the job was completed.

Several days later Lynn received the completed work orders for both jobs for filing. The alignment had taken an extra hour Lynn observed and the fan rebuild had run into problems according to the feedback. An extra hour shorter or longer was not unusual nor was a problem for most jobs since estimating was not an exact science. The bearing damage was a concern, however, and Lynn knew that it would be advisable either to have the bearing inventory number available or stage the bearing the next time the crew rebuilt the fan.

The experience of the planners makes a big difference in the success of planning. Planners must have the skills of a top level technician to create timely, useful estimates necessary for increasing labor productivity.

This discussion has concentrated chiefly on the general scope and time estimates of the job plans. The following principle addresses the specific content of the job plans regarding maintenance procedures and specific details. Although top level technicians should be utilized for planners, there is still a great reliance on the craft skills. The uti-

lization of superior skilled planners does not mean that unskilled technicians are acceptable in the work force.

PRINCIPLE 5: RECOGNIZE THE SKILL OF THE CRAFTS

Planning Principle 5 (Fig. 2.8) states

The Planning Department recognizes the skill of the crafts. In general, the planner's responsibility is "what" and the craft technician's responsibility is "how." The planner determines the scope of the work request including clarification of the originator's intent where necessary. (Work requiring engineering is sent to plant engineering before planning.) The planner then plans the general strategy of the work (such as repair or replace). The craft technicians use their expertise to determine how to make the specified repair or replacement. This arrangement does not preclude the planners from being helpful by attaching procedures from the file for reference.

This principle dictates that planners count on the work force being sufficiently skilled so that the planners can get all the work planned through putting a minimum level of detail into job plans. Strict adherence to the job plan is not required of technicians as long as feedback is received at job completion.

The crossroads encountered regarding this principle is primarily a choice between producing highly detailed job plans for minimally skilled crafts or producing less detailed job plans for highly trained crafts. An associated issue involves whether all the work should be planned or are there only certain jobs that would benefit from planning.

◆ Principle 5 Plans Recognize the Skill of the Crafts

◆ What, Why - Not How

◆ Some Standard Plans

◆ Some Engineering?

◆ Coordination of Engineering

FIGURE 2.8 The planning department's guidelines on level of detail.

Another issue is whether strict adherence to a job plan by the technicians is required. The resolution of these questions regards considering the company's desire for productivity and quality.

Planning promotes productivity by examining work for potential delays and scheduling work. Planning and scheduling more work increases labor productivity. Nearly all work has potential for delays and benefits from learning from past history, and so most work merits planning attention. The plant has better control over work that is scheduled, and so most work merits some schedule control. The objective of the plant is to complete work. To assist the plant in completing work, planners need to plan most of the plant's work. First, planners have to be careful not to put so much detail in a plan that they cannot get around to planning all the work. A general strategy for 100% of the work hours is preferable to developing a detailed plan for only 20% of the work hours. How much detail should planners put into plans? If there is a procedure already in the file or the persons who worked on the equipment previously wrote down some things that are important, the planner will include those items in the work package. If no file information exists, planners do not spend a lot of time developing a procedure. The planners must respect that the craftpersons know how to work on something. The planner is in a sense developing a "performance spec." That is, the plan describes the intent of what needs to be done, not necessarily how best to accomplish it.

In addition, there are frequently different ways to do the same job, and the plant generally wants the technician to do the job in the way in which the technician is most familiar. Classical industrial engineering seems to hold another view, namely that there is one best way to perform each job. However, engineered standards help productivity for jobs that are repeated twice per day, not twice per year or less. In other words, planning seeks more to avoid past delays and provide scope and scheduling assistance than to minutely examine each welder's technique on any individual job. In addition, individuals generally have perfected their individual methods of accomplishing routine tasks. Requiring a technician to perform a particular task in a way less familiar, though not necessarily superior, may lead to lower quality simply from unfamiliarity. It is the supervisor's job to help promote good work practices, not the planner's job to dictate consistency among equally valid work practices.

In addition, continual iterations back through planning to approve every modification to the plan is a deterrent to productivity. It is also unfair to both groups to consider that the planner who has not taken the time to disassemble a device to have perfect knowledge. Vital information might only be practical for the field tech to discover and handle.

On the other hand, there may be a procedure already in the file or persons who worked on the equipment previously recorded information that was important. The planner would include those filed items in the planned package. In addition certain tasks such as a large pump overhaul may benefit from the planner having a "standard plan." This plan would describe steps and procedures unique to certain equipment and not likely to be subject to individual preference.

Planning concentrates on adding value. Before there was a planning function in existence, the technicians had to decide how to accomplish the work requests. Planning does not take over this function, but rather adds a new function of value. The planners give the tech a head start from scoping the field situation and reviewing the history file review, and planners give the supervisor information for scheduling control.

Therefore the planners must count on the skill of the crafts. Supervisors must shore up technicians with deficient skills rather than have the planners planning jobs for a lower skill level.

Even when including a minimum of detail, the planner must be cognizant to include certain information. First, a planner should include information as to why the planner

chose a certain job strategy, especially when the file history helped make the decision. For example, "This valve is being replaced since patching it in the past has not worked well" (the planner knows the file history). The technician needs this information to avoid making unwise field decisions. A planner at one company reviewed the history file and recommended a valve be replaced because of past unsuccessful repair attempts. The planner did not mention the history leading to the replacement decision on the job plan. Consequently, when the technician finished the job, he returned the completed work order with the following feedback, "I saved the company money by repairing the valve instead of replacing it." Second, the planner should include known legal or regulatory requirements if adherence to a particular procedure is necessary and not commonly known by technicians.

The company is also interested in quality of maintenance. Responsibility and satisfaction through ownership contribute to quality. There are different schools of thought for ownership of work orders.

One school believes that technicians must execute the job precisely as planned for two reasons. One reason is that the planner had access to the necessary information including specifications, history, and engineering to develop the proper job plan. Any deviations from the job plan must be approved by planning before execution, and recommended changes that appear during the job execution must also be immediately coordinated with planning for approval. A second reason is that restricting execution to the plan ensures reliable history records without having to count on accurate job feedback. One can recognize this school by work order forms or computer systems that have limited or no space for reporting job feedback. An example of an area where this may be appropriate would be an automobile repair shop. One would like to approve any work done to one's car before it is begun. This type of arrangement normally has a larger planning staff because of the iterations sometimes necessary before a job can commence. So in the first school where the planning department essentially owns all jobs throughout the work process, a more substantial planning investment is required and less emphasis is placed on technician competency for determining the job scope and procedure for execution. Better history records are thought to come from less dependency on field feedback.

On the other hand, this book follows another school of thought. While a methodology of strict adherence to job plans may be necessary for some industries (nuclear power comes to mind), it could be counterproductive. In the first place, planners do not possess the time to develop a detailed step-by-step procedure for every job. In addition, even if they did, field technicians may have an equally valid way to execute the job in which they are more comfortable. In the second place, technicians are skilled, knowledgeable, and empowered. This is the type of employee a company desires to develop if it has not already. The company expects the technician to know the proper method to execute most of the routine, day-to-day maintenance operations, which is the focus for improving productivity. If technicians have questions or problems, they can contact their supervisors or they themselves can access the equipment files. The best planning practice prefers that 30 technicians do a little hunting around rather than a single planner continuously helping jobs-in-progress or trying to plan for every conceivable contingency on every future job. The technician giving feedback helps the planner anticipate probable specific delays to avoid on repeated specific jobs. The first school of thought keeps ownership in the hands of the planners for control of the work. On the other hand, the second school of thought keeps moving ownership of the job to the current holder of the work order. This second school is the accepted model for this book. When the job is being planned, the planner owns and controls the work order. Later, after assignment, the field technician owns the work order and is responsible for it. When the job is being planned, the planner uses field scoping, file information, and per-

sonal experience to develop a good general job scope for the right job avoiding past or other anticipated delays. Planning has given the technician a head start. Scheduling has given the technician a time requirement. When the technicians receive the work order in the field, it is their job. They own it. The technician is part of a team in the process, however, and this process requires good feedback for file history to help future work. In the second school adopted by this book where the ownership actually passes to the field technicians, a leaner planning effort requires more competent and empowered field technicians. A higher reliance is made on receiving good feedback to make history records accurate and allow avoiding future job delays.

This arrangement could be a stumbling block for the planning group that feels they "own" all the jobs from start to finish and are responsible for making sure the crews execute the jobs properly. Explicit advice is necessary to these planners to reorient their thinking to the team concept.

Keep in mind that the skill of the technicians does not mean that anything will do. The principle requires that skilled technicians will know what standards to follow for their craft specialty. This may involve their being able to follow a provided technical manual correctly. A certified welder will know how to perform weld heat treatment. A skilled mechanic will be able to follow and perhaps improve upon a guide to rebuild a boiler feed pump. The planner may have to provide particular standards for particular jobs such as unusual safety precautions or machine tolerances. Warren Riggs and Harrington of Eastman Kodak (1995) correctly note that empowerment is in direct conflict to standards and that some jobs require standards.

After planning the job, the planner no longer owns the job. The planner gives the technician a head start on the job, but the technician now owns the job. After beginning the job, the technicians are free to accomplish the job scope as they see fit. They may have a closer intimacy with the job than the planner had time to develop. The technicians must give feedback on any job changes or delays encountered so that future plans can benefit.

Once planning accepts this principle, planned coverage can take a big leap as shown in Fig. 2.9. Planned coverage is the percentage of all work hours spent on planned jobs. 100% planned coverage would indicate that the company spends all labor hours on work

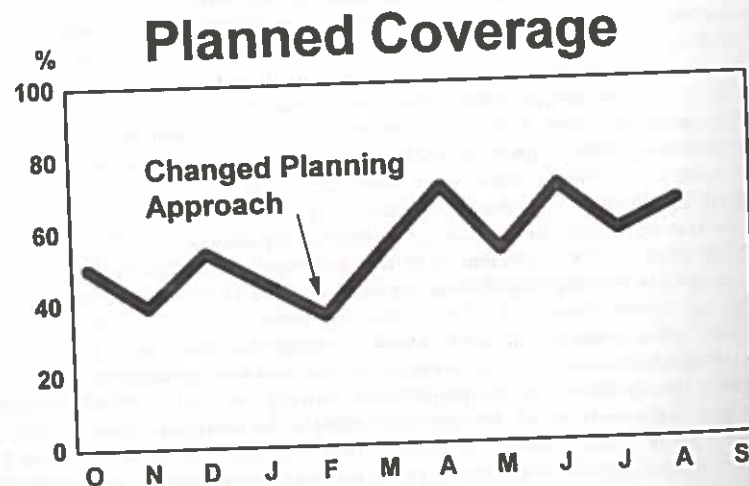


FIGURE 2.9 Putting less detail on plans.

assignments only on planned jobs. 50% planned coverage would indicate that the company spends half of the labor hours on planned work. This company was able to move from work crews spending only about 45% of their work hours on planned work to about 65% of the work. The company made the improvement simply by changing its approach to allow more dependency of the skill of the technicians. Planners were able to plan more work for the crews by spending less time specifying unnecessary details. Craft satisfaction with the work plans also increased as technicians felt more responsible for determining particular craft operations. Not only were planners planning more of the work, but they were no longer insulting the technicians.

Here is another sensitive area for an existing planning group that management billed as putting total information on every plan. The less skilled technicians may begin complaining when less details start to appear on job plans. Communication and management commitment to the program must focus here on the purpose of planning. One of the problems is that unless they are informed, technicians and supervisors may not understand how helpful a simple job plan is. A simple job plan may have a good job scope, craft identification, and time estimates along with a knowledge of previous job delays to avoid. The supervisor must accept the responsibility to assist weaker technicians on certain jobs.

The crew supervisor still has an option regarding work plans deemed unsatisfactory. The supervisors can return job plans to planning for additional detail or information as long as they have not yet assigned the work. Once the work has been assigned or has commenced, the crew owns it and should resolve problems and give appropriate feedback to improve future planning efforts.

Finally, engineering assistance merits some comment. Planners should plan work within their level of expertise. Planners should recognize, but not become bogged down with, design considerations beyond their expertise. The planner is responsible for coordinating work requested for plant engineering where appropriate. The planner still owns the job at this point and should request a quick turnaround of answers to routine questions. If the questions point to an extended effort on the part of engineering, the planner should take other steps. The planner should formally assign the work order to the engineering group or otherwise request that a project be initiated. A few plants have an engineer assigned under the planning supervisor to provide easy access to engineering support. This engineer would answer uncomplicated questions and coordinate questions requiring more extensive research or determination. Utilize caution when mixing a staff engineer into the production environment of the planning department. The planners must not become staff assistants to the engineer gathering file information. Planners must not become distracted from their planning chores.

Illustrations

The following illustrations demonstrate this principle of planning. The first section shows problems occurring as a result of not following the principle. The second section shows success through application of the principle.

Not This Way. Typically it seemed the crews worked only about one out of five jobs on a planned basis. This distressed Hosea, the supervisor of planning. The problem was not so much that the supervisors did not want the planned work, but that planning simply could not get to the jobs before the crew had run out of planned work. In these cases the crew naturally turned its attention to the unplanned work backlog. There were ample planners. There were five planners for only 100 technicians. The planners were busy as well. The planners continually worked to provide detailed procedures on every plan.

The problem with the crews working unplanned work was that they were simply not able to take advantage of parts lists or other information the planners had available from past work. Supervisors also had inadequate information to control schedules. That brought up another problem. With the planners being so busy, they were not filing all of the completed work orders. So even on planned jobs, the files were not as helpful as they might be.

There were also some indications that particular members of some of the crews thought planning was a "waste of time," in their words. Hosea had talked to one electrician who told him flat out that he did not need to be told how to run a conduit. This electrician had felt irritated at the thought that he had to be baby sat.

One of the planners had also expressed irritation recently, but not for the same reason. This planner was upset that the crew supervisor had not taken the plan's advice to rewind a motor in-house. Instead the supervisor had agreed with the technician to send the motor out to a local motor shop. The planner wanted to know why the supervisor did not understand that in-house work could provide better quality. The planner asked if Hosea would bring the matter to the plant manager to resolve.

This Way. Typically it seemed the crews worked about four out of five jobs on a planned basis. This was acceptable to Hosea, the supervisor of planning. The problem was not so much that the supervisors did not want the planned work, but that sometimes the supervisors directed technicians to unplanned work. The unplanned work was pressing and did not appear to require much planning. Hosea knew that after becoming more used to planning, they would want even more of their jobs reviewed by planners before starting them. There were ample planners. There were five planners for only 100 technicians. The planners were busy as well. The planners continually worked to provide adequate job scopes, time and craft estimates, file parts information, and other notes to help avoid previous job delays. The planners were able to provide planning for all the work orders that the supervisors had not immediately written up and started themselves.

The advantage of the crews working mostly planned work was that they were able to take advantage of parts lists or other information the planners had available from past work. Supervisors also had adequate information to control schedules. The planners were busy, but still filed all of the completed work orders. So to improve all of the planned jobs, the files were becoming ever much more helpful.

There were still a few technicians that did not understand how helpful the scoping and file information were to them or the scheduling information was to their supervisor. Some technicians thought that without a detailed, step-by-step procedure, planning was a waste of time, in their words. Hosea had talked to one electrician who told him he did not receive a diagram on how to run some field conduit. Hosea carefully explained to the technician that the planner had considered this to be a field decision. On the other hand, the planner had reserved 60 feet of conduit to avoid a parts delay, enough to satisfy any layout.

The planners had accepted their roles of giving the technicians a head start and the planner duty carefully to save any feedback on actual job performance. One of the planners had recently received feedback that a plan to rewind a motor in-house had been contracted. The planner made sure to record the contract motor shop's address and warranty information for the files. The planner also checked with the supervisor to see if future plans should consider such an option or if this was just a one-time event.

Planning provides the what, the technicians provide the how. This ensures that the company best leverages the skill of the technicians. The company wants the technicians to do what they were trained to do. At the same time, this allows the planners to ensure planning all the work so that every job can have the benefit of advance planning. This principle presumes the company invests in the acquisition and training to produce and

maintain a staff of skilled technicians. Planning gives skilled technicians a head start.

PRINCIPLE 6: MEASURE PERFORMANCE WITH WORK SAMPLING

Planning Principle 6 states

Wrench time is the primary measure of work force efficiency and of planning and scheduling effectiveness. Wrench time is the proportion of available-to-work time during which craft technicians are not being kept from productively working on a job site by delays such as waiting for assignment, clearance, parts, tools, instructions, travel, coordination with other crafts, or equipment information. Work that is planned before assignment reduces unnecessary delays during jobs and work that is scheduled reduces delays between jobs.

Principle 6 ordains that measuring how much time craft technicians actually spend on the job site versus other activities such as obtaining parts or tools determines the effectiveness of the maintenance planning program. This principle holds that delays are not simply part of a technician's job and should be avoided. Figure 2.10 shows an example of the distribution of technician time. Only category 1 is productive time on the job. All of the other categories identify delay time.

The mind of management must resolve two crossroads considerations. (1) Does management have a specific mission for planning to keep technicians on job sites or does

◆ Principle 6 Measure Planning Performance by Analysis of Delays with Work Sampling Distribution of Time

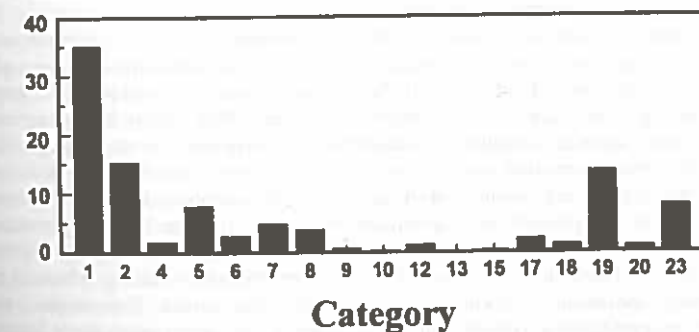


FIGURE 2.10 This company's time on the job is only 35%.

management have a more vague idea of planning somehow contributing to effectiveness? (2) Is working in a delay area such as obtaining parts or tools merely part of the job or is it a delay to be avoided? Does management's strategic vision involve moving technicians out of delay areas and onto job sites or does the vision only have technicians working hard to do everything necessary.

The purpose of planning is to help put everyone on their tools in front of a job instead of traveling, waiting for parts, or otherwise being delayed. The purpose of planning does not include making sure persons are productively working once they are in front of a job and not being delayed. The issue of productively working once on a job is important, but it is not centrally associated with planning (other than the planner setting an informal time standard through the estimate). Nevertheless, consider that whether or not time in front of a job is as productive as possible, simply increasing the proportion of time so spent by a work force should increase the number of jobs completed by maintenance. That improvement is the purpose of planning. Similarly, planning is not concerned with administrative time spent for activities such as training, meetings, or vacation. Planning concerns itself with the time technicians do have available to work under the control of their supervisors.

Work sampling (also known as wrench time) gives this measure of how much planning helps. The time the employees are at their job sites working is called direct or productive work. At issue is not so much the time the technician spends doing productive work. What is actually important is the analysis of the nonproductive time. For example, how much time is spent waiting for parts; how much time for tools; how much time for instruction? If the technician is obtaining a part, instruction, or tools, the job is actually not progressing. Separate studies done over time indicate if planning is becoming better or worse with regard to reducing these delays. Has the time waiting for parts gone down; has time waiting for tools gone down; has time waiting for instruction gone down? Interestingly, measuring the technicians tells about the planning function, not the technicians. The planning tool should have an effect on the technicians.

The interesting thing about this principle is that it does not make planning work per se, it only measures how well planning is working. A company could believe in planning and successfully implement planning according to the other planning principles without ever conducting a wrench time study. Similarly an automobile could function flawlessly without a speedometer. Nonetheless, measuring wrench time does tell directly if the objectives of planning are being met. The objectives of planning are to reduce delay times and put technicians on their tools. Measuring wrench time thus also gives an overall indication of how well the other principles have been implemented or accepted. The other principles must be in place for planning to succeed. Wrench time analysis is an indicator, not the control of planning or the work force. Chapter 10 deals exclusively with the control of planning.

While management might not use wrench time measurement to conduct or control planning, it might use it to demonstrate the need for planning. Maintenance planning effectively helps improve labor productivity exactly because there is such a great misunderstanding of the current level of direct work time. That is why analysts present the results of work sampling studies to management, supervisors, and technicians. The realization that delays consume over 70% of work force time and direct work is less than 30% generates extremely beneficial dialogue toward accepting the concept of planning and productivity improvement. An important issue is that everyone understands that while technicians are being paid by the hour to handle delays, the company is not receiving any benefit from such activities. The company benefits when productive maintenance keeps equipment in service to make a product for market. The company does not benefit from avoidable activities that consume over 70% of its work force labor hours. Such a discussion time is a marvelous opportunity to explain that delays are undesirable.

The technicians view the results of the initial wrench time studies as even more remarkable when they realize that during the course of the study, they had made a special effort to be productive. That means the observation effect of the study showed the results to be even more confirming that at best the productivity had been less than 30%.

Simply conducting a wrench time study to illustrate what planning is all about and why the company employs technicians (to work on equipment) could be worth more than the results of any study itself. The measuring of wrench time does not yield planning improvement, it only quantifies it. A properly structured planning system within a maintenance organization yields the improvement whether or not it is measured.

It is difficult to agree with industry claims that productive time could possibly be so low without the results of a valid study. One supervisor submitted a scenario showing how hard it would be for an employee to try to have such a low wrench time. This supervisor showed a theoretical technician through an average day. The tech first took 30 minutes to start going in the morning. During the course of the day the tech spent 45 minutes receiving instructions from the supervisors and 60 minutes waiting at either the tool room or storeroom. 45 minutes were consumed traveling. The tech took a total of 90 minutes in breaks and 30 extra minutes for lunch. The tech also took 90 minutes for showering and otherwise getting ready to go home at the end of the day. With all this wasted time, the tech had only 210 minutes left out of the 10-hour shift for work. This time arrangement netted the tech a 35% wrench time and 65% delay time. Incredible as it seems, the typical wrench time reported in industry ranges between 25% and 35%. While some employees at each plant are in more productive situations than others, studies show overall productivity measurements are in this range. A few minutes here and there add up to a productivity problem with significant delays.

Wrench time is accurately measured with a properly structured, statistical observation study. The study sets up statistical procedures to ensure proper observation techniques. Generally, a study conducts observations over several weeks or months to ensure a time period representative of the work force's normal activities. An observer has a list of maintenance employees at the plant each day of the study and has a methodology for selecting a sample of employees to locate each half hour or other time period. The first moment the observer locates a selected employee, the observer categorizes the activity as a type of work or delay. The observer does not merely follow an employee around to gain observations. The observer also does not locate jobs instead of persons because some persons may not be even assigned to work. At the end of the study, the study reports the proportions of observations in each category. Appendices G and H present actual work sampling studies conducted at an electric utility.

Other less formal methods of measuring wrench time have been explored. One method has been to have several individuals in the work force carry special scorecards. A clerk pages these individuals at specified random times during the day. When a person's pager goes off, that person records the appropriate category on the scorecard. The problems with this method are several. First, there is not a single person deciding the appropriate category to use. Second, there tends to be great reluctance on the part of any but the most productive employees to participate and carry a scorecard. Third, this method requires extreme integrity on everyone's part instead of on a single observer. Fourth, there is also extreme "observation effect" in that the person being measured is continually aware of the ongoing measurement. As might be expected, studies using this method have recorded average wrench times about 20 to 25% higher than what a normal study would show on the same work force. That means when the actual work force wrench time was probably about 35%, there would be reports of 55 to 60%. On the other hand, studies such as this can often be conducted with good humor and effectiveness, not to find out wrench time, but to help educate the work force of the importance of direct work versus delay activities.

Similarly, efforts to have entire crews where everyone keeps track of their daily time in the different categories have resulted in reported wrench time hardly ever below 80%. These studies with everyone participating even if just to raise awareness are probably not a good idea. They seem to degenerate into a "liars' club," damaging the integrity of everyone and everything, including the wrench time concept. It is about impossible for an individual to keep track of the minute-to-minute delays that impact one's work on a continual basis. This factor combined with the often disbelief that wrench time could be fairly low anyway leads everyone to guess high. Consider this point applicable to work order or time sheet systems that expect everyone accurately to quantify all their delays during a job or time period.

Nearly everyone has apprehensions that conducting a wrench time study could be taken by supervisors and technicians in a mean-spirited way. That does not have to be the case. Communicate the reasons before, during, and after the study. After the study report the results to everyone. It is difficult to imagine too many persons objecting to a program designed to boost productivity only to 55%. Also, after some studies work forces were able to demonstrate the need for new tool boxes, a better storeroom, and even go-carts. During the study consider using a familiar, agreeable person as the observer.

A further mention of administrative time is appropriate in the discussion of wrench time. The wrench time study observations do not include any employees not available for work. If employees are scheduled for training all day, those employees are not observed. This administrative time is time the company has decided to invest other than for immediate work. On the other hand, consider the implications about wrench time. Consider if employees are only available for work 80% of the time because of administrative time. A wrench time of only 35% is only a measure of the percentage of time available to work that the employee was directly working. The percentage of time paid that the employee was directly working was a mere 28% ($35\% \times 80\%$). Looking at the cost to the company another way, say that the technician is paid \$25 per hour. Because the employee is only working 28% of that time on the average, the company actually pays \$89 for work that the employee accomplishes. This is why contracted repair persons charge a seemingly high rate for time spent at the company's location. The work force needs to understand its own high cost to the company and join forces with management to raise productive time and lower the rate of company labor cost. While planning can help with the productive portion of available time, the company cannot take the impact of the other administrative time lightly. The company must balance among providing competitive company benefits, investing in training, and making technicians available to work.

Illustrations

The following illustrations demonstrate this principle of planning. The first section shows problems occurring as a result of not following the principle. The second section shows success through application of the principle.

Not This Way. Management could not understand why reliability continued its slow decline. From discussions with the planning department, nothing seemed to be out of the ordinary. The crew supervisors claimed to have their hands full, but were able to stay on top of things.

This Way. Management could not understand at first why reliability continued its slow decline. From discussions with the planning department, nothing seemed to be out

of the ordinary. The crew supervisors claimed to have their hands full, but were able to stay on top of things. However, from observing the general state of the work force, management suspected a lower than desirable productivity. Management had noticed lines at both the tool counters and storerooms. In addition, it appeared that breaks were somewhat excessive. Management decided that direct work time on the jobs needed to be improved and that meant there was a problem with the planning and scheduling process.

Planning has the responsibility to help move personnel onto jobs and out of delay situations. Even without making formal measurements, understanding this concept of wrench time as valuable time and delay time as waste leads to improvement. Properly conducted studies can quantify the direct work time, help educate the work force on the need for improvement, and demonstrate improvements. The wrench time is not so much a measure of the work force's performance, but that of the success of the leverage being employed by the planning process. Planning takes direct aim at reducing the causes of job delays.

SUMMARY

So far the planning effort has mainly focused on making individual jobs ready to go by identifying and planning around potential delays. Consideration of six basic principles greatly boosts the planning program efforts toward success. Each principle resolves a crossroads decision that affects the planning effort. At each crossroads, the company has to make a decision regarding alternate ways to conduct planning. The decision the company makes regarding each situation determines the ultimate success of planning. Each principle presents the recommended solution to the crossroads. While a plant must incorporate or consider all of the planning principles to be successful, ignoring a single one can often spell the ineffectiveness of the entire planning effort.

The principles are having planning in a separate department, focusing on future work, having component level files, using planner expertise to create estimates, recognizing the skill of the crafts, and measuring planning performance with work sampling for technician direct work time. Having planners separate from the control of crew supervisors avoids the temptation of using planners for field work instead of for planning. Planners also need to avoid continually being interrupted to resolve problems for jobs already under way. Planners need to focus on future work not yet begun. Because most jobs are repetitive, file history can help technicians avoid previous problems encountered. Only when planning keeps a separate file for each piece of equipment is it practical to retrieve information when needed. Planners must possess the experience of top level technicians in order to scope jobs, utilize files, and estimate times adequately. Engineered standards or other sophisticated time estimating techniques are unnecessary to accomplish the specific objectives of maintenance planning. At the same time, craft technicians must also demonstrate considerable skill during job execution. Planners count on technician skill and the planners focus on providing adequate job scopes rather than on providing an abundance of job procedure details. During actual job execution, technicians decide how best to accomplish job scopes and later give adequate feedback for planner files. Finally, wrench time measures whether the objectives of planning are being met, that of reducing job delays.

So utilizing planned work packages increases the maintenance department's ability to complete work orders effectively, efficiently, and safely. With maintenance planning based on the six planning principles, will the planning effort "work"?

Here is what one utility discovered. They had only a marginal planning program. The planning department consisted of apprentices tasked with developing very detailed job

plans on lower priority work orders. The crews worked very few of the planned jobs and primarily worked only on unplanned higher priority work as soon as operations wrote the work orders. With only this planning program under way, management commissioned a work sampling study. Wrench time was only 37% and an analysis of the delay areas indicated that the plant could do a better job with parts and tools. This was either symptomatic of tools and parts availability problems or planning problems, or both.

Considering this and other information, the company placed a renewed emphasis on planning. Management replaced the apprentices with technicians for planners. (However, there was no compensation program to make planner pay competitive. In fact, because the plant did not allow planners to work much overtime, the real pay of planners ended up lower than that for most field technicians.) The company also purchased separate hand tools for each craftsperson to reduce sharing problems. The company also virtually doubled the number of parts categories carried by the storeroom to reduce ordering needs. A follow-up work sampling study revealed that wrench time was still at only 37%.

Since analysis of the last wrench time study showed travel time was at 22%, management purchased bicycles and golf carts to help reduce travel time. At the same time, however, management overhauled the planning program and adopted the six planning principles. The company took the planners out from under the control of the crews. The company encouraged the technicians not to seek planner assistance for problems on jobs already started. The company adopted an equipment numbering system to begin creating specific equipment files and filing by system ceased. The company again replaced the planning personnel. This time management selected technicians who had all passed the supervisors test, but were yet not promoted due to a lack of positions. These new planners began to rely on the skill of the crafts and focused more on providing good job scopes and estimates rather than on providing detailed job plans. With these principles in place, certainly planning would succeed. The third wrench study revealed only a 35% wrench time. See Fig. 2.11. How surprising since analysis showed travel time had dropped to 15%.

Wrench Time

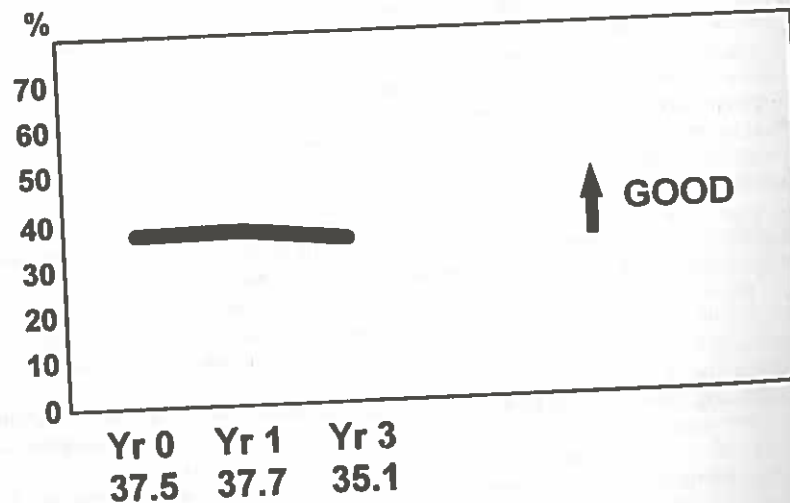


FIGURE 2.11 Different studies over time.

The analysis of this last study revealed a very interesting phenomenon. Large delay times did not exist for parts, tools, instructions, or travel categories. Those were the areas that planning on individual jobs might help to avoid. Large delay times did exist for excessive startup, break, lunch, and shutdown categories. Despite these delay times, to their credit, the technicians had consistently been able to complete all the work assigned them.

Even so, a review of the wrench time for each hour of the day indicated a scenario of how technicians completed their work. When receiving their work for the day, the technicians would scope out the jobs and begin work intermingled with social time and some parts gathering. Then after lunch an incredible burst of activity would see all the work completed where upon the technicians could ease up until the end of the day. Over the years, supervisors had apparently become accustomed to how much work the crews could execute during a day and continued to assign that amount of work every day. The only problem was that now with several systems in place to allow doing more work, supervisors needed to assign more work. Obviously, management needed to consider scheduling of planned work in the planning picture. Maintenance needed some methodology to ensure assigning enough work. This leads to the next chapter on scheduling principles.

CHAPTER 3

SCHEDULING PRINCIPLES

Effective scheduling is inherent in effective planning. This chapter explains the reason why routine maintenance needs scheduling and then presents the principles of effective scheduling. Together, these principles create a framework for successful scheduling of planned maintenance work. Each principle sets guidelines on how maintenance should handle a different portion of the scheduling process.

Just as for planning, six principles greatly contribute to the overall success of scheduling. First, planners plan jobs for the lowest required skill levels. Second, the entire plant must respect the importance of schedules and job priorities. Third, crew supervisors forecast available work hours one week ahead by the highest skills available. Fourth, the schedule assigns planned work for every forecasted work hour available. And sixth, schedule compliance joins wrench time to provide the measure of scheduling effectiveness. Figure 3.1 shows the entire text of these principles.

WHY MAINTENANCE DOES NOT ASSIGN ENOUGH WORK

Aids such as planning good job scopes and having parts identified and ready make it easier to complete maintenance jobs but do not ensure that more work will be done. Adopting all six planning principles from Chap. 2 does not ensure that more work will be done. The reason why is because these aids and principles make it easier to complete individual jobs. That is, each job assigned should be easier to complete than it would have been without such help. If a particular job that used to take about six hours now takes four hours, that does not mean more work was done. Why? The simple reason is that still only a single job was done. Figure 3.2 explains that productivity cannot increase if supervisors do not assign additional work.

Supervisors are typically responsible for assigning individual work orders to technicians, and there are a number of reasons why supervisors might usually assign an insufficient amount of work. In concert, these factors perpetuate a powerful culture to maintain the status quo. This is not a problem of the personalities of the supervisors. It is a system problem encouraged by how plant management has arranged the processes of maintenance.

First, crew supervisors develop a feel for how much work persons should complete in a day. During the past years that seasoned supervisors, no planning function existed. The plant also may not have had an adequate storeroom, tools, or other resources now becoming available. It used to take all day for a few technicians to complete one or two work assignments. The technicians had to work hard and stay busy rounding up parts and tools. Frequently they had to clarify instructions and job scopes during job execution. They persevered and completed their one or two jobs.

Wrench Time Cannot Improve If Crews Are Not Given More Work

FIGURE 3.2 The reason planning includes scheduling.

Now, however, with it easier to complete those one or two jobs, the maintenance supervisors may not be assigning more work. Habits are hard to change.

Perhaps the supervisors do assign more work. Perhaps they assign two or three jobs to the two technicians. The supervisors would thus feel very supportive of the company mission. But why two or three jobs? Why not four or five?

Now shift to explore another phenomenon. Consider a scheduled outage such as a major overhaul, sometimes called a turnaround. A maintenance schedule dictates the completion of certain jobs, often at certain times. This is true even for many short unscheduled outages for emergency repair. Everyone also shares a sense of urgency. The maintenance group completes a lot of work. Schedule pressure drives the outage. A consideration for doing quality work and doing the work right may alter the schedule, but the maintenance group still completes a lot of work in a short amount of time. However, that is not the phenomenon being considered here. After the outage, the crew supervisors know that they have just accomplished a lot. They have restored production capacity to full availability, and it is time to relax. What? The phenomenon encountered is that the supervisors may think they are rewarding their crews by not pushing for completing a lot of work every day. The supervisor thinks, "How could I expect to work my crew like dogs around the clock during such a critical time and then 'press them' the next day?" The supervisor may feel the outage where everyone works so hard justifies not working so hard later.

In addition, many supervisors feel that the company really does not have quite enough persons during an outage, but that during a regular, nonoutage work day it is a little overstaffed. The supervisor reasons incorrectly that the company has to carry extra persons so it can be ready for the outages. This reasoning is faulty because there is much work that needs to be done on a normal work day for the competitive company. Outages exhaust maintenance personnel because crews work hard, but they always need to work hard to be competitive. One reason they can still work hard without an outage is that normally there should not be an inordinate amount of overtime when there is not an outage situation. Maintenance personnel can work hard for 40 hours each week without being too exhausted.

The crew supervisor may also feel that there is not enough work for the crews on nonoutage days because they are only working on the urgent or high visibility jobs. They may be ignoring the lower priority jobs to prevent future failures. The crews keep somewhat busy fixing those things that break or fail. The high priority jobs give an enormous sense of satisfaction because technicians can directly relate their completion to plant availability. The lower priority jobs' link to availability is less clear. Extra time exists (remember they can now do a 6-hour job in 4 hours) for performing other maintenance jobs to head off failures. Supervisors just do not seem to assign those lower priority tasks. To make this situation even worse, crews try to make the backlog of satisfying jobs last so they do not run out of work.

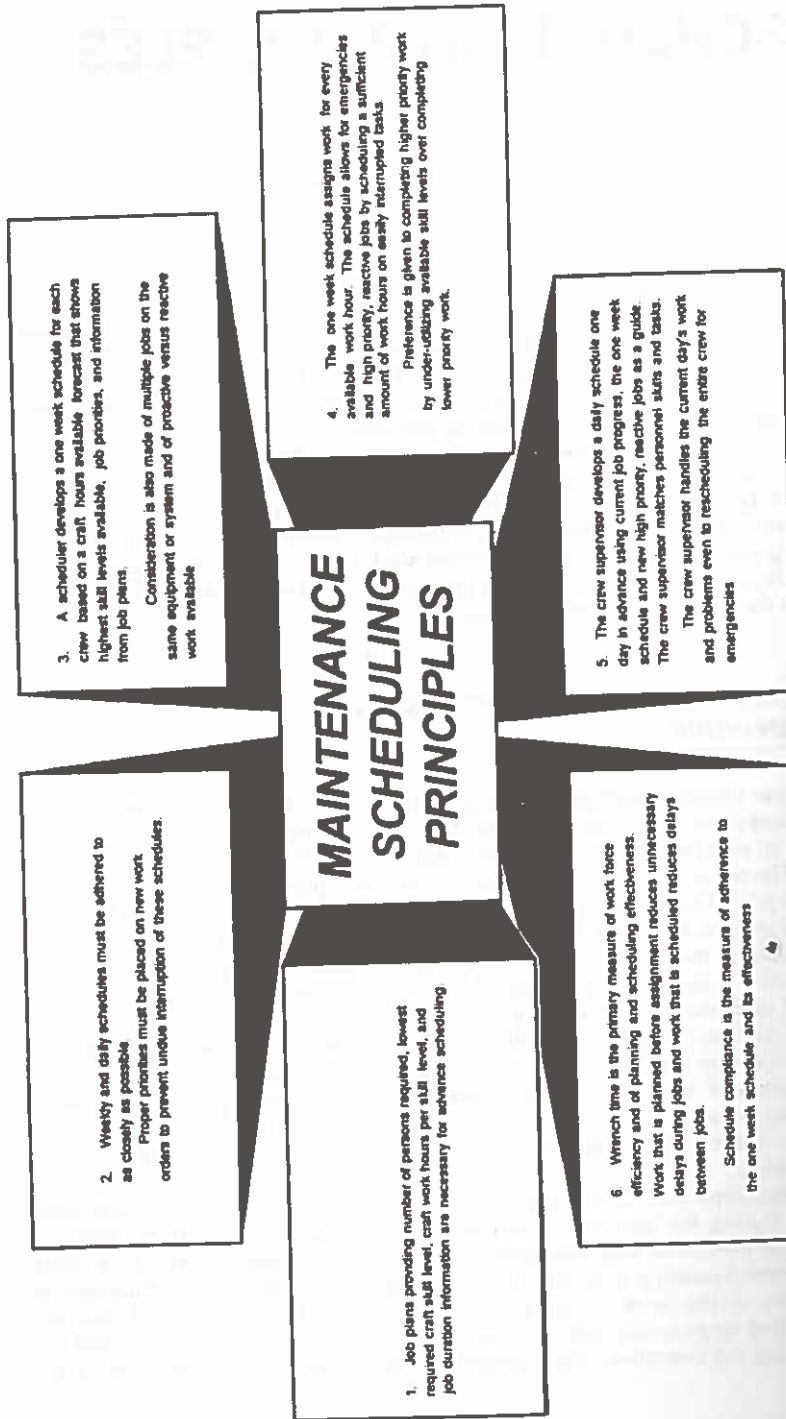


FIGURE 3.1 The six maintenance scheduling principles.

A related practice is a technician receiving a single job assignment at a time with the understanding to come back for a second job when he or she finishes the first. Three things occur. First, the technician feels that the first job is *the* job for the day unless it is very obvious it should only take an hour or two. So nearly every job becomes an 8- or 10-hour job depending not on the job details but on the hourly shift duration. Second, the psychology of the arrangement encourages the technician to presume the next job is somehow a worse job. The fear of the unknown gives appreciation for the current job. "Why rush through it to go to the next job? In fact, I bet the next job is the worst job in the plant, shoveling out the boiler." Third, if the technician does return for the next job, the crew supervisor "cherry picks" through the backlogged work orders in the order of what is urgent and not necessarily by what is serious. If there is nothing urgent in the backlog, the supervisor may well assign the technician to help someone else on an urgent job currently in progress.

Similar to the manner in which many jobs are assigned or executed as 8- or 10-hour jobs, the practice of assigning two persons to each and every job may exist. True, many jobs require the safety consideration of an extra set of hands, but this practice could become a bad habit. Supervisors as well as planners may always assign two persons, needed or not.

Many of the circumstances just noted support a powerful counterproductive culture of peer pressure. Ample reason exists for not productively completing jobs quickly. Very little reason apparently presents itself otherwise. To try to counter this, many facilities do not even write on the technicians' copy of the work orders how many hours the jobs should take. These facilities fear the technicians will slow down if they know they can beat the time estimate. This is not a recommended practice. The technicians are part of the team and the time estimates help them understand the expectations of the job plan. Maintenance management needs a tool that helps supervisors know how much work to assign.

Thus planning is a maintenance manager's valuable tool. Having the estimates of how long a job should take and the number of persons of each skill required is a simple, overwhelming powerful addition to the situation. If a job plan expressly requires a single welder for only 4 hours, two persons for the entire day is obviously not acceptable. A planned estimate may have reduced a task otherwise consuming two persons, 10 hours each, to a 4-hour task. Real labor savings are available to assign elsewhere. Planning has introduced an element of accountability. This is not to say that the crew supervisors were intentionally mismanaging their resources, but planning provides a helpful tool to counteract the natural tendencies.

On the other hand, remember that only a single job has been completed. Even with individual jobs having time and personnel estimates, the proper application of planning provides an allocation of work for a period for the entire crew. This establishes crew accountability in the form of a check and balance system. The principles of scheduling implement this reasoning. Therefore, planning's primary task is not to provide advance information on parts and tools. The most vital application of planning gives the manager the necessary tool to manage how much work an entire maintenance crew should accomplish.

The utility at the end of Chap. 2 had planning without scheduling. Wrench time studies indicated that planning had freed time from earlier delay areas, but overall productive time did not increase. This was because the maintenance group did not assign more work.

Modern maintenance planning considers advance scheduling as an intricate part of planning. Scheduling is necessary for maintenance improvement. The basics of scheduling are centered on giving enough work to the crews to fill up the crews' forecast of work hours available.

ADVANCE SCHEDULING IS AN ALLOCATION

The basics of scheduling involve giving enough work to employees to fill up a forecast of crew work hours available whether for a day or a week. *Advance scheduling* is actually more of an *allocation* of work and not a detailed *schedule* of exact personnel and time assignments (see Fig. 3.3).

Advance scheduling enough work for an entire week *sets goals* for maximum utilization of available craft hours. It helps ensure assignment of a *sufficient amount* of work. Advance scheduling also helps ensure that *sufficient proactive work* to prevent breakdowns is assigned along with reactive work. It also allows more time to coordinate resources such as *intercraft notification* and *staging* of parts. There is also more time to coordinate doing all the work on a system once the operations group clears the system for maintenance.

The planning department can make the advance schedule. Creating the advance schedule in the planning department involves the serious responsibility of selecting the optimum mix of work for the best interest of both the short- and long-term operation of the plant. The scheduler might consult with an operations coordinator to achieve this optimum mix. The craft crews have the responsibility to execute and complete the selected work. This arrangement changes the perceived status quo of the decision previously made by the maintenance crew supervisor about what work maintenance should be performed. Now the scheduler decides what work maintenance should be performed, and the crew supervisor is responsible only for performing it. The crew supervisors see this check and balance system as an unnecessary loss of their control. However, the plant priority system that sets priorities for individual work orders remains the primary driver regarding the order in which crews begin different jobs. The schedule has merely provided the supervisors a service by reviewing the entire plant backlog of work and selecting enough work orders for the crews for the coming week. The supervisor no longer has to pick through an entire plant backlog each time to select individual work orders. The supervisor now has a small week's worth of backlog from which to choose.

The vision of planning is simply to increase labor productivity. The mission of planning is to prepare the jobs to increase labor productivity. The mission of scheduling is to allocate the jobs necessary for completion. Scheduling forms an integral part of planning.

◆ Advance Schedule - Why?

- ◆ Sets Goals
- ◆ Ensures a Sufficient Amount of Work
- ◆ Staging
- ◆ Intercraft Coordination
- ◆ Ensures Sufficient Proactive Work

FIGURE 3.3 Reasons why advance scheduling helps.

Just as outages benefit from having set schedules, routine maintenance benefits as well. The following principles provide a framework to accomplish effective scheduling.

PRINCIPLE 1: PLAN FOR LOWEST REQUIRED SKILL LEVEL

Scheduling Principle 1 (Fig. 3.4) states

Job plans providing number of persons required, lowest required craft skill level, craft work hours per skill level, and job duration information are necessary for advance scheduling.

Maintenance cannot schedule work without some idea of the number of persons and time frames required. Maintenance job plans provide this information in a manner that allows the efficient scheduling of work.

Maintenance job plans first tell what craft specialties are required. Does a particular job require a welder, a painter, or both? Does the job require mechanics or machinists? Does the job require two mechanics or just one? Does the job require three helpers to assist a certified electrician? How many persons are required?

Consider a job that required a certified welder, but the job plan did not specify the number of persons or craft at all. The supervisor would be limited to assigning persons based solely on an interpretation of the job description. The supervisor might err in sending two mechanics to perform the work. In this case, both mechanics would later return to the supervisor explaining their need for welding assistance. Similarly, if a job requires a highly skilled, certified welder, the job plan cannot specify a mechanic with light structural welding abilities. The supervisor needs the information to assign enough welding expertise to the work order.

On the other hand, the essential part of Principle 1 is that job plans identify the lowest skill necessary to complete the work. By identifying the lowest skill necessary, the crew supervisor has even more capability when assigning individuals to execute each

◆ Scheduling Principle 1 .

Plans with Lowest Required Skill Level

◆ Identify Skills

◆ # Persons, # Work Hours, Duration

FIGURE 3.4 Scheduling requires job plan information.

job plan. For example, the job plan should specify one mechanic and one helper if a job requires two persons, but only one needs to be a skilled mechanic. The job plan should not specify two mechanics in this case. The correct specification allows the supervisor who has only a single mechanic to assign the work, presuming the supervisor has other personnel that could be helpers. If the plan incorrectly required two mechanics, the supervisor could not assign the work. Consider a job that requires only light structural welding. The plan should not specify a highly skilled, certified welder. Specifying too high of a skill would severely restrict the supervisor who may see a backlog of mostly certified welding jobs but who may have only one certified welder. The supervisor may have several mechanics that were trained to do light welding. Job plans must specify the lowest qualified skill level to give the supervisors the most flexibility.

Another consideration is if a job could be done equally well with different combinations of persons and hours. Perhaps one person could do the job in 10 hours where two persons would require only 5 hours each. How should the planner plan the job? In these circumstances, the planner does not need to go to great lengths to determine the absolute optimum strategy. The planner's feel for the crew supervisor's preferences usually guides these decisions. The supervisor may normally work technicians in pairs or as individuals. However, the planner should not plan the job example just discussed for two persons with 10 hours each.

Job plans also specify the work hours for each craft skill and the total job duration hours. Work hours are not the same thing as job duration hours. Work hours normally differ from job duration hours for a job. Work hours are the individual labor hours required by each technician. Job duration is the straight calendar time the technicians work on the equipment. Each is necessary for scheduling. Consider a job requiring one mechanic and one helper for 5 hours each to rebuild a pump. The job duration is 5 hours, but the work hours total 10 hours. If the job plan called for an additional 5 hours afterward for painting the equipment, the work hours would total 15. There would be 5 hours each for the mechanic, the helper, and the painter. The job duration would be 10 hours since the painter would have to work after the pump was rebuilt.

The schedulers and crew supervisors need to know how many persons each work order requires and for how many hours each. The job plan specification of persons, craft skills, and labor hours gives this information. The schedulers and crew supervisors also need to know when to send or expect back the appropriate persons on each job. The job plan specification of job duration gives this information.

The operations group also needs to know the duration that equipment will be unavailable for production. The additional time necessary for the operations group to clear up or prepare a piece of equipment for maintenance activities or restore it to service are not included in the time estimates for individual jobs. The estimates are primarily for the use of the maintenance group to schedule maintenance resources. The operations group does their own allocation and arrangement of personnel. Advance coordination keeps technicians from sitting around waiting for the operations group to ready equipment.

For outages, the overall outage schedule addresses where the operations group requires time to prepare and restore equipment, but the estimates for individual job plans do not include this information.

Planners should avoid two common traps when estimating the job requirements on plans. One is always assigning two persons. The other trap is setting the time by using half or whole increments of a shift. First, some situations do require two persons for safety reasons or to handle certain job peculiarities. Even work not inherently dangerous might justify needing two persons if located in the midst of an industrial setting away from other personnel. Two persons may also save the overall job time. For example, two technicians might be able to do a certain job spending 2 hours each, whereas a

single technician would take 10 hours. However, planners err when they always presume two technicians must work together. Hanging an office bulletin board or repacking certain valves might be jobs for which one person should be planned. Consider also having single technicians carry a communication radio for job safety in some cases. Second, planners make a mistake if they always round off work hours to shift increments. For example, one might see most jobs requiring either 4 or 8 hours for crews that happen to work 8-hour shifts. Likewise, one might see most jobs requiring either 5 or 10 hours for crews that happen to work 10-hour shifts. This practice damages the scheduling effort. Many jobs require only a couple of hours and many jobs do not require an entire shift to complete. Consider a 2-hour job and a 6-hour job. Both of these jobs could be completed in a single 8-hour day. However, maintenance would incorrectly assign them if one job had been planned for 4 hours and the other for 8. In correct actual practice, planners plan jobs for their true expected time requirements. Then scheduling is able to fit jobs together to improve overall productivity.

Planners also frequently need to address other situations peculiar to specific jobs. These are not usually too difficult to handle. Perhaps insulation has to be removed and replaced. Perhaps the operations group could restore the pump to service before painting if painting could be done on-line. The important point to note is that both job duration and work hour estimates are necessary for scheduling work. The job plans provide this information.

One question that companies ask is whether plans or schedules consider a high or low wrench time. Usually, job plans and schedules account for technicians having a high wrench time. Job plans do this because the plan time estimates do not allow for unanticipated delays. Moreover, the job plan attempts to avoid or minimize anticipated job delays that the planner feels could occur during individual jobs. Similarly, the weekly schedule attempts to minimize delays that could occur between individual jobs such as excessive idle time, break time, or assignment time. The weekly schedule does this by providing enough work that is ready to go so that crews do not have to waste time receiving new assignments. Because these planning and scheduling efforts aim to reduce delays, they also aim for relatively high wrench time. Remember that high wrench time consists of having technicians on jobs doing productive work rather than being in delay situations.

Illustrations

The following illustrations demonstrate this principle of scheduling. The first section shows problems occurring as a result of not following the principle. The second section shows success through application of the principle.

Not This Way. Paul planned five jobs during the morning before break. Each job required two technicians. The first job required replacing a high pressure steam valve and needed two certified welders for 10 hours each, an entire day. The second also required two certified welders to construct a work bench for the maintenance shop. Paul planned it to take 5 hours for each. The third job was a simple request to move several barrels of waste oil. He planned this job to take two mechanics with a forklift and barrel attachment only 2 hours. The fourth job required replacing a check valve. This was planned to take two certified welders 5 hours. The fifth job required working on a leaking critical control valve. Paul planned this job to require two mechanics an entire day. Before taking his break, Paul figured that he had already planned 64 labor hours' worth of work for the crew.

Later the crew supervisor began to assign work orders to various members of the crew. James had two certified welders, three mechanics, an electrician, and three mechanical apprentices. In addition to the other jobs available to work for the next day, the backlog included the five jobs Paul had planned. There was a significant quantity of mechanic work and, as usual, more work requiring certified welders than the crew had available. Frequently, James had to second-guess the planner and use the apprentice mechanics for some of the mechanic work.

This Way. Paul planned five jobs during the morning before break. Most of the jobs required two technicians. The first job required replacing a high pressure steam valve and needed one certified welder and a helper for 6 hours. The second also required welding to construct a work bench for the maintenance shop. Since mechanics could handle light structural welding, Paul planned it to take one mechanic and a helper 4 hours. The third job was a simple request to move several barrels of waste oil. He planned this job to take one helper alone with a forklift and barrel attachment only 2 hours. The fourth job required replacing a high pressure check valve. This was planned to take a certified welder and a helper 3 hours. The fifth job required working on a leaking critical control valve. Paul planned this job to require one mechanic and a helper 8 hours. Before taking his break, Paul figured that he had already planned 44 labor hours' worth of work for the crew.

Later the crew supervisor began to assign work orders to various members of the crew. James had two certified welders, three mechanics, an electrician, and three mechanical apprentices. In addition to the other jobs available to work for the next day, the backlog included the five jobs Paul had planned. James usually had confidence in the planner's estimate of skill required and knew when apprentices could be sent on jobs as helpers. James first assigned the certified welder and an apprentice to replace both the high pressure steam valve and the check valve in 1 day. James assigned a mechanic and an apprentice to the light structural welding for the work bench to help maintain the mechanic's welding skills. After assigning all the other work, there simply was no electrical work. Although not usually done, James decided to use the electrician as the helper to a mechanic on the critical leaking control valve.

As one can see, the planning function gives the crew supervisor or scheduler the craft skill and time requirements for scheduling work. A job plan tells how many persons the job requires and the minimum skill level. By not unduly restricting the skill requirements, the planner increases the maintenance crew's flexibility for using different persons for the work.

PRINCIPLE 2: SCHEDULES AND JOB PRIORITIES ARE IMPORTANT

Scheduling Principle 2 (Fig. 3.5) states

Weekly and daily schedules must be adhered to as closely as possible. Proper priorities must be placed on new work orders to prevent undue interruption of these schedules.

The originator of a work order first picks an appropriate priority for the work based on established plant guidelines for setting work order priorities. Depending on the particular plant, the priority may then be reviewed and adjusted by the originator's

◆ Scheduling Principle 2

Schedules Are Important

Job Priorities Are Important

FIGURE 3.5 Two essentials that management cannot overlook.

supervisor, an operations coordinator, planners that code work orders, and at a daily meeting of plant managers or supervisors. The resulting priority should reflect not only the work's level of importance for achieving the plant's objectives but its importance relative to other backlogged work. Therefore, the plant priority system should play a large role in creating the schedule of the work the maintenance group will assign and complete. Management must treat the proper use of the priority system as a serious matter. The plant must expect maintenance crews to work on the jobs that the priority system through the schedule dictated. Management must treat working on scheduled work as a serious matter.

It might seem unnecessary to mention that schedules and job priorities are important, but they cannot be overlooked nor presumed. This is a common area of failure in maintenance management. Advance scheduling enough work for an entire week sets goals for maximum utilization of available craft hours. It helps ensure that a sufficient amount of work is assigned. Together with the priority system, it also helps ensure that the right work is assigned.

A significant source of inefficiency in the maintenance group is the interruption of low priority jobs when more urgent jobs arise. If a true emergency arises, it is always appropriate to delay another job. However, the maintenance group should recognize that interruptions on any particular job add extra time putting away tools, securing the job site, and later refamiliarizing oneself with the job. An urgent job that is not an emergency should be worked as the next job rather than interrupt any job-in-progress. A nonurgent job should wait until the next day or week altogether so that the job can be scheduled into the overall priority of importance for the plant. Later, parts and tools might be staged to make executing the job more productive at a more appropriate time.

Jobs with priorities falsely set too high improperly interrupt work or cause work to begin without proper preparation. The end result is that the maintenance group completes less work overall. Then a vicious cycle begins. Higher priority work must interrupt lower priority work because there is not enough productivity to complete all the work plus the interruptions. Quite possibly, the maintenance group could complete all the work with more organizational discipline in setting initial job priorities. This would lower the incidence of job interruptions and lowered productivity. Management commitment is important in this area. Conscientious management attention to enforcing adherence to the priority system helps maintenance.

If everyone assigned a high priority to their work just to ensure its completion, then improperly prioritized jobs would also make it hard to recognize true instances of when schedules or work should be interrupted. They might delay starting true high priority jobs even if they did not interrupt them.

In addition, inadequate confidence that crews will execute scheduled jobs hurts the staging program. Staging, as discussed in Chap. 6, helps increase crew productivity by having a job's planned parts and tools ready to go. They are already withdrawn from inventory or storage and ready for the technician to utilize. Planning stages the material before the anticipated execution of the job begins. Technicians avoid delay areas that they might otherwise encounter if they had to gather the parts themselves. Inadequate confidence that crews will execute scheduled jobs may discourage planners from staging parts. On the other hand, if planning continued to stage parts, the staging area might become overflowing with staged parts for jobs that did not start. In this case, the storeroom might run into stockouts for other jobs that maintenance chose instead to start. The stockouts might occur because of parts that were withdrawn for staging. These circumstances significantly diminish the great potential for staged parts to expedite jobs.

Illustrations

The following illustrations demonstrate this principle of scheduling. The first section shows problems occurring as a result of not following the principle. The second section shows success through application of the principle.

Not This Way. Mike finished his operator rounds and wrote work orders for problems he had noticed. Although most were not yet serious, Mike wanted to make sure maintenance completed them. Therefore he set a priority of 1 on the most important ones and 2 on the rest.

Nearly all the jobs in the maintenance backlog had been prioritized as 1's or 2's. They were either urgent or serious. This made it difficult for the crew supervisor to select which jobs maintenance should work the next day. Abby selected all twelve priority-1 jobs and three priority-2 jobs to assign.

Near the beginning of the next day, the plant manager asked that Abby immediately assign a few technicians to correct a dripping flange on the installed backup feed pump. Abby interrupted two technicians on one of the priority-2 jobs. These technicians first hastily put their ongoing job in a state where they could leave it. Then with the operations group clearing the pump and themselves having to find suitable gasket material, they worked the rest of the day to replace the flange gasket and correct the leak.

This Way. Mike finished his operator rounds and wrote work orders for the problems he had noticed. Most were not yet serious and Mike set a priority of 3 or 4 on them. He set a priority of 2 on a couple of serious ones.

Mike's supervisor afterwards had Mike change the priority of both of the serious work orders. They changed one to priority 1 (urgent) and the other to priority 3 (routine production).

The backlog had work orders with a variety of priorities. Priorities ranged from 1 (urgent) to 4 (routine nonproduction). This made it fairly easy for the crew supervisor to select which jobs maintenance should work the next day. Abby selected all five priority-1 jobs and eight priority-2 jobs to assign. She also assigned two priority-3 jobs.

Near the beginning of the next day, the plant manager wrote a priority-2 work order for Abby's crew to correct a dripping flange on the installed backup feed pump. Planning went ahead to plan and stage the gasket material. Abby included the flange job with the assignments she was making for the next day. She was also able to assign most of the backlog priority-4 work orders as well. Abby requested the operations group to clear the pump in time for her crew to begin work on it the next morning.

The next morning two of the assigned technicians picked up the staged gasket material and began the flange work order. They completed it within a couple of hours and began another job.

Maintenance should avoid interrupting scheduled jobs or jobs-in-progress. Maintenance should also place great importance on the plant following the plant priority system.

PRINCIPLE 3: SCHEDULE FROM FORECAST OF HIGHEST SKILLS AVAILABLE

Scheduling Principle 3 (Fig. 3.6) states

A scheduler develops a one week schedule for each crew based on a craft hours available forecast that shows highest skill levels available, job priorities, and information from job plans. Consideration is also made of multiple jobs on the same equipment or system and of proactive versus reactive work available.

The first two principles set the prerequisites of scheduling. These next three principles introduce the concepts of the foundations of the advance scheduling process.

Principle 3 establishes a 1-week period as the advance schedule of allocation of work time frame. It also presumes that a person apart from the crew supervisor will be the scheduler. The scheduler selects the week's worth of work from the overall plant backlog. The scheduler uses a forecast of the maximum capabilities of the crew for the coming week. The scheduler also uses priority and job plan information. The scheduling process also looks at performing all the work available for a system once maintenance begins work on that system. This includes proactive work.

◆ Scheduling Principle 3

Schedule from Forecast of Highest Skills Available

◆ One Week

◆ Consider Multiple Jobs on
Same System

◆ Consider Proactive Work

FIGURE 3.6 The basics of the advance schedule.

First, the advance schedule selects a 1-week period for making an advance allocation of the work. Advance allocation means the schedule will select all the work that the crew should be able to finish in a single week. The schedule selects the work from the overall plant backlog. The scheduler does not assign the work orders to individual crew members. The scheduler also does not set specific hours or even certain days on which the work on each work order should start or end. The scheduler merely specifies a block of work as a list or package of work orders. *Advance scheduling* is an allocation of work for maintenance and not a detailed schedule of exact personnel and time slots.

A 1-week period strikes a balance between creating set goals and allowing for gradually changing plant needs. On one hand, a 1-week period is long enough to allow establishing a set block of work for a crew goal. This set block of work also allows planners enough time to stage parts for scheduled work. On the other hand, the plant is constantly writing new plant work orders. The new work orders gradually change the relative importance of all the work in the plant backlog. A 1-week period is short enough for the schedule normally not to need significant alteration due to this new work identification. This may be less true in a plant with more than a moderate amount of reactive work. These plants may normally experience a significant deviation from the set schedule. The 1-week schedule also covers a short enough time period to allow supervisors enough certainty in knowing which of their individual crew members will be available for work.

In addition, a curious phenomenon appears regarding the accuracy of job estimates for individual work orders. Experience has shown that job estimates for individual work orders may be off plus or minus as much as 100%. That means that on average, a job planned for 5 labor hours has as much chance of being accomplished in 1 or 2 hours as it might in 10 hours. This is especially true of the smaller work orders that make up the bulk of many maintenance operations. Does this mean that planner estimates are worthless? No, on the contrary, the planner estimates are very accurate overall as the work horizon widens out to as much as a week. Over a week's worth of crew labor, the overall estimate planned hours becomes extremely accurate, only off as much as 5% or less. That means that practically as many jobs run over as under due to the myriad of special circumstances surrounding individual work orders assigned to individual technicians on individual days. This confirms that a week is the appropriate allotted time period for advance scheduling. Remember that the objective of scheduling is not to produce accurate time estimates. It is to accomplish more work by reducing delays.

The scheduler publishes this schedule to give to maintenance crews, the operations group, and management. The crews receive the schedule as allocations of goals for the coming week. Supervisors of different maintenance crafts receive the schedules to have an idea of upcoming coordination needs. The operations group receives the schedules to have an idea of what equipment will eventually need clearing. The operations group may also be able to give the maintenance group timely advice of maintenance redirection needed. The operations group as well as management receives the schedule as an indication that maintenance is making progress on work orders. Many times, areas apart from the maintenance group see it as a "black hole" into which work orders enter, but never emerge. Tangible proof of work order schedules increases cooperation from the operations group.

Second, having a person separate from the crew supervisor allows a system of checks and balances. A person separate from the crew determines how much work the crew should be able to accomplish. The question is not necessarily: Which work orders should be done? The plant priority system drives that. The question is: How many work orders should the crew complete? The scheduler is best included as part of the planning department because this person uses planning as well as crew information. Many times it is appropriate for a supervisor of a planning group to perform the duties of scheduler. This allows the planning supervisor routinely to review job plans.

Third, the scheduler receives a labor forecast for each crew supervisor. This forecast tells how many labor hours each crew has for the next week. The scheduler needs this information. The scheduler intends to allocate hours of planned backlog on the basis of the labor hours available for each crew. The crew supervisors are in the best position to forecast the available labor hours on their crews. The crew supervisor may tell the scheduler that the crew will have 1000 labor hours for the next week. The scheduler then has a basis for knowing how many hours of planned work to allocate.

Fourth, the crew supervisor must make the labor hour forecast in terms of the highest skills available. By identifying the highest skills available, the scheduler has more latitude when actually determining which job plans could be executed the next week. Highest skills available means that if a crew has two certified machinists and seven mechanics available for the next week, the supervisor would not just forecast that the crew has nine persons or nine mechanics. The latter forecast would reduce the flexibility of the scheduler who would not be able to assign any complex machining jobs. The scheduler has more flexibility when knowing that there are two certified machinists. The scheduler can then assign complex machining jobs. The scheduler might also decide to assign routine mechanic jobs to the machinists. There is more freedom in what jobs can be assigned.

Fifth, the scheduler will use information from the individual job plans and a feel for the overall priority of plant systems. The scheduler looks at the priorities of the backlogged work to help select jobs. The scheduler looks at the labor hours planned to select enough jobs. Chapter 6 will discuss the actual steps the scheduler follows in this process.

Sixth, the scheduler also considers plant equipment and systems when selecting work. When selecting work for an entire week, the scheduler is able to group work orders for the same equipment. The scheduler may override some individual work order priorities to accomplish this. For example, a priority-2 and priority-3 work order may be both assigned because they are on the same piece of equipment. This might be preferred over assigning two priority-2 work orders on two separate pieces of equipment. Schedulers can also exercise flexibility by initiating certain PM work orders early to take advantage of equipment downtime for other work. This allows improved overall efficiency because the operations group can clear the equipment a single time and the maintenance crew can work on a number of jobs together.

Finally, it is easier for the scheduler to include preventive maintenance or other work to head off failures on a weekly basis. On a daily basis, there is often sufficient justification to put off these seemingly lower priority work orders. On the other hand, when combining a week's worth of work, it becomes clear that PM cannot be delayed. The weekly schedule includes this type of work to encourage the supervisor not to put it off forever, 1 day at a time.

Illustrations

The following illustrations demonstrate this principle of scheduling. The first section shows problems occurring as a result of not following the principle. The second section shows success through application of the principle.

Not This Way. As maintenance manager, George felt that maintenance could increase its productivity. Lately, he had seen more and more technicians heading home early. This was a problem since reliability seemed to be slipping at the plant. He knew that there was a considerable backlog of work, but the supervisors had assured him that they were assigning as much work as the technicians could handle. George was also concerned that supervisors had a habit of putting off PM work orders.

George felt that advance scheduling of some sort was the answer, but the last attempt had been disastrous. Planning had first scheduled hour by hour what work maintenance should accomplish for an entire week. However, by the end of the very first day, the schedule was in shambles. Half of the scheduled jobs could not start at their target times because other jobs had run over their expected completion times. By the middle of the second day, the actual work-in-progress bore no resemblance whatsoever to what the advance schedule had predicted. At this point, the plant had abandoned the concept and gone back to assigning work 1 day at a time. George felt that now was the time to implement a gate carding procedure to make sure employees worked their entire shifts.

This Way. As maintenance manager, George felt that maintenance was increasing its productivity. Reliability seemed to be gaining at the plant. He knew that there was a manageable backlog of work and the scheduling process was helping the supervisors to assign as much work as the technicians could handle. George was also pleased that supervisors were not putting off PM work orders.

George felt that advance scheduling had been a great success. Planning had first developed a list of all the work orders that maintenance should accomplish for an entire week. The amount of work was determined by the labor hours that the crews would have for the week. At the end of the week, George discussed with each supervisor the results of what had actually been accomplished. Although no crew had completed all the allocated work, most crews had finished more work than they had thought possible. By the end of the second month, crews had a firm idea of the amount of work they were responsible for and were becoming more productive. As a result, maintenance crews were executing more work and the plant was increasing its reliability.

The proper period for an advance schedule is normally a single week. This time frame allows setting a goal that can stay relatively fixed as the plant continues to identify more work. The week's worth of work is not an hour-by-hour schedule of work orders, but a bulk allocation. The crew labor forecast is an important part of the scheduling process. Not only should the supervisors forecast how many labor hours are available, but how many in each specialty.

The following principle discusses two concepts relating how the scheduler compares the labor hours available with the planned hours in the backlog.

PRINCIPLE 4: SCHEDULE FOR EVERY WORK HOUR AVAILABLE

Scheduling Principle 4 (Fig. 3.7) states

The one week schedule assigns work for every available work hour. The schedule allows for emergencies and high priority, reactive jobs by scheduling a sufficient amount of work hours on easily interrupted tasks. Preference is given to completing higher priority work by under-utilizing available skill levels over completing lower priority work.

Principle 4 brings the previous scheduling principles together. The first part of this principle is that the scheduler assigns work plans for the crew to execute during the following week for 100% of the forecasted hours. This means that if a crew had 1000 labor hours available, the scheduler would give the crew 1000 hours worth of work to do.

Overassigning and underassigning work are also common in industry. However, each causes unique problems that could be avoided.

◆ Scheduling Principle 4

Schedule for Every Work Hour Available

- ◆ 100%, not 120%, not 80%
- ◆ Work Persons Down

FIGURE 3.7 How planned hours and forecasted hours become scheduled hours.

For example, consider the case of assigning work for 120% of a crew's forecasted work hours. This would mean that the crew that had 1000 labor hours would receive 1200 hours of assigned work. This strategy may seem to be a way to provide enough work for the crew in case operators could not finish some of the jobs. It would also seem to be a way to encourage the crew to stay busy. This is because it sets a more ambitious goal for work completion. This strategy also creates several problems. It becomes difficult to gauge the performance of the crew. Maintenance management has a more difficult time comparing what the crew did accomplish to what it should have been able to do. This is because now there are three factors to compare: what labor the crew had available, what the crew was assigned, and what the crew actually accomplished. In the 100% case favored by this book, the first two factors are identical. The 120% method's three factors makes it more complicated for management to question a crew's performance. If a crew did not accomplish all its scheduled work, management would normally want to know why. However, management might be hesitant to question why a crew only accomplished 1100 hours worth of work with the 1000 work hours it had available. Nearly any source of confusion in communication regarding crew performance is not in management's best interest. Management needs to lessen opportunities for misunderstandings whenever possible. In addition, maintenance coordination with plant operators and other crafts may be more difficult with the 120% arrangement. This is because there is less confidence that jobs will be worked.

Conversely, assigning work for only 80% of forecasted work hours may seem to provide a way to handle emergencies or other high priority work that may occur. However, the maintenance force is trying to eliminate emergencies altogether. Planning significant resources to handle emergencies that may or may not occur is counterproductive. It might also encourage work order originators to claim false emergencies knowing the availability of the resource. In reality, assigning work hours for 100% of a crew's forecasted work hours nearly always inherently includes some jobs that can be easily interrupted in case emergencies arise. A 100% scheduling strategy encourages originators to understand that for every emergency, other work is delayed. The 80% scheduling strategy also makes it difficult to gauge crew performance. Maintenance management also

finds it difficult to ask a crew to improve if the crew completed all of its assigned work. A self-fulfilling prophecy is possible. Every week that emergencies do not occur, the crew might complete less work than possible. If the crew completes less work than possible, the work left undone might be work to head off emergencies. Consequently the plant experiences emergencies that justify leaving labor forces unscheduled each week. On the other hand, the 80% arrangement may be preferred in certain situations where maintenance crews must work within an overall time limit. Perhaps an outage with a critical time constraint might meet this criteria. The 80% arrangement might also be justified if the maintenance group has a particular credibility problem with the operations group. The maintenance group could publicize the work that it plans to accomplish and give regular reports to the operations group of its success.

Principle 4 prefers the 100% strategy primarily for accountability and clarity of communication. The 100% rule also keeps the crew busy accomplishing a practical goal. Maintenance handles any emergencies through interrupting jobs-in-progress. Maintenance management should not plan for regular emergencies in this regard.

The second part of this principle, "working persons down," is somewhat more subtle. On a major construction project requiring 20 welders and 20 helpers, the project would simply hire 20 welders and 20 helpers. However, in normal maintenance, the most beneficial jobs requiring completion rarely match the exact skill composition of the standing maintenance force. As a simple illustration, see Fig. 3.8. Consider a planned backlog consisting of 100 hours of high priority work requiring only helpers and 100 hours of low priority work requiring machinists. If there were only 100 hours of machinists available, then the plant should assign them all to the high priority work even though it requires only helpers. The principle has the scheduling process recognize that machinists can do helper work and allows assignment of persons to higher priority work in the plant. Otherwise, think of a not-so-extreme case where there was no machinist work in the backlog and machinists could not "work down." Would a company have high priority helper work sitting in the backlog and machinists sitting in the break room? This is a problem with the automatic scheduling logic of some CMMS systems.

Consider what type of multicraft or work agreements are necessary to take advantage of the opportunities in this area.

See also how the note numbers in Fig. 3.8 illustrate the scheduling principles discussed so far. The backlog work is planned by lowest skill level (Principle 1). The backlog is ordered by priority or importance of work (Principle 2). The resources to work the jobs are forecasted by the highest skill level available (Principle 3). Principle 4 shows the correct assignment of technicians to jobs.

Craftpersons typically should not mind working outside of their primary specialties for work that is obviously in the best interest of the plant. It does become a source of resentment when the plant abuses the priority system. Consider management assigning a first class electrician to be a helper for a mechanic. If it is obvious that the mechanical work is much less important than backlogged electrical work, there is a problem.

Illustrations

The following illustrations demonstrate this principle of scheduling. The first section shows problems occurring as a result of not following the principle. The second section shows success through application of the principle.

Not This Way. Fred examined the plant's backlog of planned work and selected the work for the maintenance crew for the following week. The crew had forecasted 400 hours' worth of total labor for all the various craft specialties. Normally Fred only

"Working Persons Down"

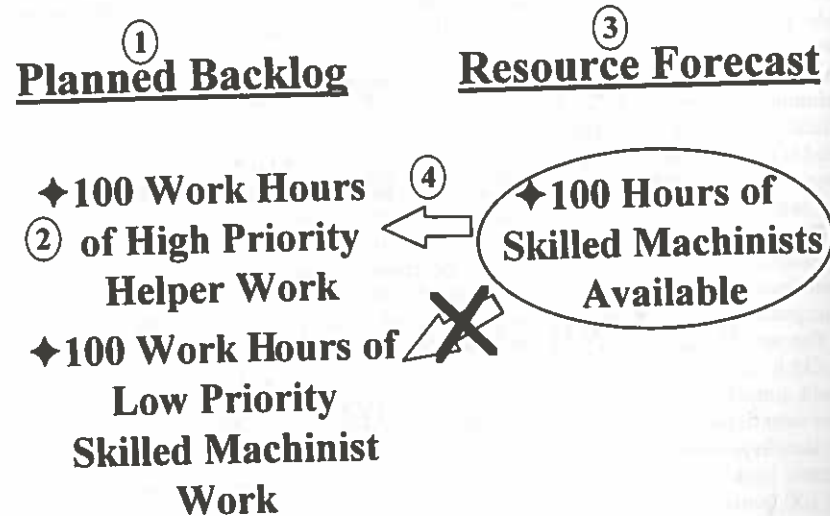


FIGURE 3.8 Doing work most profitable for the plant.

scheduled for 80% of the crew's forecast to allow for emergencies. This meant that sometimes he was not able to schedule all of preventive maintenance due on the equipment. This week he was able to schedule 60 hours of PM. At one point when allocating work out of the backlog, it became difficult to match the jobs needing attention with the remaining available electrical skills. Therefore, Fred assigned 20 hours of lesser important priority-4 work. This work required first class electricians and the first class electricians had hours available. The resulting advance schedule was an allocation of 320 hours of planned work for the crew. During the next week, the maintenance crew did not experience any emergencies and completed all 320 hours of work.

This Way. Fred examined the plant's backlog of planned work and selected the work for the maintenance crew for the following week. The crew had forecasted 400 hours' worth of total labor for all the various craft specialties. Fred was able to schedule about 80 hours' worth of preventive maintenance into the schedule. At one point when allocating work out of the backlog, it became difficult to match the jobs needing attention with the remaining available electrical skills. Therefore, Fred put in 20 hours of work requiring only a third class electrician even though the crew had only first class electrician labor hours still available. The third class work was priority-3 work, whereas all of the first class electrical work left in the plant backlog was less important priority-4 work. The resulting advance schedule was an allocation of 400 hours of planned work for the crew. During the next week, the maintenance crew did not experience any emergencies and completed 360 hours of the work.

Scheduling Principle 4 dictates that the scheduler should match the advance allocation of work to the number of hours a crew has available. To accomplish this task, the advance scheduling process considers working persons out of their strict classifications or below their level of expertise. This methodology allows the scheduler to select the

best combination of work orders to achieve plant goals such as reliability and efficiency. The combination of work orders is one in which the crew does possess the skill required to accomplish the work.

Principle 4 establishes a methodology in the planning office to assign enough work. In addition, it is worthy to note what actually happens in the field on a day-to-day basis. Because many jobs run over or under, the crew supervisor frequently does not ever have to assign persons outside of their normal crafts. On a day-to-day basis, the supervisor is usually able to assign work from the weekly allocation by craft. There are more occasions where technicians may be used as helpers. For example, a job planned for one mechanic and a helper may be assigned to two mechanics. The next principle describes the basis for the crew supervisor instead of the scheduler making the daily work assignments.

PRINCIPLE 5: CREW LEADER HANDLES CURRENT DAY'S WORK

Scheduling Principle 5 (Fig. 3.9) states

The crew supervisor develops a daily schedule one day in advance using current job progress, the one week schedule and new high priority, reactive jobs as a guide. The crew supervisor matches personnel skills and tasks. The crew supervisor handles the current day's work and problems even to rescheduling the entire crew for emergencies.

- ♦ Scheduling Principle 5
- Crew Leader Handles Current Day's Work
- ♦ Daily Schedule
- ♦ Matches Names to Tasks
- ♦ Coordination of Resources & Clearances
- ♦ Emergencies

FIGURE 3.9 The crew supervisor is in the best position.

Once the week has begun, obviously some jobs will run over and some will run under their planned work hours. Experience shows that although individual jobs show a wide variance between planned and actual times, over the course of a week there is remarkable agreement between the sums of the planned and actual times. That is the first reason that daily scheduling is best done by the crew leader or supervisor who is close to the field situation of job progress. Equally important is the ability of the crew supervisor to assign particular jobs to individuals based on their experience or even their need to learn.

Each day the crew supervisor assigns the next day's work to each technician. If working 10-hour shifts, each technician would receive assignments totaling 10 hours of work for the next day. The supervisor intends for each technician to complete 10 hours of planned work each day. The technicians may be continuing on a single job that spans several days or working several smaller jobs in a single day.

During the course of the day, the supervisors are out in the field assessing job progress. If a job runs over the planned hour estimate, the supervisor may have to schedule additional time for the next day. If a job runs under the planned estimate, the supervisor may have to assign additional work to begin a day earlier than expected.

The supervisor normally assigns new work orders out of the work allocation. The supervisor is also free to assign urgent jobs that come up during the course of the week. Ordinarily, the supervisor has the planning group quickly assess urgent jobs. Then the supervisor assigns them as soon as qualified technicians complete current jobs in progress. Because emergency jobs are begun immediately, the supervisor handles them by interrupting jobs in progress. Emergency jobs do not receive planning attention. They are handled entirely as jobs in progress from a planning standpoint.

Because jobs may finish earlier or later than expected, it is not practical to schedule work order assignments more than a day in advance. Because the crew supervisors keep abreast of individual job progress, they are in the best position to create the daily schedule. The crew supervisor creates the daily schedules and works the crew toward the goal of completing all the work allocated in the advance schedule.

The second reason the crew supervisors need to make the daily schedule is they understand the specific abilities of their various technicians. There also might be various personalities making a crew supervisor favor pairing certain technicians together and keeping certain others apart. Some technicians might also work better alone on jobs, while others might work better as a team. A crew supervisor is also best aware of daily personnel concerns, such as persons that call in sick.

To meet the goal of the weekly schedule allocation, the supervisor may also have to challenge some of the technicians. In the past, the supervisor may have allowed certain technicians to accomplish less work or less challenging work than others. Faced with a goal amount of work orders to complete, the supervisor may now be more encouraged to help technicians rise to the occasion. The supervisor approaches these considerations carefully. The situation may be a benefit to technicians who have been "frozen" at their current level of expertise because they only received jobs they could handle.

Because the supervisors create the daily schedule, maintenance also gives them the responsibility to coordinate other daily activities. These may include requirements for another craft to assist on a job. The supervisor makes timely requests from the operations group. Many plants accomplish this type of daily coordination with a brief daily schedule meeting each afternoon. All the craft supervisors attend with the key operations supervisors.

Illustrations

The following illustrations demonstrate this principle of scheduling. The first section shows problems occurring as a result of not following the principle. The second section shows success through application of the principle.

Not This Way. The maintenance planning scheduler sat down to make the weekly allocation of work. This was done by developing a series of daily schedules for a week. After the schedules were complete, the scheduler sent the operations group a list telling which systems and equipment to have cleared at different times each day for work.

As the crew supervisor visited the various job sites during the day, he had a good idea of which jobs would finish early or late. This required constant communication with the operations group, which generally voiced displeasure about the situation. The operations group expected maintenance crews to be able to work on the jobs to which the planning schedule had committed them. Operators generally wasted time clearing systems when the maintenance group did not have personnel ready. He had done the operations group a favor, however, when he was able to immediately put two persons on a fan problem at their request.

The maintenance supervisor did not think that the new scheduling system was any improvement over the past. In the past, the maintenance supervisor had assigned each technician one job at a time after he had checked with the operations group regarding clearances. The operations group could then count on maintenance personnel being ready to work on the cleared equipment.

This Way. The maintenance planning scheduler sat down to make the weekly allocation of work. This was done by developing a list of work orders for a week. After the allocation was complete, the scheduler sent the operations group the list showing which systems and equipment the maintenance group planned to work on sometime during the week.

As the crew supervisor visited the various job sites during the day, he had a good idea of which jobs would finish early or late. The crew supervisor knew that in order to complete the weekly allocation of work, he would have to assign each crew member a full 10 hours of planned work for the next day. After making a preliminary daily schedule, he attended the daily scheduling meeting. The operations group said it could clear up all the requested work for the next day. They also said they had earlier written a work order for a fan problem that probably could not wait until next week. The crew supervisor said that he would check with planning to see if they had started planning it. Depending on the craft skills needed, he would probably be able to start it the first thing in the morning. He had several persons who were ready to start new jobs. After the meeting, he called planning. They had just planned the job for two mechanics. The crew supervisor called the operators group, who said they would have the fan cleared for work. He made the necessary changes on his schedule and went to the crew meeting area to post the assignments for the next day.

The supervisor is in the best position to make the daily schedule. This person has the latest information on field progress and can judge when operations should clear equipment. This person has the responsibility of working toward the weekly allocation of work. However, the crew supervisor is still responsible for breaking the weekly schedule when necessary to take care of urgent problems.

PRINCIPLE 6: MEASURE PERFORMANCE WITH SCHEDULE COMPLIANCE

Scheduling Principle 6 (Fig. 3.10) states

Wrench time is the primary measure of work force efficiency and of planning and scheduling effectiveness. Work that is planned before assignment reduces unnecessary delays during jobs and work that is scheduled reduces delays between jobs. Schedule compliance is the measure of adherence to the one-week schedule and its effectiveness.

Work sampling or wrench time is considered the best measure of scheduling performance. However, maintenance management also tracks schedule compliance.

The bottom line is whether or not planning and scheduling have improved the work force's efficiency. Planning and scheduling aim to do this by reducing delays that otherwise keep technicians from completing work orders. Planning individual jobs can reduce delays such as waiting to obtain certain parts, tools, or technician instructions. However, other than setting an individual job time standard, planning does nothing to reduce delays between jobs. These delays include such circumstances as technicians not receiving an assignment after completing their current work. In addition, not having a sufficient amount of work assigned may encourage technicians to take excessive breaks or have lengthy mobilization and shut down periods at the beginning and end of each day. Scheduling aims at reducing these type delays. Work sampling or wrench time studies quantify both of these type delays. They give the primary measures of planning and scheduling effectiveness.

Schedule compliance is also an important indicator. John Crossan (1997) says that weekly schedule compliance is the ultimate measure of proactivity. When the maintenance force has control over the equipment, the maintenance force decides when to take certain actions to preserve equipment. When the equipment has control over the work force, the equipment drives the efforts of maintenance. A more reactive plant environment has more circumstances of the equipment experiencing problems and causing the maintenance force to break the weekly schedule. The proactive maintenance force in control of its equipment experiences few circumstances of a sudden equipment problem that interrupts scheduled work. Schedule compliance is merely a measure of how well the crew kept to the scheduled allocation of work for the week. Supervisors who adhere to the schedule as much as possible ensure accomplishing as much preventive maintenance and other timely corrective work as possible.

Schedule compliance provides a measure of accountability. It guards against crews working on pet projects or other jobs that are not more important than the allocated

◆ Scheduling Principle 6

Measure Performance by Analysis of Schedule Compliance

| Case | Sched | Start | Finish | Compliance |
|------|-------|-------|--------|--------------|
| ① | 10 | 10 | 9 | 100% not 90% |
| ② | 1 | 1 | 0 | 100% not 0% |
| ③ | 1000 | 900 | 850 | 90% not 85% |

FIGURE 3.10 Making schedule compliance acceptable to supervisors and practical to calculate.

work. Yet if other more urgent or serious work arises, crew supervisors must redirect their crews to handle them. The schedule compliance provides a standard against which to discuss those actions. A supervisor may explain a low schedule compliance by telling what other work had to interrupt the schedule. A supervisor may have a low schedule compliance and no other interrupting work. This might indicate there may be a problem such as storeroom performance that needs to be identified and resolved. The schedule compliance scores facilitate discussion and identification of plant problems between maintenance managers and supervisors.

Similarly, a technician's performance measured against the planned estimate of a single job helps facilitate discussion between the supervisor and the technician. The technician must ignore the planned estimate when the actual dictates of the job demand otherwise. The technician and supervisor may need to send job feedback to the planning department to prevent certain problem areas from hindering future work.

Schedule compliance is not a weapon to hold against supervisors. Maintenance management and supervisors want to use schedule compliance as a diagnostic tool. Therefore, it is expedient to measure schedule compliance in a way to give the crew the benefit of any doubt. Figure 3.10 illustrates this approach. Consider if a crew is given 10 jobs and the crew starts all 10 but only completes 9. The crew receives a score of 100% schedule compliance rather than 90%. The second case explains this reasoning where a crew receives only one job, works it all week without interruption, but does not finish. It is not fair to grade the crew as having 0% schedule compliance. Again, the crew receives a score of 100% schedule compliance. In actual practice, case 3 shows how maintenance measures schedule compliance. Schedule compliance actually tracks the *planned work hours* delivered to the crew for the following week's work (1000 work hours). At the end of the next week, the crew returns all work they did not even start (100 work hours). Maintenance calculates the schedule compliance as 90%, which is $(1000 - 100)/1000$ times 100%. Giving the crew credit for jobs only started in the calculation accomplishes two results. First, the measure gives the crew the benefit of any doubt. This avoids supervisors feeling the calculation gives an unfair poorer-than-actual view of their performance. Second it makes the score very easy to calculate. Otherwise consideration would have to be made for the estimated remaining planned hours of jobs-in-progress. That adjustment would be very subjective and again possibly not seen to the supervisors' advantage. Third, one should remember that the objective is to encourage supervisors to work on scheduled jobs, the objective is not to have a scientifically accurate correlation between an indicator and field performance. The preferred method of calculating schedule compliance is expedient in all of these three regards. Instead of the term "schedule compliance," some companies prefer to call this measure "schedule success" to indicate the plants' attempt to gain control over the equipment rather than over the supervisors.

That the crew in case 3 may have only actually completed 850 work hours is not a problem as long as carryover hours the next week are monitored. For example, there would be a problem if the crew consistently claimed that it had about 200 hours of carryover work each week when the crew only had 200 available labor hours. Carryover hours are part of the crew forecast the supervisor makes each week to determine available labor hours.

Earlier, Scheduling Principle 3 stated that a 1-week period is short enough normally not to need significant alteration due to new work identification. This may be less true in a plant with more than a moderate amount of reactive work. These plants may normally experience a significant deviation from the set schedule. These plants especially should continue to schedule and track schedule compliance. This indicator would determine what improvement maintenance has been able to make in overcoming the reactive situation.

Illustrations

The following illustrations demonstrate this principle of scheduling. The first section shows problems occurring as a result of not following the principle. The second section shows success through application of the principle. Chapter 10, Control, shows an example of the actual calculation of schedule compliance for a crew.

Not This Way. Three plants considered schedule compliance. It made no sense at Plant Shelton to track schedule compliance. The plant simply had too many reactive work orders. However, the crews had become very efficient at taking care of the plant. It was never a problem for maintenance expeditiously to resolve most circumstances encountered.

Plant Bains had made a commitment to track schedule compliance. The plant had assigned an analyst almost full time to the task. Rather than only give the crews credit for completed jobs, each week the analyst would also give credit for some of the work hours for jobs-in-progress. The analyst carefully recorded the actual work hours that technicians had already spent on jobs not completed and added them to the total of the planned hours for completed jobs. There was some concern that the calculation was mixing actual work hours for uncompleted jobs with planned work hours for completed jobs. One alternative was having the planners give an estimate of the planned hours left on each partially completed job. Another alternative was having the supervisors give an estimate of the percentage of each job remaining and proportioning the original planned hours. The analyst doubted there was adequate time to fine tune the calculations each week using either alternative.

Plant Calvin used the schedule compliance indicator as a hammer. The most important task for any supervisor was to finish allocated work. Management used schedule compliance scores as the major part of each supervisor's periodic evaluation. This ensured that crews accomplished all the scheduled preventive maintenance and other work to keep the plant reactive work to a minimum. Supervisors never failed to take charge of emergencies, but they were understandably reluctant to resolve otherwise urgent situations before they became emergencies. Management knew that this was the price to pay for concentrating on proactive work. In the long run, they felt this strategy would provide the plant with superior reliability.

This Way. Three plants considered schedule compliance. It made sense at Plant Shelton to track schedule compliance. Plant Sheldon called it "schedule success." The plant had many reactive work orders. The crews had become very efficient at taking care of the plant. It was never a problem for maintenance to resolve most circumstances encountered expeditiously. On the other hand, the maintenance crews scored fairly low on schedule success each week. The schedule success indicator gave maintenance management one of its few tools to assess the plant's situation. Management knew that somehow they needed to reduce the amount of reactive work at the plant. As management implemented various solutions, they examined the schedule success scores to see if there was any improvement.

Plant Bains had made a commitment to track schedule success. At the end of each week, the planning supervisor gathered back all the work orders that the crews had not been able to start. Then the planning supervisor would sum the planned hours on the work orders separately for each crew. Subtracting these sums from the amount of planned hours the crews had originally been allocated allowed a simple measure of schedule success. This procedure consumed about 2 hours of the supervisor's time near the end of each week, primarily for gathering back the work orders that the supervisors knew that they would not be able to begin. The supervisor reflected that the work

orders not started would have to be gathered each week in any case because the scheduler needed them to add back to the plant backlog. The scheduler would then begin the process of allocating work for the coming week.

Plant Calvin used the schedule success measure as an important indicator. It was important for any supervisor to concentrate on allocated work. Management used schedule success scores as one part of each supervisor's periodic evaluation. This ensured that crews understood the importance of accomplishing scheduled preventive maintenance and other work to keep the plant reactive work to a minimum. Supervisors never failed to take charge of emergencies and were also quick to resolve otherwise urgent situations before they became emergencies. Management ensured that supervisors understood their role to keep the plant out of trouble. In the long run, management felt this strategy would provide the plant with superior reliability.

As one can see, the plant's objective is not to have a high schedule compliance. The plant's objective is to have a reliable plant. A low schedule compliance indicates opportunities for management to address other problems in the plant to increase the plant reliability. The schedule compliance score facilitates discussion and investigation of problems. When supervisors are appropriately following the advance schedule and reacting to urgent plant developments, the schedule compliance score indicates the degree to which the plant is in a reactive or proactive mode. A plant cannot bring itself out of a reactive mode by insistence on blind obedience to the advance schedule. If it did, the consistent neglect of urgent developments might put the company out of business. Once it occurs, reactive maintenance needs cannot be ignored.

Summary

Maintenance planning will not increase labor productivity if it only concentrates on planning individual work orders. Making it easier to accomplish individual work orders does not necessarily mean that supervisors will assign more work. A number of system problems discourage crew supervisors from assigning more work orders for completion. Maintenance management must consider scheduling in the maintenance planning strategy to avoid these problems.

Six basic principles form the foundation of successful scheduling. These are using job plans providing time estimates, making schedules and priority systems important, having a scheduler develop a 1-week advance schedule, assigning work for all available labor hours, allowing crew supervisors to make daily schedules, and tracking schedule compliance. When setting craft and time requirements, job plans must plan for the lowest required skill level. This increases later flexibility in choosing jobs. Adhering to schedules is important because interrupting jobs leads to overall inefficiency. The priority system must properly identify the right jobs to start. A separate scheduler from the crew provides a check and balance. A 1-week period strikes a balance between a set goal and changing plant needs. In addition, a 1-week period is long enough to smooth out differences between planned estimates and actual times on single jobs. Knowing of the lowest skills required for jobs and the highest skills available in the labor pool allows developing a schedule with the proper work for the week. The uncertainty of actual job progress and the incidence of unexpected reactive work place the crew supervisor in the best position to create the daily crew work schedule. Finally, schedule compliance joins wrench time as an important indicator of maintenance performance.

Principles 1 and 2 are prerequisites for scheduling. Principles 3 through 5 establish the basis of the scheduling process. Principle 6 sets the overall indicators for scheduling control.

So utilizing planned and scheduled work packages increases the maintenance department's ability to complete work orders effectively, efficiently, and safely. Will the planning effort work with maintenance planning based on the six planning principles and the six scheduling principles?

Here is what the utility discussed at the end of Chap. 2 discovered. The utility established a weekly allocation of work based on all six scheduling principles. The plant management and crew supervisors quickly became extremely frustrated. The frustration was not due to supervisors having a set goal of work. Management and supervisors both accepted the responsibility of the crew to work toward the allocated goal and also respond quickly to urgent plant problems. Management and supervisors understood the balance of both responsibilities. The frustration was caused by the inability of the planning department to adapt the role of the planners for urgent plant needs.

The planners had recognized the supervisors had to deal differently with urgent, reactive work. The problem was that the planners did not recognize that the planners themselves had to deal differently with urgent, reactive work.

The planners insisted on developing significant job plans for reactive work. This delay kept supervisors in a state of frustration having either to wait on planning or proceed without any planning. The former case frustrated the planners who had to hurry. The latter case frustrated the planners whose eventual job plans were ignored. Supervisors realized the need of meeting the urgent needs of the plant, but the planners did not.

Obviously, management needed to consider urgent, reactive work in the planning and scheduling picture. Planning needed to make some adaptation of its work for reactive jobs. This leads to the next chapter on what makes the difference and makes it all come successfully together. The next chapter presents the final consideration necessary for the planning and scheduling strategy to succeed. Planning must not plan reactive jobs in the same manner as proactive work.

CHAPTER 4

WHAT MAKES THE DIFFERENCE AND PULLS IT ALL TOGETHER

This chapter explains the final concepts necessary to make planning work. These concepts make planners do different things for different types of jobs and greatly influence the overall application of the principles. Lack of appreciating these factors frequently makes planning programs fail. The programs fail because they try a one-size-fits-all approach to different types of jobs. Primarily, the programs are not sensitive to the immediate needs of reactive jobs. This chapter distinguishes between proactive and reactive maintenance. Likewise, it distinguishes between extensive and minimum maintenance. Most importantly, this chapter describes the resulting planning adjustments. This chapter also discusses communication and management support regarding these adjustments.

The preceding chapter's second illustration of Plant Calvin depicted a fundamental maintenance concept. While the plant should actively engage in activities to prevent problems, they must be dealt with quickly once they arise.

At Plant Calvin, maintenance crews understood the importance of accomplishing scheduled preventive maintenance and other work to keep the plant reactive work to a minimum. Furthermore, crews also never failed to take charge of emergencies and were quick to resolve otherwise urgent situations before they became emergencies. Management ensured that supervisors understood their role to keep the plant out of trouble.

On one hand, maintenance supervisors must change their past philosophy of executing mostly reactive work. Supervisors must assign more proactive work to head off reactive work. Advance scheduling helps facilitate this change. On the other hand, planners must change their past philosophy of planning all jobs as proactive work. Planning must adapt to an alternative method of planning reactive work. Making several adjustments to the planning department's process removes the last barrier to having an effective system.

PROACTIVE VERSUS REACTIVE MAINTENANCE

The recognition of the existing maintenance culture helps management change maintenance crews to focus on proactive work. Proactive work heads off problems before they occur. John E. Day, Jr. (1993) has done excellent work developing the concept of proactive maintenance. He points out the standard definitions of maintenance:

"Success" Level of Effectiveness

- ◆ >95% Availability
- ◆ >55% Wrench Time
- ◆ >80% Planned Coverage
- ◆ >3 Week Backlog and
Equipment NOT Breaking
- ◆ Reactive Work < 20% and OT < 3%
- ◆ Contractor Work Only on Specialty Items

FIGURE 4.7 Typical company maintenance objectives.

tenance force should prefer maintaining its own equipment for quality reasons. The use of contractors is justified where there is not enough in-house work to justify maintaining necessary qualifications or experience.

SUMMARY

After establishing fundamental principles for planning and scheduling, a few final concepts become apparent for making planning work. Planners must plan different types of jobs differently. This is primarily due to the immediate needs of reactive jobs. Planners put less effort into planning reactive work to accommodate crews that must soon begin work. This also allows the planners time to plan all the work and concentrate more on important proactive jobs to head off failures. Planners also abbreviate their efforts on small tasks that do not justify much planning effort. These tasks are called *minimum maintenance jobs*. These planning adjustments require communication and support from management because of their effect on the plans that crews receive. Crews that previously received detailed job plans may now receive less information on individual jobs without appreciating its value. These concepts make the difference and pull it all together.

CHAPTER 5 BASIC PLANNING

The previous chapters have described the principles underlying effective planning and scheduling. This chapter describes exactly what a planner does in the context of the preceding chapters. The chapter follows the entire actual planning process including areas such as how a planner scopes a job, what a planner writes on a work order form, and how a planner files.

More magazine articles have described the concepts of maintenance planning than have described exact steps a planner might take to fulfill those concepts. This may be because there are often many different options for exact steps. Nevertheless, many programs with the right concepts have failed due to difficulty in determining how to execute the concepts. Therefore, this book undertakes the obligation to describe exact steps to clarify the role of a planner to fulfill the concepts. The following sections describe specific planner actions. After understanding what is necessary to execute the principles of planning, readers may implement alternative steps than the ones prescribed. The following sections address some of the considerations involved to allow readers to tailor their own systems appropriately. In this manner, this chapter covers the question: "Exactly what does a planner do?"

Before examining the basics of hands-on planning, observe a planner through a normal work day. This company has a correctly established planning organization. Read the following illustration and try to recognize the principles and concepts affecting planning. The section also repeats the illustration identifying the principles and concepts encountered.

A DAY IN THE LIFE OF A MAINTENANCE PLANNER

Maintenance Planner Terry Smith came in to work on Wednesday morning looking forward to another routine day of helping the maintenance department boost its effectiveness and efficiency.

After checking his electronic mail for important bulletins, he went to the "waiting-to-be-planned" file to select work orders to plan for Steam Unit 1. There were not any "reactive-type" work orders, so Terry returned to his desk to close work orders already completed by maintenance. Terry filed information on repairs made, delays encountered, and parts and tools used for each job. The closing included totaling the cost for each work order to help guide future repair or replace decisions. On one job it was not clear what extra part had been used by the technicians. He made a note to ask them later after break so the plans for future jobs could have the part number available.

Now it was about 9:30 AM and the new work orders had come from the supervisors' morning meeting to the waiting-to-be-planned file. As usual, each work order had pertinent

information recorded by the originator. Terry started with the reactive work orders. Terry made a copy of each for note taking and placed the originals in the planner active file by his desk. The first job was obviously a simple welding job and required only minimum maintenance attention. The other two jobs needed extensive maintenance consideration.

All of the equipment involved in the jobs had component tag numbers identified on the work orders. Only one piece of equipment did not have a corresponding minifile, so Terry quickly made a minifile for it. He then entered the work order number and problem description in each minifile. The entry would also later enable any duplicate work orders to be caught by a planner before planning. Terry also checked the computerized maintenance management system for each extensive maintenance work order to see a total job history for the equipment. For all of the work orders, Terry then made a field inspection. Afterward, from his personal experience and the minifile information, he made a planned package for the work order. He did this by explaining the work needed on the original work order forms and attaching available technical information from the minifiles. As in the case of most plans, he was careful to plan the general strategy of the job and not spend time including "how to" details unnecessary for a competent technician. Terry was pleased that for one work order he was able to identify a special tool that had slowed down the last job when it was not available. He then finished the planning for each job by putting the planned package in the "waiting-to-be-scheduled" file and updating the work order status on the computer. As was normal, all the reactive work was planned before lunch.

After lunch, Terry concentrated on the proactive work orders in the waiting-to-be-planned file. Two jobs required extensive maintenance planning and two jobs required only minimum maintenance planning. On the first extensive job, a thermography route had shown a slight leak for a valve. A check of the minifile showed that this valve had a history of leaking. The second extensive job, for a pump, had no identified component tag number because schematics and coded tags were still being developed for that section of the plant. There were no minifiles for the pump and the equipment for the minimum maintenance jobs. A computer check for each job showed no additional information.

Terry put on his hard hat and safety glasses, then went out for a field check to scope the proactive work orders. He noted that although the valve was in high pressure service, it had flange connections and would not require a certified welder. Terry decided to include scaffolding in the plan. Since the pump job had no component tag number, Terry attached a temporary tag directly on the pump by the nameplate. One of the minimum maintenance jobs was as expected, but he had to clarify the other one with the originator. Terry then returned to the office.

He first finished the minimum maintenance work plans, making a minifile for each piece of equipment and putting the planned packages in the waiting-to-be-scheduled file. Then Terry turned to the extensive maintenance jobs. The valve's minifile history showed that the seat and disk had been reconditioned as well as replaced without too much improvement in its time between failures. Terry decided the present valve was marginal for the service and planned the job to replace the valve with an upgraded valve from the warehouse. For the pump, Terry made a minifile from the temporary tag number he had installed. Since the job was proactive, Terry took the time to research the technical and vendor files for certain clearance and parts information. After Terry found the information he needed, he copied it to the new minifile and finished the work plan. The next time the pump was worked on, that information would be readily available.

With the time remaining in the day, Terry reviewed the feedback from several preventive maintenance routes. Each PM route covered multiple pieces of equipment within a single plant system. These inspections usually uncovered most of the problems for which work orders were written in the plant. Terry changed the frequency of one route from every week to every other week because the route had been run for several months without identifying any adjustments or situations needing correction.

At the close of the day, Terry walked to the parking lot. He thought about the part he played in the high availability that Steam Unit 1 enjoyed. The backlog of planned work allowed the scheduling of planned work to match the forecasted available craft hours for the next week. The weekly schedule set a work goal and made the advance coordination of other crafts and parts staging possible. These basics would normally boost work force wrench time beyond the 35% typical of industry to about 45%. Keeping the plant on a constant learning curve by using information gathered in the minifiles actually increased wrench time to 50%. Technical data was available and previous job delays were avoided. As the computer system became more developed, wrench time was slowly creeping up to 55%. At 55% the productivity of the 25 people for which Terry planned would be the same as for 39 people working at only a 35% wrench time. The benefits of planning actually involved productivity and quality savings. The productivity savings came from reducing delays during and between assignments. The quality management time. This allowed them to focus on troublesome jobs requiring more attention and an opportunity to do more proactive work. This proactive work included root cause analyses on repair jobs, project work to improve less reliable equipment, and attention to preventive maintenance and predictive maintenance. Terry felt good that his work in planning contributed to a cycle of continuous improvement.

The following narrative repeats this case with planning principles and concepts affecting planning identified.

Maintenance Planner Terry Smith came in to work on Wednesday morning looking forward to another routine day of helping the maintenance department boost its effectiveness and efficiency (mission of planning).

After checking his electronic mail for important bulletins, he went to the waiting-to-be-planned file to select work orders (work order system) to plan for Steam Unit 1. There were not any reactive-type work orders (reactive versus proactive), so Terry returned to his desk to close work orders already completed by maintenance. Terry filed information (Principle 2, feedback) on repairs made (history), delays encountered (path to improve productivity), and parts (parts lists) and tools (special tools) used for each job. The closing included totaling the cost for each work order to help guide future repair or replace decisions (Principle 5, overall strategy of job). On one job it was not clear what extra part had been used by the technicians. He made a note to ask them later after the break so the plans for future jobs could have the part number available (Principle 2, feedback and future work).

Now it was about 9:30 and the new work orders had come from the supervisors' morning meeting (other tool, communication) to the waiting-to-be-planned file. As usual, each work order had pertinent information recorded by the originator (organizational discipline). Terry started with the reactive work orders. Terry made a copy of each for note taking and placed the originals in the planner active file by his desk. The first job was obviously a simple welding job and required only minimum maintenance attention. The other two jobs needed extensive maintenance consideration (minimum versus extensive maintenance planning).

All of the equipment involved in the jobs had component tag numbers (Principle 3, equipment numbers) identified on the work orders (organizational discipline). Only one piece of equipment did not have a corresponding minifile (Principle 3, component level files), so Terry quickly made a minifile for it. He then entered the work order number and problem description in each minifile. The entry would also later enable any duplicate work orders to be caught by a planner before planning. Terry also checked the computerized maintenance management system for each extensive maintenance work order to see a total job history for the equipment. For all of the work orders, Terry then made a field inspection. Afterward, from his personal experience (Principle 4, planner skill) and the minifile information, he made a planned package for the work order. He did this by

explaining the work needed on the original work order forms and attaching available technical information from the minifiles. As in the case of most plans, he was careful to plan the general strategy of the job and not spend time including how-to details unnecessary for a competent technician (Principle 5, technician skill). Terry was pleased that for one work order he was able to identify a special tool that had slowed down the last job when it was not available. He then finished the planning for each job by putting the planned package in the waiting-to-be-scheduled file and updating the work order status on the computer. As was normal, all the reactive work was planned before lunch (reactive versus proactive planning).

After lunch, Terry concentrated on the proactive work orders in the waiting-to-be-planned file. Two jobs required extensive maintenance planning and two jobs required only minimum maintenance planning (extensive versus minimum maintenance planning). On the first extensive job, a thermography route (other tool, predictive maintenance) had shown a slight leak for a valve. A check of the minifile showed that this valve had a history of leaking (Principle 2, past job helping future job). The second extensive job, for a pump, had no identified component tag number because schematics and coded tags were still being developed for that section of the plant (Principle 3, equipment numbers for files). There were no minifiles for the pump and the equipment for the minimum maintenance jobs. A computer check for each job showed no additional information.

Terry put on his hard hat and safety glasses. Then he went out for a field check to scope the proactive work orders. He noted that although the valve was in high pressure service, it had flange connections and would not require a certified welder (Scheduling Principle 1, lowest skill required). Terry decided to include scaffolding in the plan. Since the pump job had no component tag number, Terry attached a temporary tag directly on the pump by the nameplate (Principle 3, equipment number for files). One of the minimum maintenance jobs was as expected, but he had to clarify the other one with the originator. Terry then returned to the office (Principle 1, separate planning department).

He first finished the minimum maintenance work plans making a minifile (Principle 3, files) for each piece of equipment and putting the planned packages in the waiting-to-be-scheduled file. Then Terry turned to the extensive maintenance jobs. The valve's minifile history showed that the seat and disk had been reconditioned as well as replaced without too much improvement in its time between failures. Terry decided the present valve was marginal for the service and planned the job to replace the valve with an upgraded valve from the warehouse (Principle 2, past job helping future job). For the pump, Terry made a minifile from the temporary tag number he had installed. Since the job was proactive, Terry took the time to research the technical and vendor files for certain clearance and parts information (further research for proactive jobs). After Terry found the information he needed, he copied it to the new minifile and finished the work plan. The next time the pump was worked on, that information would be readily available (Principle 2, past job helping future job).

With the time remaining in the day, Terry reviewed the feedback from several preventive maintenance routes (other tool, PM program). Each PM route covered multiple pieces of equipment within a single plant system. These inspections usually uncovered most of the problems for which work orders were written in the plant. Terry changed the frequency of one route from every week to every other week because the route had been run for several months without identifying any adjustments or situations needing correction.

At the close of the day, Terry walked to the parking lot. He thought about the part he played in the high availability (objective of planning) that Steam Unit 1 enjoyed. The backlog of planned work (Principle 2, future work) allowed the scheduling of planned work to match (Scheduling Principle 4, schedule for 100% of hours) the forecasted available craft hours for the next week (Scheduling Principle 3, schedule one week from forecast of highest skills). The weekly schedule set a work goal and made the advance coordination

of other crafts and parts staging possible (objective of scheduling). These basics would normally boost work force wrench time (Principle 6, wrench time) beyond the 35% typical of industry to about 45%. Keeping the plant on a constant learning curve by using information gathered in the minifiles actually increased wrench time to 50%. Technical data was available and previous job delays were avoided. As the computer system became more developed, wrench time was slowly creeping up to 55%. At 55% the productivity of the 25 people for which Terry planned would be the same as for 39 people working at only a 35% wrench time. The benefits of planning actually involved productivity and quality savings. The productivity savings came from reducing delays during and between assignments. The quality savings came from correctly identifying work scopes and providing for proper instructions, tools, and parts to be used. The productivity improvement also freed up craft, supervision, and management time. This allowed them to focus on troublesome jobs requiring more attention and an opportunity to do more proactive work. This proactive work included root cause analyses on repair jobs, project work (other tool, project work) to improve less reliable equipment, and attention to preventive maintenance and predictive maintenance. Terry felt good that his work in planning contributed (other tools needed, no silver bullet) to a cycle of continuous improvement.

The previous account shows that the steps job planners take reflect the important principles and concepts of planning and scheduling. The account also demonstrates that the planning system resides as a process within the work order process. The next section describes the overall process of completing work with the work order process from job origination to job closure and notification of the originator. After this section, the chapter focuses on the planning process activity in the work order process.

WORK ORDER SYSTEM

As explained in Chap. 1, the work order system is the most valuable tool for improving maintenance effectiveness and productivity. Basically, the system helps maintenance personnel obtain necessary origination information and control all the work. The work order system avoids an inconsistent utilization of verbal statements, electronic mail, Post-its, and phone calls. The foundations of the work order system are a consistent format for information and a designated flow for work to proceed. The information needing to have a consistent format (whether on computer or paper) is origination information, plan information, and feedback information. The work order system prescribes the use of specific forms, codes, and work processes. Appendix J provides a complete, sample work order system manual, and also presents a flow chart showing the steps maintenance takes to complete emergency work without planning assistance.

Figure 5.1 shows the steps of the work order process for a typical company using a paper work order system. *Paper* means that the work request is written on a physical paper form. This same physical form passes to the planning department and then to the field for work execution. The form is then returned to the planning department with job feedback. This company also uses the term *work order* to refer to the document when it starts as a work request as well as after it is authorized and becomes a literal order to do work. The form is known as the *work order form*. The company uses a computer, but only to track the work order forms. This book's illustration of a company with a paperwork order system allows the best explanation of the planning process. This typical company process will be used for the remainder of this chapter and the next two chapters to illustrate the planning and scheduling steps. A computer may be used to add value, but it cannot replace the basic process. After the basics of planning are mastered, Chap. 8 explores the possible employment of a computer system.

The first step in Fig. 5.1 shows the origination of the work order. This person may be an operator, a maintenance technician, or anyone in the plant. The originator obtains a work order form and fills it out with the required information. The originator describes the problem or work requested including identification of the involved equipment and its location. The originator makes an estimate of the work's priority. The originator also gives an opinion, if possible, as to which crew or craft the work would be assigned and whether or not the work must be done during an outage. The originator also provides any other information dictated by the particular work order form as well as any other information that might be helpful. This person also hangs a deficiency tag on the equipment if applicable. The originator's supervisor, if required, then reviews the work order, makes any adjustments required, and places the form in a designated collection place. The particular work order form utilized by the company may have multiple carbonless copies to provide copies or a copy machine might be utilized. The collection places are the preferred locations that maintenance planning has established to help speed the work order flow. The collection places might be simple boxes in the control rooms, by the elevators, in the front office, or near other work locations. Maintenance planning collects the work orders placed in these boxes at regular times. The intent is to avoid work orders being placed in the interoffice mail or otherwise delayed or lost through some unusual means of transmission.

After collection of the work orders, the second clockwise box in the flow diagram shows coding. Planners go through the new work orders to code the work orders. When the planners code the work orders, they are placing appropriate codes from the plant coding system on every work order. These codes include designation of work type, whether the work is reactive or proactive, whether the work is minimal or extensive, and other codes. The planners also designate which crew would receive the work order.

The third box shows a step where the work orders are brought to the morning meeting where managers and certain supervisors may swiftly review them to see what is going on in the plant. Plant engineers attend these morning meetings. Any work order may have its priority changed, may be canceled, or may be referred to a project group. The concept of a morning meeting originated before the existence of planning and used to be the place where new work orders were passed from operations to maintenance every day. The use of the morning meeting now is usually a meeting to review a list of work orders and not the work orders themselves. The work orders themselves remain in the planning department where planners may begin planning them and clerks may finish entering them into a computer system. The next step in the flow process allows the maintenance planning clerk to enter any data that any computer system may need. For example, this company uses a CMMS, but just enters the work order information into the computer to allow having a backlog list of work orders. The company also uses two other separate computer systems for inventory and payroll time sheets. The clerk must enter work order numbers to authorize inventory transactions and payroll accounting. After entering the work orders, the clerk puts the work orders in a waiting-to-be-planned file for the planners.

The planners plan work in accordance with the steps discussed in this chapter. Informal planning refers to crafts that do not have planning. Many plants only implement planning for mechanical maintenance when it has the bulk of the work. Electrical and I&C craft supervisors or technicians plan their work on an informal basis. After planning, the planners place the work order forms and all associated pieces of the planned package together in a waiting-to-be-scheduled file.

A scheduler then schedules the work in accordance with the process steps recorded in later sections of Chapter 6. Informal scheduling refers to crafts that do not have planning. After scheduling, the scheduler delivers the scheduled work order forms and planned packages to the appropriate crew supervisors.

The crew supervisors then work the scheduled work into daily crew assignments. The crew supervisors obtain equipment clearances from the operations group, with a copy of the work order if required.

WORK ORDER GENERAL WORK FLOW

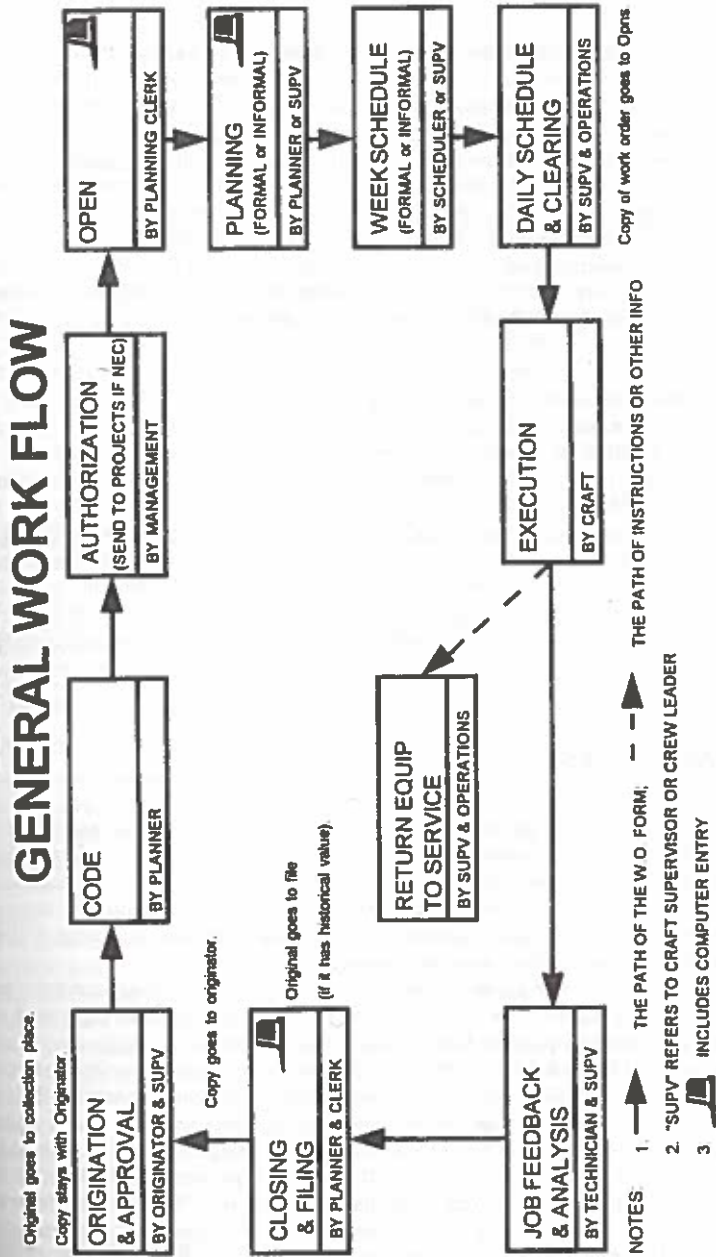


FIGURE 5.1 Example maintenance work flow diagram.

The next step has the technicians executing work on cleared equipment. After job execution, the technicians report job completion to the crew supervisor. The supervisor soon reports job completion to the operations group. The supervisor does not wait until the shift end to report multiple job compilations all at once. Giving the operators timely notice allows the operators time away from their own shift change periods and reduces confusion in restoring equipment. Timely notice also allows the operators to restore equipment to service while technicians are still at the plant in case problems are encountered.

The next step requires the technicians to carefully record helpful feedback on the work order form. The technicians and supervisors should go ahead and fill out this information while their memories are fresh. A later section in this chapter thoroughly covers required and desired information for feedback since feedback is essential to the planning improvement process.

After receiving feedback, the last step is for planners to assess the completeness of feedback and file appropriate information including the work order form. The planner may proceed to update future plans even before the plans are required. The planning clerk enters designated information to close work orders in various computer systems. The clerk may also have filing duties. A later chapter section prescribes possible clerk duties. Finally, Fig. 5.1 closes the circle of the work process by sending notification of work completion to the original requester. This notification could be accomplished by copy of the work order, electronic mail, or spoken communication. Only in organizations where the operations group has complete confidence in the maintenance group should the notification of work completion be skipped. Alternately, a computer system where everyone has free and easy access to check work order may suffice for operations to see whether maintenance has completed their work.

PLANNING PROCESS

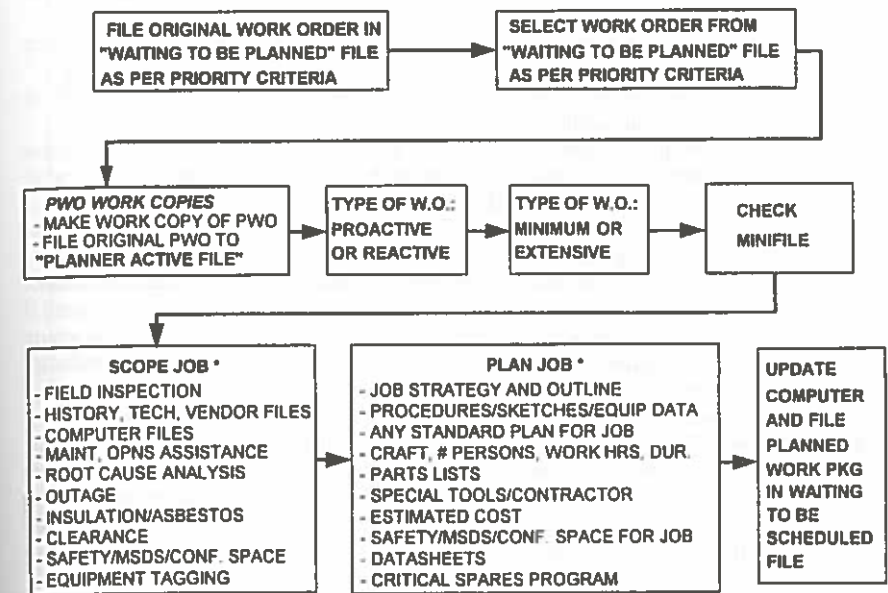
In the planning process, the planners take new work orders and add necessary information to allow more efficient scheduling and execution of the work. Figure 5.2 expands the single box that called for planning in the overall work order process. All of the activity shown in Fig. 5.2 occurs within the single planning step of Fig. 5.1. Figure 5.2 shows the general sequence of the planning operations. Understanding this sequence will help explain the discussions that follow in this chapter.

The first box shows where planners place the work orders after coding, computer entry, and morning meeting adjustments have taken place. The planners put all unplanned work orders in the waiting-to-be-planned file. Normally this file has only a single day or two of unplanned work in it because the planning principles and concepts allow for keeping up with the work on a daily basis. However, in a plant just starting to implement planning, there may be a substantial amount of unplanned work in the backlog. In those cases, the file will also have to allow access to crew supervisors who may have to assign jobs before planning has time for them. The work orders are placed in the file to allow easy identification of their planning needs. Normally, the work orders are placed by plant unit. Within the work for each unit the work is arranged by priority code. If there are multiple planners, each planner may be responsible for certain crews or crafts and the file arrangement may reflect this order.

The next box shows the planners taking work orders from the file. The planners generally take the reactive work orders out ahead of the proactive ones. These normally carry a higher priority. The planners want to plan such work orders quickly in case the crew supervisor requests them.

The next box shows a step to provide the planner with a draft copy of the work order to allow note taking while in the field scoping work. The planner does not take the original

PLANNING PROCESS FLOW CHART



* According to guidelines for type of work order and plan.

FIGURE 5.2 General flow of planning activities.

work order form out into the field. The planners leave the original work order forms out on their desks and go into the field with copies. Alternately, there may be a set location for a "planner active file" in each planner's office or cubicle. Leaving the original in the office also allows the supervisor of planning to help crew supervisors find certain work orders if necessary.

The planners note the type of work orders they are planning. They will plan each work order differently depending on its type: reactive or proactive, minimum or extensive.

The next box shows that a planner will nearly always check the files to see if previous job information will be helpful.

Next the planners scope the job according to the guidelines of the type of work. After scoping the jobs and understanding what they require, the planners will sit down to develop an actual job plan. The planner may update the job's status as planned on the computer. The planners finally file each completed job plan in a waiting-to-be-scheduled file. This file is kept in the planning office area.

WORK ORDER FORM

Many maintenance departments use separate work request and work order forms. In such a system, an originator fills out a work request describing the work requested and turns it in to the maintenance department. After planning or other processing, the maintenance department issues the crew or technician a new form, the work order form, which describes the actual work to be done.

This book prefers a single form. Having a single form simplifies the maintenance process and also may avoid the loss of originally attached information. A separate form may also lead to inaccurately copied information to the second form.

After origination, maintenance planning uses the same form to record nearly all planning information.

The scheduler handles the work order forms for scheduling. The form helps the technician and supervisor include vital feedback helpful information.

After job completion, the planner can easily check the structured form for its completeness and any need for the planner to seek additional feedback or initiation of additional work orders. The planner files this form to help future jobs.

When planning a new job, a review of past jobs recorded on consistent work order forms enables the planner to recognize and avoid previous job delays and problems.

Another issue involves work order numbers. Each work order having a unique number facilitates discussion of work orders. Having unique numbers helps persons understand if they are discussing the same work. Sequential, unique work order numbers are easily printed on the top of preprinted work order forms. Unique numbering is almost mandatory for computer systems.

Figure 5.3 shows an example of a typical, structured work order form for a company that employs planning. This example helps to visualize its use in the maintenance process. Many companies have much more complex work order forms with a multitude of specific boxes requesting information. Structured forms provide for consistent information input for all phases of a job. These phases include origination, planning, job feedback, and coding. Figure 5.4 points out the different main areas of the work order form. For the purposes of illustrating the planning process, this book uses the simple work order form shown in Fig. 5.5.

Consider now an example work order. An operator notices a strainer starting to plug and originates the work order shown by Fig. 5.6. The pressure drop is high, but not too severe. The operator uses the priority codes found in App. J to code the work order as an "R2." "R" means that the situation involves plant reliability and "2" deems it serious. The operator fills in other information required by the plant.

CODING WORK ORDERS

Two planners go through the new work orders early every morning to code work orders. When the planners code the work orders, they are placing appropriate codes from the plant coding system (such as found in App. J) on every work order. These codes include designation of work type, whether the work is reactive or proactive, whether the work is minimum or extensive, and other codes. The planners also designate which crew would receive the work order. If a number of work orders have been received in the middle of the day or if there are fairly urgent work orders, the planners may not wait until the usual morning period to code them. If the company utilizes an operations coordinator, this person reviews the work order priorities and has the authority to adjust them as needed. The operations coordinator might also be responsible for gathering work orders to bring to planning. Frequently, an operations coordinator is a member of the operations group on loan to planning. Less commonly, planners have the authority to adjust work order priority.

Plants code data to increase their ability to use information. For one thing, it clarifies communication. It provides for a consistent designation for each type of information to reduce confusion. For example, if everyone called the boiler feed pump by a different name, information might get lost. Different persons might call the south boiler feedpump the BFP B, the south boiler feed pump, or the B feed pump. How should the information be filed? Would technicians work on the correct pump? Using the designation N02-DP-002

| | | | |
|--|--|---------------------------------------|---|
| WORK ORDER # | | | |
| REQUESTER SECTION | | | Priority ___ |
| Equipment _____ | | | Tag # _____ |
| Problem or Work Requested: _____ | | Def Tag # _____ | |
| By: _____ | | Outage Req? Y/N Date & Time: _____ | Clearance Req? Y/N Confined Space? Y/N |
| APPROVAL: | | | |
| PLANNING SECTION | | | |
| | | Assigned Crew: _____ | Attachment? Y/N |
| Description of work to be performed: | | | |
| Labor requirements: | | | |
| Parts requirements: | | | |
| Special tools requirements: | | | |
| By: _____ | | Date & Time: _____ | Job Estimate: _____ |
| Actual: _____ | | | |
| CRAFT FEEDBACK (Modify plan sections above: actual labor, parts, & tools) | | | |
| Work performed including equipment changes & any problems or delays: | | | |
| Date & Time Started: _____ | | Date & Time Completed: _____ | |
| By: _____ | | Date: _____ | APPROVAL: |
| CODING | | | |

FIGURE 5.3 An example of a work order form to help guide input.

indicates that the pump referred to is the North Unit 2 Boiler Feedwater Pump B. Once planners code a work order, persons using the work order later might not have to digest the entire document to get necessary information. For example, once the planners code a work order as reactive, later interpretation is not necessary when the planner is reviewing many work orders to select several to plan. For another thing, plants code their data to allow better analysis of information. For example, coding all breakdown work as work type 5 allows the plant later to evaluate the percentage of plant work it does on equipment after it has failed.

| |
|-------------------------------|
| WORK ORDER #001234 |
| REQUESTER SECTION |
| PLANNING SECTION |
| CRAFT FEEDBACK SECTION |
| CODING SECTION |

FIGURE 5.4 The main areas of a work order form.

Coding all pumps as equipment type 01 may help find pump work orders or plans later on a computer database.

There might be a number of codes the plant develops to enable various uses of plant data. Appendix J shows typical codes. Examples are work type, priority, outage, department, craft, crew, plant, unit, building, plant area, process group, process system, equipment type, manufacturer, proactive versus reactive, and minimum versus extensive.

The planners code the work orders rather than everyone in the plant coding his or her own work orders. This maintains better consistency of data. The planners maintain the

plant's filing system and the coding allows access to this critical information. Because the codes lend themselves to interpretation at times, it is best to use as few persons as possible to code them. This is similar to a library. Once a book is returned to the wrong shelf location, it becomes lost for all intents and purposes. A computer especially requires consistency of data. The exception to this guideline is having the originators place the initial priorities on work orders because they have first hand knowledge of the work situation. The plant consistently using an intelligent, equipment numbering system helps ease the problem of selecting the wrong codes.

| |
|---------------------------|
| WORK ORDER #001234 |
| REQUESTER SECTION |
| APPROVAL: |
| PLANNING SECTION |
| CRAFT FEEDBACK |
| APPROVAL: |
| CODING |

FIGURE 5.5 Example simple work order form used for illustration.

| | |
|---|-------------|
| WORK ORDER #001235 | |
| REQUESTER SECTION | Priority R2 |
| #2 Control Valve B Strainer (N02-FC-003) has high pressure drop. Def. Tag #010304. No outage required. Needs mech crew. Clearance Req. No Confined Space. | |
| J. Smith 4/21/98 3:00pm APPROVAL: S. Brown 4/21/98 | |
| PLANNING SECTION | |
| | |
| CRAFT FEEDBACK | |
| | |
| APPROVAL: | |
| CODING | |

FIGURE 5.6 Work order after the originator completes the information.

The planning department uses at least two planners for coding because the work orders must be processed without fail. Two persons allows the absence of one planner not to delay the coding.

Each morning, designated planners code spaces at the bottom of the work order form for each new work order. This means that planners are the first persons in the maintenance department to see new work orders. Sometimes the planners notice insufficient data supplied by the originator. The planner may be able to obtain this information later when scoping the job. However, if the originator supplies all the readily available information, maintenance planning has a much easier job planning the work.

Receiving new work orders with insufficient data is a very sensitive area. On one hand, the plant desires all persons to be able and willing to write work orders as they see areas in the plant needing attention. On the other hand, poorly written work orders hinder the maintenance effort (going back to the days of illegible Post-its). This is a management commitment area to stress how timely information helps maintenance support the entire plant's reliability. Planners should not simply complain of widespread problems with origination, but help management understand the problem with specific work order examples.

Figure 5.7 shows the example work order after morning coding. The planner used the coding system in App. J. The planner could have made a case for coding the work order as P (proactive) since at first glance this important plant process had not yet been affected. This logic was furthered by the operator setting the priority as a 2 (serious) rather than 1 (urgent). However, the planner realized that normally the operators blew down strainers into the oil tank without a need for maintenance attention. The strainer had failed and needed manual cleaning. Therefore, R (reactive) was the proper code. For similar reasoning, the work type was 5 (trouble and breakdown) rather than 9 (corrective maintenance). The work was also not minimum maintenance since planning desired to keep track of strainer work in history. The planner coded it as E (extensive). The equipment group was F (fuel) and the specific system was C (service pump). The equipment involved was an 18 (strainer). Crew 1-2 would be assigned the work and the proper outage code was 0. No outage was necessary.

USING AND MAKING A COMPONENT LEVEL FILE

The planner begins the planning process by selecting work orders from the plant's unplanned backlog. The waiting-to-be-planned file holds this work. The planner normally picks several work orders at the same time. This may allow scoping several jobs at once in a common plant area. After selecting the proper work to start planning, the planning process dictates that the planner should first consult the information already filed for the equipment in question. The planner should consult the files before scoping the jobs in the field. The files may yield information on past events that would help the planner know what to look for. The planner may also not find certain information that could be gathered in the field. The planner would then know to gather that information when inspecting the equipment on site.

Checking the files simply involves simply walking to the file section and looking for the appropriate minifiles. Component level files are called minifiles because they do not contain information for more than a single, specific piece of equipment. A minifile was made the first time the planning department ever planned for the involved equipment. If the planner finds that a minifile exists for the piece of equipment, the planner scans the included information inside. If there is no component level file for that equipment, the first thing a planner would do is make one. Chapter 7 describes how a planner makes a minifile.

Planners should not underestimate the value of making a minifile for nearly every piece of equipment on which maintenance performs work. If certain equipment in the plant is important enough to have a separate identification number, it is important enough to have a minifile.

The planner gains what useful information is available in the minifile for each piece of equipment before scoping the work orders.

For our example work order, there was no file for that piece of equipment, so the planner created a new file using the equipment number N02-FC-003. Then the planner proceeded to scope all the selected work orders.

| | | | | |
|---|--------------|----------------------------|----------|--|
| WORK ORDER #001235 | | | | |
| REQUESTER SECTION | | Priority R2 | | |
| #2 Control Valve B Strainer (N02-FC-003) has high pressure drop. Def. Tag #010304. No outage required. Needs mech crew. Clearance Req. No Confined Space. | | | | |
| J. Smith 4/21/98 3:00pm | | APPROVAL: S. Brown 4/21/98 | | |
| PLANNING SECTION | | | | |
| | | | | |
| CRAFT FEEDBACK | | | | |
| | | | | |
| APPROVAL: | | | | |
| CODING | Plan Type RE | Group/Syst FC | Crew 1-2 | |
| | Work Type 5 | Equip Type 18 | Outage 0 | |

FIGURE 5.7 Work order after the planner completes the coding.

SCOPING A JOB

Scoping simply means identifying all the work required. Scoping is a subset of the planning process. Scoping refers to the overall work scope and not other planning tasks such as identification of parts and time estimates. Scoping is necessary even though the person who requested the work provided descriptive information. Work requests sometimes have only a description of the problem itself. If the work request states that "The boiler feed pump is

running hot," obviously the work needed to remedy the problem has not been defined. The process of defining that work is called scoping. At other times, work requests come with a description of the work desired. A work order may state, "Replace the gasket for the leaking flange." Although the work appears to be defined well enough to continue planning, scoping by the planner is still beneficial. The planner scoping the job looks through the eyes of a skilled maintenance technician, rather than those of an operator or less skilled technician. The skilled technician planner may see a pipe hanger 10 feet away has come loose causing the flange to leak. The planned job scope should include attention to the pipe hanger in addition to the flange. Instead of the pipe hanger, the planner may realize that a nearby valve is leaking instead of the flange where the drip appears. Whether the valve packing needs tightening or the valve needs replacing becomes the job scope decision. The scope may include a need for scaffolding after the planner sees the height of the valve. The planner ensures that the plan specifies the right job through scoping work orders.

During scoping, the planner may alter specific information contained in the work request. Consider the example of a leaking valve causing a flange to appear to be leaking. The originator requested the flange gasket be replaced. The planner would mark over the request and explain the actual problem, the valve. The planner would specify that the valve be replaced if that is the proper course of action. The planner would correct any equipment tag information in the request. The planner would have to change the equipment tag number specified from the pipeline to the valve.

The work involved in correctly scoping a job increases in complexity from simple minimum maintenance, reactive work to extensive proactive work.

Beginning with work that is both minimum maintenance and reactive, the key is personal planner experience for scoping. The planner should not need to consult any minifiles or the computer. A field inspection may not even be necessary, but is usually recommended. A work request might state, "Replace the broken window in the field office." In this case, a field inspection might be necessary to ensure the correct job is planned. Close inspection of the window job might reveal that the broken window has a rotten wooden casing so its replacement must also be put into the job scope. The consequence of missing the rotten casing could be the wasted hour or two of an assigned technician. The technician would return and declare the window cannot be replaced before a carpenter is called. That is one reason why planners should have top level technician-level skills. An experienced technician has run into many of these type problems and knows what to inspect.

For jobs that are reactive but also extensive the planner would always consult the minifile and the computer. The planner would always make a field inspection. However, because of the urgency in processing reactive work, only if there is great uncertainty would the planner consult operators or otherwise proceed further in investigation.

For proactive work, urgency is not critical. The objective is to avoid future reactive work by planning excellent proactive work. For proactive work, the planner may take time to consult any minifiles and the computer even for minimum maintenance work to develop a good job scope. For proactive work that is extensive, the planner develops the best job scope possible, not hesitating to consult operators or other knowledgeable sources, if needed. Sources to be researched for proactive work may require looking beyond the minifiles and include equipment technical files and vendor files. These files are described in Chap. 7, Forms and Resources Overview. A root cause analysis may also be advisable. Operation of the equipment may be necessary to observe the problem in some proactive cases.

However, any time proactive or reactive work requires in-depth troubleshooting, predictive testing, performance testing, or engineering, the planner refers it to the planning supervisor for possible reassignment. Reassignment is desirable for a couple of reasons. One reason is not to bog down planners with a few unusual jobs and neglect the rest of the backlog. Another reason is to get special expertise when needed.

First, the planner cannot afford to become bogged down on one or two jobs and not plan the other 20 jobs. Most of the work performed by maintenance is routine. That

means it does not require extraordinary measures to scope the jobs. Jobs such as valve replacements, flange leaks, and loose linkages far outnumber situations where a skilled technician cannot make a fairly rapid determination of the job requirements. The planner needs to make sure all of those routine jobs are planned so that crews can schedule their work and avoid unnecessary delays, such as having to find part numbers already available in the files.

Second, some jobs merit specific expertise. Resources for planning to consider might include engineering such as plant engineers, predictive maintenance, performance testing, and the plant controls group. Planners must involve these groups when necessary.

The planning supervisor or planning department may have guidelines for when the planners should request assistance. The guidelines for what jobs to reassign and whether to have an engineer in the planning group itself depend on what type jobs would slow the planners. A very skilled planner group may be able to handle a wider variety of complex jobs than a less experienced group without becoming bogged down. One of the supervisory responsibilities of the planning supervisor would be to monitor what jobs are troublesome and cost too much time in planning for the planning group.

Planning groups must also maintain an awareness of plant procedures to coordinate certain actions with outside agencies. The plant may have an agreement with its insurance carrier to notify it whenever a fire prevention system is turned off for maintenance. Normally, the primary responsibility for this type of notification would fall with the operators who perform the actual clearing and shutting off of the system. However, the planners may be able to use their file systems to provide helpful reminders. Some plants also place a burden on specific plant engineers to remember and fulfill these requirements.

The plant also benefits from having some mechanism to allow canceling of work orders. The best scope of work may be not to do the requested work and the planner sometimes coordinates these decisions. The work orders may not be thought necessary because of the broader scope of knowledge of plant operations that planners may possess. Certain work orders may not be needed because of a soon-to-be-executed project to resolve the situation. The plant may be able to cancel certain work orders to repair portions of an old demineralizer beyond immediate repairs if the project group intends on installing a new demineralizer. The plant can reconcile work orders to planned projects in different ways. Plant engineers may have the responsibility of reviewing new work orders with this in mind. Planners may have the primary responsibility to be aware of these projects to turn back unnecessary work orders.

The following illustrates the actions of a planner to scope different types of work orders. The planner selects four work orders from the waiting-to-be-planned file.

In the first case, the planner has to scope a reactive, minimum maintenance job. A plant engineer has written a work request to replace a pressure gauge. The planner knows there are many of these gauges in the storeroom. The planner walks out in the field to make sure which gauge the engineer is referring to. The planner also checks to see if the gauge has an isolation root valve or if the system has to be cleared.

In the second case, the planner has to scope a reactive, extensive maintenance job. The operators have reported a control valve that is leaking through. The planner consults the minifile for the valve and inspects the valve in the field. Since this valve has no information in the minifile to indicate otherwise, the planner decides that maintenance should replace the valve.

In the third case, the planner has to scope a proactive, minimum maintenance job. The plant environmental engineer has written a work request to make and place a "No Swimming" sign by the percolation pond. The planner reviews the area and decides the sign should be attached to an existing fence. The planner asks the engineer if this would be acceptable.

In the fourth case, the planner has to scope a proactive, extensive maintenance job. The predictive maintenance group has reported another control valve leaking through.

The planner consults the minifile for the valve and inspects the valve in the field. The planner decides that maintenance should try to replace the valve. Since this valve has no information in the minifile, the planner spends some time to research several technical manuals and talk to a supervisor to see if this valve might be rebuilt in place.

Note how scoping the jobs varies in complexity because of the need to move reactive work quickly to maintenance and do careful analysis on proactive work. The overview of duties for a maintenance planner in App. E provides a more formal, step-by-step type checklist of these activities for the different type work requests received.

ENGINEERING ASSISTANCE OR REASSIGNMENT

Most of maintenance is routine and can be handled by planners. The planners must get all the work planned so that effective scheduling can consider all the plant's work. Planning must not become delayed on the exception work orders that could prevent the other work from being planned.

The common maintenance task is not an engineering concern. Adjust a valve here, replace a gauge there, overhaul a pump here. These ongoing maintenance tasks make up the vast bulk of maintenance. This work could arguably include some desire for engineering scrutiny. However, the main task of maintenance is maintaining or preserving a performance level at a previously engineered specification level. This engineering was completed at the original installation of the equipment long ago. Let the engineers concentrate on analysis in projects designed to make things better, but that does not include most of what is going on in maintenance.

Occasionally jobs are received in planning that need engineering solutions or designs. An example would be an access platform where structural integrity is important or where detailed drawings are necessary. Another example would be where a repeated failure indicates a need for a different type valve or special material. In general, a reactive work order would get less of this type scrutiny and be left up to the maintenance crews to resolve, but a proactive work order's objective is to head off future reactive work, so engineering help may be appropriate. A plant engineer should be able to advise whether PVC piping could be used to replace a chronic failure situation for carbon steel. A job plan that requires sizing a pump could be handled quickly by a plant engineer. Some jobs obviously need to become turned into projects such as adding a new demineralizer. The planners need to make sure these jobs do not come through planning, but are handled entirely by a project group or the plant engineers. If a plant intends to use maintenance labor to install the equipment, the scheduling aspect may come into play. However, planners do not need to become involved in the design. Other jobs not worthy of being called out-right projects still may not need to go into planning until after a design is completed. Overhauling a steam trap system may need to go through plant engineering for trap selection and piping sizing and routing. Then planning can take the completed design to coordinate parts and assign estimates for labor and schedules.

To reassign work or receive engineering assistance, the planner consults with the planning supervisor or planning department guidelines. Some plants have a plant engineer as part of the planning group to handle quick questions without reassignment and to coordinate the jobs that do become assigned to the plant engineer group. Otherwise, the planner is responsible for keeping up with planned packages that are waiting for engineering.

A word of caution to planning groups with a strong engineering presence: The engineers should not be allowed to redirect the planners' focus. Engineers may be tempted to use planners to collect equipment data rather than allow them to plan routine maintenance work.

The planner should indicate on the final work plan any engineering input received and why. For example, the planner would not write simply "Replace with staged new valve." A better plan would be: "Replace with staged new Teflon valve per engineer Brown's recommendation to avoid previous corrosion problems." The failure to include the "why" of a job plan has resulted in many field technicians coping within their own experience to a fault. If the technicians thought they could patch the existing valve to save the company time and money, the expanded job explanation from the planner would help them see the big picture. The idea is to explain the "what" as well as possible so that the technicians can react with the best information to the actual job circumstances. Planners should always pass along technical information.

DEVELOPING PLANNED LEVEL OF DETAIL, SKETCHING AND DRAWING

Similar to scoping a job, the planner spends the least time describing what work needs to be done on reactive, minimum maintenance jobs and the most time on proactive, extensive jobs. Only on a proactive, extensive job would the planner consider searching files other than the minifiles to find new information. The planner must adhere to Planning Principle 5 and avoid telling an experienced crew "how" to do the work. The plan must emphasize the "what." Putting unnecessary "how to" steps in the planned packages causes planning problems. The unnecessary effort takes up valuable planning time and frustrates empowered technicians who take pride in their skills and techniques.

For example, a planner might say, "Repair" or "Replace" a valve, but never, "Repair or Replace." It may be acceptable in certain circumstances to say "Attempt to repair the valve unless internal valve inspection requires valve replacement."

The planner might say in the case of repair that the "Internals probably need replacing," but would not give steps on how to disassemble the valve if an experienced craftsperson should know how to do it already. On the other hand, if the minifile already had an easy-to-copy procedure available, the planner might attach it as a reference. A copy of any standard plan should be attached if there is one for the job.

The description of what work is needed goes in the planner section on the work order form. The planner should write down the scope of the job and the results of any research to give the technician helpful information. For example, "Replace the valve. History file indicates repeated failures and patches." Another example, "The equipment could not be run, but information from operator J. Smith indicates a failed bearing. Disassemble to inspect and replace the bearing or other corrective action necessary." Another example, "Replace the entire pump because cost information indicates repairing is not cost-effective."

The planner may feel that certain steps should be given to help clarify the intent of the plan. The steps may also be needed to help coordinate resources. When giving steps, the planner might number them. For example:

1. Erect scaffolding
2. Replace valve
3. Remove scaffolding

If the planner needs any more room than the space provided on the work order form, the planner might have to attach an additional page of writing.

The planner should also identify any attachments sent out with the first page of the work order form. This allows the schedulers and crews to make sure they have all of the planned information. It also allows the planner to check its return after job completion.

One intent of the job plan work scope and plan detail is to provide a good technician with enough information to reduce the incidence of the technician having to delay the job seeking additional instructions on what to do. The planners reduce potential job delays when the work order plan identifies enough information so that the technician does not have to make extra trips to seek help from the supervisor. As with any trip, the technician's leaving the job site causes a job delay. Any trip away from the job might not only consist of a momentary delay finding the crew supervisor. Frequently, trips allow other distractions to hinder the technician's prompt return to execute the work.

On the other hand, a point of diminishing returns exists for providing information. For example, consider an electrical planner sketching a conduit run. The planner had been sketching for an hour. If the planner did not do the layout, then a field technician would have to spend about an hour doing one. The crew could simply field run the conduit because system constraints did not mandate any certain route. The planner was doing the layout in order to know how much conduit to reserve from the storeroom. However, the planner could just guess that between 100 and 200 feet of conduit would be needed without doing a layout. In this case, the planner should simply reserve 200 feet of conduit and send the plan on its way. Think about it. The one electrical planner was supposed to be planning for 20 to 30 electricians. There is no way the planner can justify spending an entire hour to save a technician only a single hour in the field. A planner is worth 17 technicians because the planner can help leverage the work of 30 persons into the work of 47 persons. To plan the specific details of the conduit run in this case would be to violate Planning Principle 5. The planner violates Principle 5 in not recognizing the skill of the crafts. The planner also violates Planning Principles 1 and 4. The planner violates Principle 1 when the planner does field work the crew should do. The planner violates Principle 4 because the planner is not quickly using a planner's expertise to estimate a job. Consequently, the planner might not plan all the backlogged work. The domino effect starts. Not getting all the work planned leads to not being able to schedule enough work for a crew for a week. Thus the crew does not have a goal of work to complete. In addition, an excessive amount of unplanned jobs causes a multitude of problems. It frustrates the crews if the crews are not allowed to have it. If they are allowed to work on unplanned work, it is not only less efficient, but there is an excuse not to do planned work.

One of the reasons the electrician example ended up as a problem may be a false perception that planning takes care of all paperwork. This includes the time before and even after a job. This reasoning is false because planning is supposed to add value to the maintenance process, not just do something that someone else used to do. There is nothing wrong with a technician doing some paperwork before the job such as figuring how to field run conduit. This particular job might not require a drawn conduit run at all. Technicians filling out paperwork for feedback after a job is essential to the whole planning concept. It provides the basis for improvement on subsequent jobs. Paperwork is not a criteria involved in deciding how much detail to put into a job plan.

Sketching or drawing is a particular concern. Planners may need to provide plant schematics or other engineering drawings as attachments to jobs. However, planners should rarely have to draw diagrams themselves unless they have a gift for sketching. Some planners can make sketches to illustrate job needs faster and better than they could describe the job in words. On the other hand, many planners have felt required to provide sketches on jobs when the planners were not talented in drawing and the sketches simply were unnecessary.

The planners must respect the skills of technicians. This allows planning all of the work. The planner must also consider other plant specialists when planning. This permits utilizing the proper expertise on certain jobs.

Figure 5.8 shows the earlier example work order after the planner decides on the scope of the job and adds the necessary level of detail to describe the steps of the job.

| | |
|---|---|
| WORK ORDER #001235 | |
| REQUESTER SECTION | Priority R2 |
| #2 Control Valve B Strainer (N02-FC-003) has high pressure drop. Def. Tag #010304. No outage required. Needs mech crew. Clearance Req. No Confined Space. | |
| J. Smith 4/21/98 3:00pm APPROVAL: S. Brown 4/21/98 | |
| PLANNING SECTION | |
| Clean strainer positioned in front of the control valve. Remove strainer element, clean, and replace. Replace gasket if needed | |
| CRAFT FEEDBACK | |
| APPROVAL: | |
| CODING | Plan Type RE Group/Syst FC Crew 1-2 Work Type 5 Equip Type 18 Outage 0 |

FIGURE 5.8 Work order after the planner completes scoping and adds the appropriate level of job step detail.

CRAFT SKILL LEVEL

Planners designate craft skills needed on job plans. This allows schedulers to select the appropriate jobs matching the skill levels possessed by each crew. It also allows crew supervisors to determine to which persons to assign the jobs. With the crafts specified by the job plan, schedulers and supervisors do not have to thoroughly read each work order and decide for themselves which crafts the jobs require.

The planner also plans each job to allow the lowest qualified skill level. This increases the flexibility of the schedulers and supervisors in selecting or assigning the work. Different jobs require a different minimum craft skill level. If a certain job could be done either by a junior mechanic or a certified mechanic, the job plan would not want to specify a certified mechanic. That would limit the choices for who could do the work. On the other hand, the planner could not specify a trainee who would not have the minimum skill levels necessary to be qualified for the job.

The designation of crafts and skill levels provides for communication from the planners to the schedulers and supervisors. The planners, schedulers, and supervisors must have a common understanding of the terms used.

The following designations have been adopted for the purposes of illustrating the selection of crafts and skill levels in this book. All of the maintenance departments at the plant understand what each designation means when it appears on a work order from planning.

Trainee: Any person newly hired in the maintenance, but not yet enrolled in an apprenticeship program.

Mechanical trainee: A person newly hired in the mechanical maintenance craft, but not yet enrolled in the apprenticeship program.

Electrical trainee: A person newly hired in the electrical maintenance craft, but not yet enrolled in the apprenticeship program.

I&C trainee: A person newly hired in the instrument and controls maintenance craft, but not yet enrolled in the apprenticeship program.

Apprentice: Any person enrolled in the apprenticeship program for one of the maintenance crafts. These persons are normally not assigned work by themselves when the primary objective of the plant's apprenticeship program is for them to learn alongside higher skilled technicians.

Mechanical apprentice: A person enrolled in the apprenticeship program for the mechanical maintenance craft.

Electrical apprentice: A person enrolled in the apprenticeship program for the electrical maintenance craft.

I&C apprentice: A person enrolled in the apprenticeship program for the instrument and controls maintenance craft.

Helper: Anyone. This designation is used if the job does not require any special skills outside that of an adult maintenance employee. This person could possess only the skills of a new trainee, but may also possess the skills up to any certified technician. The planner will use this classification alongside that of a more specific craft skill to indicate that the primary need is for an extra set of hands. The planner may also require only helpers on a job. This does not mean the supervisor would assign two apprentices, but that the job does not require any specific skills.

Technician: Thus far, this book has used this term to mean anyone in the work force. This has allowed the illustration of the principles of planning without unnecessary details of craft skills. However, in the use on particular job plans, this term means a person that has passed the apprenticeship programs in one of the craft areas. The term also implies a measure of responsibility and accountability. The plant would normally hold a technician accountable rather than an apprentice for the results of a particular job.

Mechanic: A mechanic technician. In this plant, the mechanic possesses a certain amount of structural welding skills and light machining skills.

Welder: A welder technician able to do high pressure welding.

Machinist: A machinist technician able to perform most machine work for the plant.

Painter: A painter technician.

Electrician: An electrical technician.

I&C technician: An instrument and controls technician.

Lab technician: A technician that works in the plant laboratories.

Certified mechanic: A mechanic technician who has gained special experience, knowledge, and skills in the mechanical craft. The plant has given this technician the extra privilege and responsibility of being able to stop certain jobs in the field whether or not assigned to them for quality concerns.

Certified welder: A welder technician who has gained special experience, knowledge, and skills in the welding craft. The plant has given this technician the extra privilege and responsibility of being able to stop certain jobs in the field whether or not assigned to them for quality concerns.

Certified machinist: A machinist technician who has gained special experience, knowledge, and skills in the machining craft. The plant has given this technician the extra privilege and responsibility of being able to stop certain jobs in the field whether or not assigned to them for quality concerns.

Certified painter: A painter technician who has gained special experience, knowledge, and skills in coating and corrosion. The plant has given this technician the extra privilege and responsibility of being able to stop certain jobs in the field whether or not assigned to them for quality concerns.

Certified electrician: An electrical technician who has gained special experience, knowledge, and skills in the electrical craft. The plant has given this technician the extra privilege and responsibility of being able to stop certain jobs in the field whether or not assigned to them for quality concerns.

Certified I&C technician: An I&C technician who has gained special experience, knowledge, and skills in the instrument and controls craft. The plant has given this technician the extra privilege and responsibility of being able to stop certain jobs in the field whether or not assigned to them for quality concerns.

Certified lab technician: A laboratory technician who has gained special experience, knowledge, and skills in the laboratory. The plant has given this technician the extra privilege and responsibility of being able to stop certain jobs in the field whether or not assigned to them for quality concerns.

Using specific craft and skill designations provides a common ground for discussions and reduces misunderstandings. Commonly used terms can be agreed on if they do not represent specific labor classifications used by payroll.

Figure 5.9 shows the addition of craft skills to the work order. The planner has determined that the job requires two persons. One person must possess at least the skills of a mechanic technician. The other person could be anyone to assist the mechanic.

ESTIMATING WORK HOURS AND JOB DURATION

Work hours (or labor hours) are the actual craft personnel hours that technicians later enter on personal time sheets and job duration is how many hours the job lasts. Consider a pump

| | | | |
|---|--------------|----------------------------|----------|
| WORK ORDER #001235 | | | |
| REQUESTER SECTION | | Priority R2 | |
| #2 Control Valve B Strainer (N02-FC-003) has high pressure drop. Def. Tag #010304. No outage required. Needs mech crew. Clearance Req. No Confined Space. | | | |
| J. Smith 4/21/98 3:00pm | | APPROVAL: S. Brown 4/21/98 | |
| PLANNING SECTION | | | |
| Clean strainer positioned in front of the control valve. | | | |
| Remove strainer element, clean, and replace. | | | |
| Replace gasket if needed. | | | |
| Labor: 1 Mech | | | |
| 1 Helper | | | |
| CRAFT FEEDBACK | | | |
| APPROVAL: | | | |
| CODING | Plan Type RE | Group/Syst FC | Crew 1-2 |
| | Work Type 5 | Equip Type 18 | Outage 0 |

FIGURE 5.9 Work order after the planner determines the craft skill level required.

job that lasted 2 entire days and had two persons working 10 hours each day. The work hours would be 40 hours and the job duration would be 20 hours. Note that for job duration, only calendar time when someone was working on the pump applies. The estimated work hours and job duration are necessary to schedule the work efficiently.

Operators need the duration information to know how long to expect equipment should stay cleared and unavailable. The job duration is also useful when considering what work could be completed in a short outage situation. Consider a short outage that suddenly occurred and had an estimated length of 24 hours. Any backlogged outage job with an estimated job duration of equal to or less than 24 hours should be considered.

The planner uses the work order form to write the estimated work hours for each job. The planner specifies the number of persons and the work hours for each person estimated for the work. Then the planner totals all labor hours on the work order form. The planner also specifies the estimated job duration hours on the form.

The planner develops the work hours and job duration estimates from personal judgment and consultation of the minifile in most cases. The previous jobs in the minifile are helpful, but the planner is not restricted to using previous estimates or actual hours reported. The planner is attempting to estimate the hours reasonably required by experienced craftpersons without unexpected delays.

Experienced craftpersons means that the planner should plan the job time estimate for a good technician, not the average technician, not the slowest technician, and not the fastest technician. There is no way that the planner knows to whom the supervisor will assign the job. The supervisor may assign the job to the worst technician, an average technician, or the fastest technician on the crew. For whom should the planner plan? This entire consideration is essentially the same as for technician skill level where Planning Principle 5 recommended that the planner respect the skill of the crafts.

Estimating the time of each job for the slowest technician means adding a lot of extra time to every job. When every job is planned this way, the planner allows too much time that most technicians do not need. Instead of planning a job with the slowest person in mind, the planner plans knowing that although the slowest person may need extra time, the help may not come from the plan itself. These technicians might get extra help from being assigned to jobs where a more capable technician is also assigned to the same job. The supervisor may spend more time on the job with a technician in a coaching role. The supervisor may choose to give this technician the extra time that the technician requires.

On the other hand, estimating each job's time for the average technician has problems. *Average* means probably as many technicians in the same classification need more time as need less time. In addition, one might think there is a small standard deviation away from this average or mean. That is, on the whole, most of the technicians in the same classification possess about this mean level of capability. This is a very dangerous presumption that may not be true. In many organizations, the skill level widely varies within a single classification. There is no large, single aggregate of persons with a similar capability. Out of a group of 20 technicians, the more realistic case may be two or three near the bottom, three a little faster, a couple above them in speed, four above them, three considered decent, three considered good, and two or three technicians who can do almost anything quickly. To complicate matters, the general hierarchy changes with respect to different types of work within the classification. The absolute slowest technician with respect to pumps may be quite decent with respect to valves. Two of the decent technicians with respect to valves and piping may be quite deficient with regard to rotating equipment. So the fastest technicians in some respects could be the slowest technicians in other respects and there may be only an illusion of what average means.

One problem of planning all jobs for the average technician is similar to planning all jobs for the slowest technician. Although the planners can estimate less time than if they were planning for the slowest technician, the planners are still allowing more time than some persons need.

The most significant problem is that there is no standard of what time a good job should take if all jobs are planned with average in mind. If maintenance assigns a job, the company has some profit motive in mind. The company wants good work and so does the technician. What time should a good job take? Jobs planned for good technicians mean that technicians pull their weight and a little more. They are not just keeping up with the sled. Jobs planned for good technicians set a time standard for all technicians by which they can judge their skills. Planning for the level of a good technician gives the crew an idea of how good it is.

Why should planners not plan all jobs for the fastest technician? There are some problems associated with planning jobs for the fastest technician, namely schedule realism. For one

thing, the supervisor needs some accuracy to schedule work. The estimates also set time standards. The time standards should allow average technicians to rise to the challenge to do a good job. These challenges and the scheduling are not practical if all jobs were planned for the fastest technician.

How do planners know how much time a good technician needs on any particular job? Planners cannot know unless they are at least good technicians themselves. By putting a best technician in planning, management assures itself that the planners can easily judge different jobs and assess what time frames and details should be needed by a good technician.

In addition, having a superior technician as the planner gives the job plan credibility. This helps when the supervisor finally assigns a planned job in the field. The field technician presumes the job plan to be practical and does not second-guess the standard.

Another consideration is that of job delays with wrench time. Although proper planning and scheduling helps produce high wrench time, the planners do not consciously consider wrench time when estimating jobs. The planners simply estimate each job without unexpected delays.

Without unexpected delays means the planner should consider including break time, but not time to find unexpected parts, tools, or instructions that were not identified by the planner. Jobs that take longer or shorter than estimated should be identified by the craft personnel reporting what happened on the work order form. These comments help guide the planner reduce delays on future jobs. The planner may be tempted to put in an extra hour in case problems arise. If the planner automatically included time in the estimate for unexpected delays or inexperienced craft personnel, actual delays or problems may not be reported if the overall time estimates were met. The preceding discussion addressed slower technicians, but not other type delays. Even the best planned jobs can run into unexpected problems. If a job runs over or under the estimated time, it is not as important as if crews become better each time they do the job. Crews become better each time doing the job with planning around expected delays. The planner anticipates some delays from personal experience, but the best source of delay information on any particular job for any particular equipment is from its equipment file. The planner can look in the file and readily see that previous jobs required an extra gasket. So the planner includes having an extra gasket in the job plan. This improvement would not be possible if the use of an extra gasket had never been reported by the technician. Having the time estimated for a smooth job (no unforeseen problems) obligates the technician to explain and record unusual circumstances that slowed the job. Therefore, planners should not include miscellaneous extra time in job estimates.

There are also other reasons to include only the amount of time planners actually estimate the job should take. The time estimate helps explain the job scope. For instance, giving a technician a 10-hour estimate for a job that obviously should take no more than 4 hours may confuse the intent of the job plan. Consider a job scope that calls for changing the lubricant of a fluid drive, but the planned estimate includes far too much time. The technician may wrongly conclude the job includes changing all the filters as well. The estimate of only the actual time expected also gives the technician a reasonable target to shoot for and keeps the work moving. In addition, many jobs go exceptionally well and end up taking less time than the planner imagined, so any extra time included on estimates should be kept to a minimum.

Planners should be mindful of avoiding the practice of estimating job durations by shift hours. This practice might cause many jobs to be planned as 4- or 8-hour jobs when crews work 8-hour shifts or 5 or 10 hours when crews work 10-hour shifts. This needlessly adds hours to jobs and reduces the schedulers' ability to put small jobs in schedule gaps. A 3-hour job should be planned for 3 hours, not 4.

A special word concerning breaks and startup or wrapup time is appropriate. The planners' estimates do not have the precision to be unnecessarily worried about such details. The planners figure that 10 hours of work can be accomplished in a 10-hour day. Planners usually

consider there would be no breaks in short jobs, but one or two breaks in longer jobs during a single day. Similarly, the planner might realize there is a certain amount of time lost in starting up or wrapping up at the beginning and end of shifts. Plans for a short job do not make special provision for these times, but plans for longer ones might. On the other hand, job plans should recognize that time might be required for cleanup at the end of certain jobs regardless of size.

Finally, one must remember that even before management ever initiates planning and scheduling, a quality focus must be in place. Technicians must not feel they must meet a limited time estimate rather than do good work. Planning pushes so hard for productivity that the work force must have adequate concern for quality.

Figure 5.10 shows that the planner of this example work order estimated 5 hours for each person. The planner estimated the total job to require 10 labor hours and 5 duration hours.

PARTS

The identification and coordination of parts or material is an area where the planner can greatly help improve craft productivity. Although scheduling information provides the greatest planning help to maintenance, planning's help with parts is the most visible. This is the reason most organizations begin planning departments. The offer of help with parts usually encourages technicians to accept planning.

On the other hand, the advertised idea that planning will identify all future parts severely hinders the accomplishment of the planning mission. Planning cannot gather all parts information before all jobs. The technician's idea of that purpose which planning does not fulfill gives planning a poor reputation that hinders later cooperation from technicians. The vital role that planning fulfills is to save and retrieve parts information that the technicians have previously gathered. This is how planning helps future jobs. Management should first introduce planning properly to avoid later misunderstandings.

The intent of planning with regard to parts is to identify them and ensure their availability before the job begins. The planning department may also stage certain parts to reduce delays in technicians having to gather them. As with job instructions, the planners reduce potential job delays when the work order plan identifies parts because the technician does not have to make extra trips to procure them later after the start of a job.

To identify the parts a job requires, a planner first consults the equipment's minifile to review previous job requirements or problems. The plans and feedback from previous jobs contain most necessary parts information. Other material in the minifile may contain lists of possible parts. If the necessary information is not in the minifile, the planner may be able easily to identify the parts necessary in the inventory catalog or listing. The planner might do this even for reactive jobs if there is time. On proactive jobs, the planner might spend a considerable amount of time searching the plant's other technical files or vendor files. The planner makes sure to make a copy of any helpful information found to put in the minifile.

The planner writes down the information for needed parts directly on the work order form. The planner should identify only anticipated parts within the plan itself on the work order form. By only identifying anticipated parts within the work plan itself, the planner helps clarify the job scope. However, many jobs may need additional parts other than that first anticipated. The planner should include the identification of other parts that there may be a fair chance of using. This allows the technicians to obtain them more quickly if needed. The planner may identify these parts lower on the work order form and not necessarily within the plan of the anticipated work.

Even if there have not been delays on previous work, including a parts list in the planned package helps the technician understand the equipment and be ready for procuring unan-

anticipated parts. The planner might attach a list of all parts the equipment uses if the list is readily available. The planner attaches a copy of this list to the back of the work order form. The planner never sends the original out in the field. The planner also makes a note on the work order form identifying attachments. This note helps the technician know there should be attachments in case something becomes lost. It also helps the planner account for returned items at the end of the job. The planner would not attach a complete parts list for a simple job that would definitely not need any of the parts on the list. This would simply encumber the technician with extra paperwork.

| | |
|---|---|
| WORK ORDER #001235 | |
| REQUESTER SECTION | Priority R2 |
| #2 Control Valve B Strainer (N02-FC-003) has high pressure drop. Def. Tag #010304. No outage required. Needs mech crew. Clearance Req. No Confined Space. | |
| J. Smith 4/21/98 3:00pm APPROVAL: S. Brown 4/21/98 | |
| PLANNING SECTION | |
| Clean strainer positioned in front of the control valve. Remove strainer element, clean, and replace. Replace gasket if needed. | |
| Labor: 1 Mech 5hr Total labor 10hr 1 Helper 5hr Job duration 5hr | |
| CRAFT FEEDBACK | |
| APPROVAL: | |
| CODING | Plan Type RE Group/Syst FC Crew 1-2 Work Type 5 Equip Type 18 Outage 0 |

FIGURE 5.10 Work order after the planner estimates the time required.

Once a job begins the planner is no longer responsible for helping identify any necessary parts. The responsibility then falls on the crew supervisors and technicians. These persons may use any available resources including all the files in the planning department. They must record parts information uncovered during job execution as feedback on the work order form to help future work.

Equipment Parts List

Information on parts that equipment might require comes in many forms. Lists of parts are known by different names such as part breakdowns and bills of material. Manufacturer "exploded view diagrams" or illustrated views showing how the different parts fit together are extremely useful.

The specific work orders from past jobs contain parts information either in the plans or in the feedback. Numerous repetitions of previous jobs develop a thorough listing.

The planner might use a parts form to record in one place the identification collected from previous work orders. Such a form is shown in Chap. 7, Forms and Resources Overview, for planners to include in minifiles when they create them.

If there is a standard plan as shown in Chap. 7 for a particular piece of equipment, it might contain a thorough listing of parts.

The storeroom inventory might be arranged by equipment number or contain a comparable sort. In addition, the CMMS computer system inventory module might automatically record the previous use of parts by equipment. This would provide an ongoing development of a parts list for each piece of equipment as maintenance works on jobs. Unfortunately, many CMMS inventory modules do not provide this automatic feature because they presume the plant has a complete set of parts lists for all its equipment. The modules primarily concern themselves with tracking quantities on hand and reservations for specific work order numbers.

When the company purchases new equipment, the equipment normally comes with an O&M manual showing a breakdown of parts. In addition or instead, the O&M manual might contain a list of recommended spare parts. Planners must insist on receiving these manuals when new equipment arrives. Planners should then create the appropriate minifiles to facilitate their use. If the planners merely place the manuals on the technical file shelves without sorting the information into minifiles, later efforts will be hindered. The planner may later find the manual to contain information for all the manufacturer's models and the planner will then be faced with an additional identification task.

Equipment sales proposals or negotiation notes may contain listings of proposed spare parts.

The planner might obtain lists of parts from vendors or manufacturers.

Management might initiate a project to gather parts lists from vendors and manufacturers. This effort could involve the identification of desired equipment, the collection of the lists, and the insertion into the proper minifiles. The project might involve plant engineers or other technical specialists. Management might choose to involve contract labor. Management might also choose to use field technicians to gather the data. Including technicians would facilitate their acceptance of the planning file concepts.

Purchasing

Sometimes a planner finds that a part necessary to execute a job is unavailable. The planner is responsible for all planned packages that are waiting for material. This material may be out-of-stock inventory items being ordered by the storeroom or nonstock items to be ordered by the planner. For nonstock items, the planning department is responsible for procuring the part.

The planner identifies on the work order form nonstock items that the planning department procured. The work order identification would normally name the item and describe where it was placed or staged after the plant received it.

The planning department has to include a purchasing capability or some method to procure parts. This purchasing capability may involve close coordination with a company or plant purchasing department. (In some companies, planning itself may be a department within the plant purchasing department.) Planning may also be able to purchase some material through direct vendor contact and purchase orders. The planning department might control several blanket purchase orders set up by the purchasing department to allow planning to buy certain material with a minimum of paperwork and administration.

When nonstock purchased material arrives at the plant, the planning department verifies that the shipment contains the proper material and makes the work order available for scheduling.

Many planning departments employ a separate purchaser or expediter to handle most of the purchasing coordination duties. This allows one or two persons to develop more familiarity with the company's purchasing requirements. This familiarity helps the person push through urgent work requests faster through the system if needed. In addition, this person might contribute to the planning department by having a special talent for finding parts that are difficult to locate. On the other hand, the planning department might prefer that the planners locate the desired parts and initiate the purchase. The purchaser would be more of an expediter to complete the details of the transaction and ensure the timely arrival of the material. Having a separate person might take an administrative burden from the planners.

In addition, once a job is in progress, the craft supervisor is responsible for procuring any parts that were unanticipated during planning. If the storeroom does not have these parts, they must be purchased. The planning department does not want supervisors to interrupt planners, but recognizes that a specialist might best handle purchasing. Having a separate person in planning that the supervisors can access for purchasing might allow resolution of both concerns. The supervisors could receive help, but not interrupt the planners.

A planner also needs to spend considerable time in the field. A planner spends time in the field to scope work as well as to inspect jobs-in-progress. Looking at jobs-in-progress allows the planners to increase their feel for the degree that jobs proceed according to plans and the completeness of feedback. On the other hand, a purchaser frequently needs to be available to accept return phone calls from vendors. Having the purchaser separate from the planner may facilitate these different planning department needs.

A plant might consider having a separate person to handle some purchasing duties under the following circumstances:

1. There is a lot of bureaucracy or complexity in the purchasing procedures.
2. Maintenance has a person available with the special talent required.
3. The planning department is fairly large and has more than three or four planners.
4. There is a continual receiving of shipments that must be inspected and staged.
5. There is a continual need to spend time verifying that parts will be compatible with the system or existing standards.
6. Planners are each planning for 30 technicians rather than 20.

In general, the purchasers would either be responsible to or report to the planners. Depending on their duties, the purchasers may not necessarily have to be technicians. Clerks may be qualified to serve as purchasers. Appendix F includes an overview of these purchaser or expediter duties.

Storeroom, Reserving, and Staging

In addition to naming any parts on the work order form, the planner also records the storeroom identification or stock numbers. This precisely identifies the material to avoid possible misunderstanding or delays at the storeroom. The technician presumes any planned part with a stock number is kept in the storeroom. The planner identifies which storeroom stocks the material if the plant has more than one storeroom.

Next the planner reserves anticipated parts in the storeroom and marks the planned items as "Reserved" on the work order form. *Reserving parts* means that the planner has placed a reservation on an item with the storeroom. This action ensures that the storeroom will not run out of the items before maintenance executes the particular job that had a reserved part. The storeroom uses the work order number to identify the reservation requirement. Normally the planner reserves parts that the plans require from the storeroom even if the storeroom has an ample supply of the items. This allows the storeroom more timely notice of the consumption of parts and helps it prepare for replacing inventory. The planning department also develops good work habits by reserving most parts. There are certain parts that the storeroom keeps in limited supply and the reserving of parts on a routine basis reduces the possibility of overlooking their reservation. Otherwise, a technician may start a planned job and find that a planned part is unavailable.

One common problem plants encounter is not experiencing a high stockout rate when, in fact, the storeroom frequently does not have enough parts the planner or technicians seek. Stockouts measure how many times the storeroom is out of an item that the plant currently requires. Stockouts do not necessarily measure that a storeroom is either out of a material or has a less than desirable quantity on hand. The discrepancy is caused by the planners or technicians not reserving parts or requesting pick tickets for items that are out of stock. When a planner sees that there is no desired item available, the planner will often plan the job another way. For example, a planner may change a plan to replace a valve bonnet to replacing the entire valve because the storeroom is out of bonnets. A technician may change the execution of a job in the same manner. Because no one ended up requesting the deficient part, the plant never experiences a stockout. Therefore, the planner and technicians should always reserve the parts to cause a stockout even though the planner and technicians alter the jobs. In this manner, the jobs are planned and executed expeditiously and the storeroom receives the appropriate signal to have enough quantities on hand in the future.

Another related problem is the storeroom having parts reserved for jobs that maintenance has already completed. This is usually caused by technicians requesting parts at the storeroom without informing the storeroom of a previous reservation. The technician receives the requested item, but the storeroom does not reduce the reservation quantity. The storeroom handles this problem by checking work order numbers for previous reserved parts when issuing parts to technicians. The storeroom should also check completed work order numbers against outstanding part reservations occasionally and canceling the reservations.

Next the planner stages any appropriate parts and marks on the work order form which items are "staged" and where. If items will not be staged until later, the planner does not mark on the work order form. Those items will be marked later when staged.

Staging is done for the same reason the operations group clears equipment ahead of time: to avoid delays. A plant does not desire for a crew to stand around waiting for operators to clear a piece of equipment. Similarly, the plant prefers a crew not to stand around waiting for a part or tool to begin a job if the item could have been provided ahead of time. The provision of the tool ahead of time is referred to as *staging*. Staging goes beyond reserving items in the storeroom or tool room. Staging places the items in convenient locations for the technicians. These convenient locations reduce the need for crews to make more time-consuming arrangements or side trips to gather the items.

The planning department always stages special purchased parts that inventory did not carry. The planner must note on the job plan where these parts were placed after their receipt.

It may be more appropriate for supervisors or schedulers to determine whether parts should be staged based on scheduling concerns. Therefore, the next chapter on scheduling discusses guidelines to assist planners determine the need to stage parts. These guidelines are summarized in App. A.

Figure 5.11 shows an example work order after the planner has determined the necessary parts. In the equipment's minifile, the planner found that a previous job identified the gasket stock number. Because the job was reactive, the planner would not have otherwise spent much time trying to determine a gasket number if it had not been readily available. The planner noted the gasket's price when reserving it and wrote the necessary information on the job plan.

| | |
|---|---|
| WORK ORDER #001235 | |
| REQUESTER SECTION | Priority R2 |
| #2 Control Valve B Strainer (N02-FC-003) has high pressure drop. Def. Tag #010304. No outage required. Needs mech crew. Clearance Req. No Confined Space. | |
| J. Smith 4/21/98 3:00pm APPROVAL: S. Brown 4/21/98 | |
| PLANNING SECTION | |
| Clean strainer positioned in front of the control valve. Remove strainer element, clean, and replace. Replace gasket if needed. | |
| Labor: 1 Mech 5hr Total labor 10hr 1 Helper 5hr Job duration 5hr | |
| Parts: Strainer lid gasket GSK-RR-130* Qty 1 Cost \$10ea | |
| *RESERVED | |
| CRAFT FEEDBACK | |
| APPROVAL: | |
| CODING | Plan Type RE Group/Syst FC Crew 1-2 Work Type 5 Equip Type 18 Outage 0 |

FIGURE 5.11 Work order after the planner determines the parts required.

SPECIAL TOOLS

Similarly, special tools is an area where planners can help boost crew productivity by reviewing past jobs in the minifile. A *special tool* is any device that would not ordinarily be carried in a craft tool box. Examples are come-alongs, cranes, and shim packs.

The planner's intent is to allow the technicians to gather all the tools they should need before they first go to the job site to avoid extra trips later. As with parts and job instructions, the planners reduce potential job delays when the work order plan identifies special tools because the technician does not have to make extra trips to procure them later after the start of a job. As with any trip, the technician's leaving the job site delays the job and might not consist of merely traveling to the tool room and returning with the proper tool.

Special tools might be kept in the tool room or other places. Certain tools may be available in one of the craft shops. Other highly specialized tools may be kept at the site of the equipment where it is normally utilized. For example, one plant has a special bar that is used to apply enough torque to unbind a particular control valve. The plant keeps the bar next to the valve. One of the planner's duties when scoping this job is to ensure the bar is there. Another plant keeps a locker full of special tools to work on burner parts on the burner deck of its unit. The planner should remind the technicians to retrieve the locker key from the tool room when they perform work on the burners.

The primary source for special tools is the planner's personal experience and information from past jobs in the minifile. There also may be lists of special devices recommended by manufacturers or vendors in O&M manuals. These lists should be kept in the minifiles once they are found. The tool room might also employ a "job tool card" to keep track of tools issued to jobs rather than individual technicians. This allows the tool room to issue tools over a period of time to larger jobs that might be conducted by several crews of technicians working alternating shifts. In these jobs and other jobs, it might be easier for the tool room to issue the tools to jobs rather than individuals. On these jobs the planner should encourage the technicians and tool rooms to provide copies of the cards after job completion to keep in minifiles.

Infrequently, the planner may also be able to help the technician avoid carrying an entire tool box to the job site. For instance, a certain job may only require a flathead screwdriver. In these cases the planner would note that "job only requires" the particular few tools prescribed.

The planner writes special tools on the work order form. The planner writes any special identification numbers if the tool room has such a system. (As discussed later, the planner also uses this section of the form to indicate if the job needs any contractors such as insulators.) The planner also identifies any special tools that the planner staged in accordance with the plant's guidelines. Staging of special tools often helps crews avoid delays. Chapter 6 discusses staging.

Figure 5.12 shows an example work order after the planner finished writing in tool information. The technicians would take out the strainers and place it in the plastic bag. The technicians would then transport it and clean it in the shop steam cleaning room. The technicians would then replace the strainer and refasten the assembly. The technicians would clean up the area and put the rags in the special hopper in the fuel oil room. The planner needed only write down the rags, degreaser, and plastic bag as special tools.

JOB SAFETY

Job planners never take job safety for granted. The planner first makes sure the origination section of the work order specifies whether the operations group must clear the equipment. The planner contemplates if there are conditions on the job site that will affect the safety of personnel. For each special safety concern, the planner describes the necessary safety issues

| WORK ORDER #001235 | | | | |
|---|--------------|----------------------------|----------|--|
| REQUESTER SECTION | | Priority R2 | | |
| #2 Control Valve B Strainer (N02-FC-003) has high pressure drop. Def. Tag #010304. No outage required. Needs mech crew. Clearance Req. No Confined Space. | | | | |
| J. Smith 4/21/98 3:00pm | | APPROVAL: S. Brown 4/21/98 | | |
| PLANNING SECTION | | | | |
| Clean strainer positioned in front of the control valve. | | | | |
| Remove strainer element, clean, and replace. | | | | |
| Replace gasket if needed. | | | | |
| Labor: 1 Mech 5hr Total labor 10hr | | | | |
| 1 Helper 5hr Job duration 5hr | | | | |
| Parts: Strainer lid gasket GSK-RR-130* Qty 1 Cost \$10ea | | | | |
| Tools: Rags, Can of degreaser, Plastic garbage bags. | | | | |
| *RESERVED | | | | |
| CRAFT FEEDBACK | | | | |
| APPROVAL: | | | | |
| CODING | Plan Type RE | Group/Syst FC | Crew 1-2 | |
| | Work Type 5 | Equip Type 18 | Outage 0 | |

FIGURE 5.12 Work order after the planner determines the tools required.

on the work order form and attaches or references any pertinent information. The planners always ensure that any developed or researched information is copied to the minifile. The planner may find useful information already in the minifile. This is one circumstance in which a planner might do more extensive research on a reactive or minimum maintenance job.

The planner also considers whether the job will be in a confined space or involve special chemicals. As usual, the minifile becomes a repository to help scope jobs in this regard and retain useful information.

Confined Space

A confined space is an area with a potentially dangerous environment regarding respiration. The planner considers several questions regarding possible confined space work. Is it possible this is a confined space? Is it possible the space requires continuous air monitoring and a hole guard? Is there work to be done at intervals that will require special monitoring? Will the job scope change during the repair affecting the conditions as permitted?

If the work involves confined spaces, the planner ensures that the work order origination information and work plan reflect this requirement to follow the established plant procedures. The planner adds "entry supervisor" or "hole person" to the persons required section of the work order form.

Material Safety Data Sheets

If there are hazardous chemicals present on the job site, the planner writes or attaches the necessary MSDS information on chemicals present. The planner will write the process necessary to protect maintenance personnel if necessary.

The Internet is becoming a useful source for accessing MSDS sheets for certain substances. A CMMS might also be helpful in this regard.

ESTIMATING JOB COST

At one plant the planning manager had the planners stop totaling up the cost for each work order because no one was tracking it. This rationale misses the point of planning. The planners are one of the major users of this information. The planners should be able to see how much past work on a piece of equipment has cost in order to make intelligent maintenance scope decisions. If the past maintenance costs have been high, the planner can properly present a case for expensive replacement equipment without resorting to such statements as "We don't know how much it's costing us, but it's really hurting us." Management cares about bottom line cost. Maintenance professionals must learn the language of financial dealings. Management desires realistic cost comparisons over opinions. Maintenance would rather consider a case of "The old pump seals have cost \$2000 per year to maintain, but we can eliminate that cost with a new seal design for only \$3000."

Any cost collection is better than none. It is not legitimate to wait on the eventual installation of a computer or CMMS to collect cost information. The cost information provided by work plans is the first step in having useful data even if actual field costs are not gathered. This information is accurate enough to guide the decisions that will be made. Whether a job cost \$200 or \$400 is not as important as whether it cost \$400 or \$3000. The minifiles will show the trend and magnitude of maintenance costs accumulating from multiple work orders as the equipment is maintained. The minifiles cannot do this practically if the information is not estimated at the time of the work. The information needs to be in a state where the planner can easily glance at previous job costs as replacement equipment is considered. Engineers can go through minifiles and spend time occasionally to total up job costs for a few projects. However, planners must be able to see this cost data without strenuous effort as they plan routine maintenance jobs daily.

Another reason actual costs may not be critical to maintenance assessments is due to a philosophy of what the job cost. Consider a job that planning estimated for a single day, but through poor scheduling the job took 2 days to complete. However, the technician put 3 days on a time sheet because the crew supervisor did not assign any more work. Did the equipment cost the company 1 day, 2 days, or 3 days of labor and unavailable equipment? The equipment probably cost the company 1 day and poor maintenance practices cost the company 2 more

days. The reason the equipment cost only a single day was that was the job's standard as established by the planner. That was what the job should have taken. On the other hand, most accounting systems and computer programs might attribute all 3 days to the equipment. This is because they do not attribute any cost to an inefficient maintenance organization. In addition, it is very difficult to establish on a job-by-job basis the cost to the company for lost availability. Therefore most maintenance cost systems do not account for them on individual work orders. Whether or not all of these differences are meaningful is beside the point. The differences should not delay the collection of maintenance information. The rapid accumulation of helpful job information will begin when it is started.

Another reason to show cost information on the job plan is to guide technicians when working with parts. Certain low cost parts may not be practical for the technician to return to the storeroom when unused. Other small parts may surprisingly cost thousands of dollars. These parts should be handled with more care than others. The technician can only make these determinations when the planner includes price information on the job plan.

The planner first calculates labor cost. The planner first uses a standard rate for all labor hours. This allows the planner quickly to add up the total cost of labor. It also reduces jealousy among different crafts and skill levels not to have actual wage information thrown in their face. However, the use of some labor rate shows how much labor does cost the company and encourages everyone to become as efficient as possible. Using a standard rate for all labor hours is justifiable. Maintenance decisions require an accuracy showing whether certain equipment costs hundreds of dollars each year or thousands. The wage difference between a trainee and a certified electrician will not skew data used for this purpose. In addition, the planner has planned the job for the minimum skill level without any certainty who will actually be assigned. Therefore the planning department uses a standard labor wage rate. (A CMMS might easily allow using exact labor rates but caution should be used considering different crafts may not appreciate seeing exact wage differentials.)

This book uses a standard \$25 per labor hour to illustrate the concept of estimating labor hours. This figure includes all wages and benefits that the company pays per labor hour. It does not consider wrench time or administration time. It merely represents what the company would pay to an employee each year in benefits and wages divided by the usual number of hours worked each year on straight time. Job plans do not consider that jobs may be worked on overtime. Overtime is more of a cost of scheduling or maintenance practice than planning. This figure may not be appropriate for many industries or geographical areas.

The planner uses a standard rate of \$25 per hour for each work hour and writes the labor cost estimate directly on the work order form.

The planner then calculates the cost of parts. First, the planner only needs to include the cost of parts that the planner anticipates the craft will use. Second, the planner determines the cost of the items. The planner notes the inventory price when the planner reserves the part in the inventory computer system. If the computer lists several prices for an item, the planner uses the last purchased price since that is the actual cost to the company as a whole. If there is no price information, the planner makes an educated guess. The planner may also have the benefit of items identified with a price on a bill of material or other equipment breakdown list. All of these sources are usually accurate enough for the purposes of overall cost accumulation for equipment. The planner does not need to include items not of significant value such as a few dollars worth of bolts. The planner should not tie up the time of a purchaser or parts expeditor to determine routine cost information. The planner should use the parts expeditor to provide the value for parts needing special purchasing when the expeditor orders the part. The planner includes the cost for all anticipated parts on the work order form. The planner writes the individual cost for each part and includes the total cost of parts in the total estimate for the job.

Next, the planner considers the cost of special tools. The planner does not include a cost for a special tool unless the item is not available in the tool room and a special cost will be incurred. The cost for contracting out work would be included as a special cost. This chapter discusses contracting work in the next section.

The planner then totals all the cost estimates for labor, parts, and tools at the bottom of the planning section of the work order form.

Finally, the planner informally consults the planning supervisor if the estimated cost is over a certain amount established by a planning department guideline, \$5000 for example.

The planning department has a guideline to scrutinize more expensive job plans to determine if another strategy is advisable. Some persons may feel that this is an unnecessary precaution. Their reasoning suggests that because the plant already exists, it must be maintained. They reason that all jobs must be executed. However, the planner consultation is not necessarily checking to see if the plant will execute the job. The planner consults to see if a more prudent alternative exists. For expensive jobs, it never hurts to get a second opinion. In addition, perhaps the plant should not execute the job after all. This plant exists, not another plant. Sometimes employees request improvements to the plant that are simply not advisable for a number of reasons. Many times the proposed task exceeds the economic point of diminishing returns. There would be a benefit, but the benefit would not outweigh the cost of the job. Identifying projects that would modify the plant is one reason the plant classifies jobs according to work type. Project work adds capability that was not had before; the plant or equipment is better than before. Projects must be carefully weighed to see if they are good uses of the company's funds. For major projects, most companies have a project proposal and approval process, usually not involving the planning group. However, maintenance considers smaller project work continually. Sometimes the classification is not very clear; a repair job to overhaul a broken pump may be planned to include a better design impeller. These considerations occur daily in planning at the work order level, and mechanisms need to be in place to guide routine maintenance work with regard to expensive tasks.

Figure 5.13 shows the example work order after the planner finishes the job plan by completing the job estimate.

CONTRACTING OUT WORK

A contractor is a company that the plant hires to do specific tasks. Different companies have different strategies regarding contracting out work. Some companies prefer to use contractors as little as possible. Other companies regularly contract work. Some companies are themselves contractors using planning principles to increase their productivity. Normally other company divisions manage work done by contractors either as projects or general contractor work. Occasionally planning must coordinate outside contractors for ordinary work orders such as the setting of a safety valve. This section presents information for a planning department that has some interaction with contractors.

A word of caution advises management that planners and technicians sometimes fear that the establishment of the planning department promotes contractor work. Their reasoning suggests that the primary reason management implemented planning was to create work plans for contractors less familiar with plant equipment. Management might try to ease this worry by pointing out two things. One, planning should improve in-house efficiency so that contractors are less competitive. Two, Planning Principle 5 specifies that planners create plans for technicians that are familiar with plant equipment. The planner identifies and writes the cost for contractor work in the special tools portion of the work order plan.

Insulation

Presume for the purpose of illustration that a plant routinely contracts all insulation work. This plant feels that the concern for asbestos and the need for special tools and materials to

| | | | | | |
|---|-----------|----|-------------|----|----------|
| WORK ORDER #001235 | | | | | |
| REQUESTER SECTION | | | Priority R2 | | |
| #2 Control Valve B Strainer (N02-FC-003) has high pressure drop. Def. Tag #010304. No outage required. Needs mech crew. Clearance Req. No Confined Space. J. Smith 4/21/98 3:00pm | | | | | |
| APPROVAL: S. Brown 4/21/98 | | | | | |
| PLANNING SECTION | | | | | |
| Clean strainer positioned in front of the control valve. Remove strainer element, clean, and replace. Replace gasket if needed. | | | | | |
| Labor: 1 Mech 5hr Total labor 10hr 1 Helper 5hr Job duration 5hr | | | | | |
| Parts: Strainer lid gasket GSK-RR-130* Qty 1 Cost \$10ea | | | | | |
| Tools: Rags, Can of degreaser, Plastic garbage bags. | | | | | |
| *RESERVED | | | | | |
| Planner D. Lee 4/22/98 Job estimate: \$260 | | | | | |
| CRAFT FEEDBACK | | | | | |
| APPROVAL: | | | | | |
| CODING | Plan Type | RE | Group/Syst | FC | Crew 1-2 |
| | Work Type | 5 | Equip Type | 18 | Outage 0 |

FIGURE 5.13 Work order after the planner estimates the total plan cost.

work with insulation makes using a contractor advisable. The contractor also has the ability to ramp up and down personnel levels faster than the plant. This is useful for periods when the plant does not require much insulation work. The plant has the insulation contractor under a special contract that pays a specified rate for insulation work.

Insulation work lends itself to a minimum of craft interference because the contractor can remove the insulation with the equipment still in service before maintenance work commences. The insulation contractor can later replace the insulation after maintenance completes its work and the plant returns the equipment to service. Scaffolding presents a similar situation.

When insulation must be removed, the planner puts the work order in the waiting-for-insulation-work file. The planning supervisor (or another designated individual)

coordinates the insulation contractor work and returns the work order to the planner after the contractor removes the insulation. The planning supervisor gives the contractor's cost estimate for removing and replacing the insulation to the planner at this time. The planner then proceeds to finish scoping or otherwise planning the work, if needed, and passes the work to the waiting-to-be-scheduled file. The planner must exercise caution that necessary equipment tags or job markings remain in place or are replaced in order to help the technician later executing the job.

When the craft completes its work and the planner receives the work order back, the planner then makes a copy of the work order form. The planner places the copy of the form in the waiting-for-insulation-work file for the planning supervisor to coordinate the contractor for replacing the insulation. The planner uses the estimated insulation cost for the actual cost also. The paperwork of determining the actual cost from the blanket work order used for insulation is not practical. However, in unusual circumstances, the contractor informs the planning supervisor of the actual cost. This information is returned to the planner for updating the minifile.

Other Contracted Out Work

The planner handles on-site contractor work that is not routine or does not have special contracts in place the same way as purchasing nonstock parts. The planner has the planning department purchaser determine the cost and have the contractor ready to mobilize. The planner then puts the work order in the waiting-to-be-scheduled file with a note describing what coordination is necessary for using the contractor. The maintenance scheduler initiates the coordination if advance notice is required. The crew supervisor makes any coordination requiring less than a few days. The crew supervisor supervises the contractor on-site.

The planner does not supervise contractors because that would interfere with future job planning and otherwise engage the planner in an activity that does not leverage maintenance. Anyone from the crew would be spending an hour to supervise when the planner would have to spend an hour as well. There is no leverage from the planner. On the other hand, there is a leverage from the crew supervisor's standpoint. The crew supervisor should be out in the field anyway so the crew supervisor supervising a contractor may not take any time. The crew supervisor should supervise the contractor, not the planner.

Plant engineers or technical specialists normally supervise or inspect contract work performed off-site. However, some small jobs such as getting parts rebuilt might involve the maintenance force. For getting parts rebuilt off-site for a job-in-progress, the crew supervisor coordinates this work through the tool room or through the purchaser (or expeditor). For rebuilding used parts after maintenance completes a job, the crew supervisor writes and submits a new work order to rebuild and have the parts placed in stock. The planners would then coordinate the work. Placing the responsibility to initiate follow-up work directly on the crew supervisor lessens misunderstandings resulting in parts not being rebuilt.

CLOSING AND FILING AFTER JOB EXECUTION

The planner now performs one of planning's most important tasks. To move each future job up the learning curve, a planner must place information used or discovered during a job into the minifile. The planner completes the work's actual cost directly on the work order form and updates any necessary minifile sheets. The planner places the original work order form in the minifile. When filing the work order form, the planner sends a copy to the planning clerk for updating the computer for job closure. The clerk subsequently forwards that copy to the originator or otherwise notifies the originator of job completion.

If the technician or planner has indicated on the work order form that drawing or equipment technical data has changed, the clerk sends an extra copy to the plant engineering department. If the plant keeps a single CMMS database for equipment design information, the engineering department might not need information other than to revise drawings.

The planner needs to ensure that the necessary details of the actual job execution are clear enough to maintain the equipment database and help future work. Occasionally, the planner must dig and dig to get good job feedback. The planner might need to consult with the technicians or supervisors to clarify job details. A routine failure of a crew to report feedback must be brought by the planner to the crew supervisor or planning supervisor's attention. In addition, if the work order feedback indicated that maintenance made only a temporary repair, the planner may need to ensure that the necessary follow-up work orders have been written to address the situation.

The following provides guidelines for adequate job feedback the craft technicians should provide.

1. Identify quantity of persons and specific craft and grade of each person. Identify the names of the persons.
2. Identify labor hours of each person. Give start and finish times of job. Explain any variance from the plan estimates if greater or less than 20%.
3. Thoroughly describe the problem if not accurately specified by the plan.
4. Thoroughly describe the action taken if the job did not proceed according to the plan. Report any special problems and solutions.
5. Identify actual quantities of parts used and report stock numbers if not given by the plan.
6. Identify actual special tools used or made if not given by the plan.
7. Return the original work order and all attachments provided by planning. Include any field notes and return any datasheets that the technician filled out whether or not planning provided them.
8. Return updated drawings.
9. Note any changes to equipment technical information such as new serial numbers and model numbers and names. Return any manufacturer's information or literature that was received with any new parts being installed. This information is especially vital and often cannot otherwise be determined to help future maintenance.
10. Include any other information such as bearing clearances (radial and thrust), wear ring clearance, shaft runout clearance, bearing to cap clearances, coupling condition and gap clearance.
11. Make any recommendations to help future plans.

The plant might want to conduct a short, 1- or 2-hour training class for the maintenance work force to describe the basic responsibilities of craft technicians for providing feedback.

Figure 5.14 shows an example work order after the crew has executed the work and given feedback to planning. Figure 5.15 shows the closing notes the planner made to the work order to update the work order form totals for time and cost. Figure 5.16 shows a new work order an operator wrote 5 months later with a similar problem. Figure 5.17 shows how the planner was able to use feedback from the job completed previously to improve the new work order's job plan. The planner was able to identify several special tools to help the craft technician avoid an extra trip to gather an impact wrench and sockets after arriving at the job site. Notice that the planner did not change the plan for craft skill or time required. The planner still felt that the job required only a single mechanic with a helper for 5 hours.

| | | | | |
|---|--------------|------------------------------|----------|--|
| WORK ORDER #001235 | | | | |
| REQUESTER SECTION | | Priority R2 | | |
| #2 Control Valve B Strainer (N02-FC-003) has high pressure drop. Def. Tag #010304. No outage required. Needs mech crew. Clearance Req. No Confined Space. | | | | |
| J. Smith 4/21/98 3:00pm | | APPROVAL: S. Brown 4/21/98 | | |
| PLANNING SECTION | | | | |
| Clean strainer positioned in front of the control valve. Remove strainer element, clean, and replace. Replace gasket if needed. | | | | |
| Labor: 1 Mech 5hr Total labor 10hr 1 Helper 5hr Job duration 5hr | | | | |
| Parts: Strainer lid gasket GSK-RR-130* Qty 1 Cost \$10ea | | | | |
| Tools: Rags, Can of degreaser, Plastic garbage bags. | | | | |
| *RESERVED | | | | |
| Planner D. Lee 4/22/98 Job estimate: \$260 | | | | |
| CRAFT FEEDBACK | | | | |
| Cleaned strainer. Replaced gasket. Used 2" combination, 2" impact socket, and impact wrench. 2 mech-7 hours ea. Job Started 4/23 7am. Finished 4/23 2pm. | | | | |
| C. Jones 4/23/98 | | APPROVAL: L. Vincent 4/23/98 | | |
| CODING | Plan Type RE | Group/Syst FC | Crew 1-2 | |
| | Work Type 5 | Equip Type 18 | Outage 0 | |

FIGURE 5.14 Work order after the crew executes the job and provides feedback.

SUMMARY

Seeing explicit descriptions of the steps a planner takes helps one understand how the company actually conducts maintenance planning. The chapter described first the work order process and then the flow of planning activity within the work order process. As the discussion unfolded, a planner scoped and planned an example work order and the reasoning behind each step was explained. This chapter should allow companies to tailor their own

| | | | | |
|---|--------------|------------------------------|----------|--|
| WORK ORDER #001235 | | | | |
| REQUESTER SECTION | | Priority R2 | | |
| #2 Control Valve B Strainer (N02-FC-003) has high pressure drop. Def. Tag #010304. No outage required. Needs mech crew. Clearance Req. No Confined Space. | | | | |
| J. Smith 4/21/98 3:00pm | | APPROVAL: S. Brown 4/21/98 | | |
| PLANNING SECTION | | | | |
| Clean strainer positioned in front of the control valve. Remove strainer element, clean, and replace. Replace gasket if needed. | | | | |
| Labor: 1 Mech 5hr Total labor 10hr Actual 14 1 Helper 5hr Job duration 5hr Actual 7 | | | | |
| Parts: Strainer lid gasket GSK-RR-130* Qty 1 Cost \$10ea | | | | |
| Tools: Rags, Can of degreaser, Plastic garbage bags. | | | | |
| *RESERVED | | | | |
| Planner D. Lee 4/22/98 Job estimate: \$260 Actual: \$360 | | | | |
| CRAFT FEEDBACK | | | | |
| Cleaned strainer. Replaced gasket. Used 2" combination, 2" impact socket, and impact wrench. 2 mech-7 hours ea. Job Started 4/23 7am. Finished 4/23 2pm. | | | | |
| C. Jones 4/23/98 | | APPROVAL: L. Vincent 4/23/98 | | |
| CODING | Plan Type RE | Group/Syst FC | Crew 1-2 | |
| | Work Type 5 | Equip Type 18 | Outage 0 | |

FIGURE 5.15 Work order after the planner writes in the actual field cost for the history file.

systems to implement effective planning. The next chapter presents the same level of detail in describing the specific activities of advance scheduling and daily scheduling. Appendix E narrates duties through step-by-step activities for the maintenance planner and App. F does the same for many of the other persons involved in the planning process.

| | |
|---|---|
| WORK ORDER #002107 | |
| REQUESTER SECTION | Priority R2 |
| Unit 2 Cntrl Vlv B Strainer (N02-FC-003) high differential, needs attention. Def. Tag #037114. No outage. Mech crew. Clearance Required. No Confined Space. | |
| F. Balder 9/11/98 2am APPROVAL: S. Brown 9/11/98 | |
| PLANNING SECTION | |
| | |
| CRAFT FEEDBACK | |
| | |
| APPROVAL: | |
| CODING | Plan Type RE Group/Syst FC Crew 1-2 Work Type 5 Equip Type 18 Outage 0 |

FIGURE 5.16 New work order later on same equipment after the originator completes the information.

| | |
|---|---|
| WORK ORDER #002107 | |
| REQUESTER SECTION | Priority R2 |
| Unit 2 Cntrl Vlv B Strainer (N02-FC-003) high differential, needs attention. Def. Tag #037114. No outage. Mech crew. Clearance Required. No Confined Space. | |
| F. Balder 9/11/98 2am APPROVAL: S. Brown 9/11/98 | |
| PLANNING SECTION | |
| Clean strainer positioned in front of the control valve. Remove strainer element, clean, and replace. Replace gasket if needed. | |
| Labor: 1 Mech 5hr Total labor 10hr 1 Helper 5hr Job duration 5hr | |
| Parts: Strainer lid gasket GSK-RR-130* Qty 1 Cost \$10ea | |
| Tools: Rags, Can of degreaser, Plastic garbage bags, 2" combination, 2" impact socket, and impact wrench. | |
| *RESERVED | |
| Planner D. Lee 9/11/98 Job estimate: \$260 | |
| CRAFT FEEDBACK | |
| | |
| APPROVAL: | |
| CODING | Plan Type RE Group/Syst FC Crew 1-2 Work Type 5 Equip Type 18 Outage 0 |

FIGURE 5.17 New work order after the planner improves the job plan with feedback from previous work on equipment.

CHAPTER 6

BASIC SCHEDULING

This chapter continues the nuts and bolts of making the planning system work with regard to scheduling. The chapter shows exactly how to do the scheduling.

In actual practice, it may be helpful to note that persons may consider scheduling a somewhat vague term. To be more precise, *advance* or *weekly scheduling* means a scheduler allocating an amount of work orders for a week without setting specific days or times to begin or complete individual work orders. Likewise, *daily scheduling* means a crew supervisor assigning specific work orders to specific individuals to begin the next day. A maintenance group uses both weekly schedules and daily schedules. This chapter describes the activities to accomplish weekly and daily scheduling. In addition, the chapter covers how maintenance personnel stage material and tools. Although this book focuses on routine maintenance, the book also explains key scheduling concepts behind successful outages. Finally, the chapter compares and contrasts the concepts of scheduling with the concepts of quotas, benchmarks, and standards.

WEEKLY SCHEDULING

The scheduler performs most of the tasks of advance scheduling. The scheduler first gathers jobs from the waiting-to-be-scheduled file and any work returned from the previous week's schedule. The scheduler then allocates them into each crew's work hour forecast for the next week. The scheduler allocates jobs by work order priority, then number of work hours, but also makes other considerations per the scheduling principles. The scheduler utilizes scheduling worksheets for assistance. The end product is a package of jobs that the crew should be able to complete the next week. The scheduler then delivers the jobs for each crew to the crew supervisor. The scheduler also sends a copy of each work order that will need intercraft coordination to the supporting craft.

Each day the crew supervisor makes the daily schedule mostly from the work orders allocated in the weekly schedule. The crew supervisor assigns work to individual crew members based on the current day's activities and progress on work. The supervisor attends a daily scheduling meeting with other craft supervisors and the operations group representative to coordinate work for the next day. Near the end of the week, the crew supervisor returns to the scheduler the jobs that he or she does not expect the crew to start that week. The scheduler then considers them for inclusion in the advance schedule then being prepared.

Here are the step-by-step actual activities for weekly scheduling. This is the type of physical process which must be understood and which a computer CMMS would mimic.

Forecasting Work Hours

Each crew supervisor forecasts the crew's available work hours as the first step in the advance scheduling process.

This activity takes place near the end of the work week, usually at the beginning of the last shift for the period already in progress. For example, this would be Friday morning for a crew that works Monday through Friday, 8-hour day shifts or Thursday morning for a crew that works Monday through Thursday, 10-hour day shifts.

Near the end of the work week, the scheduler takes a Crew Work Hours Availability Forecast worksheet (shown in Fig. 6.1) to each crew supervisors that next week they will be responsible for completing the amount of work for which they have labor. They are involved in the process. The scheduler is only helping them determine how many and which jobs should be selected from the backlog.

The Crew Work Hours Availability Forecast worksheet has blanks to guide the crew supervisor in determining how many hours each craft level has available. This section and the following sections illustrate the crew supervisor's use of this form.

The crew supervisor fills out and returns the availability forecast worksheet as soon as possible after receiving it from the scheduler. The supervisor receives the forecast worksheet from the scheduler at 8 AM. The crew supervisor should already have an idea of who will be in training and who has requested vacation for the next week. On the other hand, the supervisor may need to check on jobs currently in progress to determine which ones the crew will probably not finish this week. Those jobs will need carryover hours reserved for them next week. In addition, the supervisor needs to assess which new jobs the crew will start today. Some of these jobs might be finished or might also run over into next week. One thing the supervisor does not plan for is unexpected absences. Scheduling is not based on the unexpected. The supervisor may later use unexpected absences that occurred to explain why the crew did not meet a schedule. When the crew supervisor finishes these determinations, he or she gives the scheduler the completed Crew Work Hours Availability Forecast worksheet. The crew supervisor also hands over any physical work orders which the crew received to do this past week, but will not start. The crew supervisor makes all these determinations by 10 AM and returns the worksheet. This gives the scheduler time to create the weekly schedule by 1 PM after lunch. (The scheduler must finish the weekly schedule by early afternoon so that the crew supervisor can make a daily schedule for the first day of the coming week. The crew supervisor must attend a late afternoon daily scheduling meeting to give the operations group information on clearances for the beginning of the following week and initiate coordination with other crafts, if necessary. The supervisor may also begin to make individual technician assignments.)

The maintenance group can easily computerize the availability forecast worksheet. Many CMMS packages contain work calendars for the crew supervisor to update crew member availability for the coming work days. Then the scheduler can access the data whenever needed. Of course, the crew supervisor must keep the data current. Even without a CMMS system or CMMS labor calendar module, the company can use a computer network. The scheduler can make a form on email or attach a spreadsheet program or word processing document with a representation of Fig. 6.1. By exchanging this form back and forth by email, the crew supervisor and scheduler produce the necessary forecast information.

Without getting current information from the crew supervisor, the scheduler might use a standard forecast of how many work hours were normally available. In other words, the scheduler would presume for a given crew that a certain number of labor hours were available every week. This standard forecast might presume that for a 10-person crew, one person would be unavailable for one reason or another. So the scheduler would schedule for nine persons each week. The scheduler and the crew supervisor would meet together occasionally to assess any needs to adjust the standard. The problem with using a standard forecast is that crew supervisors may not take the resulting schedule seriously. Whether or not they finish all their scheduled work, they will get the same amount of new work the next period. There is not much attention to carryover work which could be a significant problem. This approach figures that carryover work from the previous work remains about the

CREW WORK HOURS AVAILABILITY FORECAST

For week of: / / to / /
 For crew: By: Date: / /

| Craft | # Persons | Paid Hrs | Leave | Train | Misc | Carry-over* | Avail Hrs |
|---------------|-----------|----------|---------|---------|---------|-------------|-----------|
| _____ | x 40 = | _____ | - _____ | - _____ | - _____ | - _____ | = _____ |
| _____ | x 40 = | _____ | - _____ | - _____ | - _____ | - _____ | = _____ |
| _____ | x 40 = | _____ | - _____ | - _____ | - _____ | - _____ | = _____ |
| _____ | x 40 = | _____ | - _____ | - _____ | - _____ | - _____ | = _____ |
| _____ | x 40 = | _____ | - _____ | - _____ | - _____ | - _____ | = _____ |
| _____ | x 40 = | _____ | - _____ | - _____ | - _____ | - _____ | = _____ |
| _____ | x 40 = | _____ | - _____ | - _____ | - _____ | - _____ | = _____ |
| _____ | x 40 = | _____ | - _____ | - _____ | - _____ | - _____ | = _____ |
| _____ | x 40 = | _____ | - _____ | - _____ | - _____ | - _____ | = _____ |
| _____ | x 40 = | _____ | - _____ | - _____ | - _____ | - _____ | = _____ |
| Totals | | x 40 = | _____ | - _____ | - _____ | - _____ | = _____ |

***Carryover work is any work which has been physically started in the current period, but will not be finished and will run over into the forecast period.**

FIGURE 6.1 Worksheet to assist crew supervisors forecast how many labor hours are available for scheduling work the following week.

same each week. Carryover work would be work that the crew started the previous week but did not complete. One of the main reasons to base weekly scheduling on a precise weekly forecast is to facilitate communication about performance. Scheduling to a standard forecast hinders achieving this purpose. Nonetheless, this approach may be necessary in situations of extreme crew reluctance and minimal management support.

Figures 6.2 and 6.3 illustrate the use of the Crew Work Hours Availability Forecast worksheet for a mechanical maintenance crew working a 10-hour shift. B. Jones, supervisor of A Crew, has just received the availability forecast worksheet from the scheduler. The crew consists of five persons: one skilled welder, one apprentice, one painter, and two

mechanics. Jones feels that one of the mechanics possesses a very high degree of mechanical skill, but the other mechanic is significantly less capable at the present time. Jones knows that none of the crew will be in training any of next week, but the painter will be off 2 days for vacation. Jones considers the current jobs in progress. The welder's current job will not be finished today and requires about 5 hours next week to finish. The higher skilled mechanic has been working a job for the past 2 days and claims it will take 5 hours next week as well. The other mechanic will finish one job and start another job today that will also take about 5 hours next week to finish. The other crew members should finish their current work today as well. Jones plans to have them start and finish a new assignment. With this information, Jones estimates the total carryover work to be 5 hours of skilled welding, 5 hours of highly skilled mechanic work, and 5 hours of lesser skilled mechanic work.

Figure 6.2 shows that the supervisor begins completing the availability forecast worksheet by starting with a craft skill level listing for this specific crew. First, note that the worksheet considers apprentices simply as helpers. This plant does not regard apprentices as strictly in training for their craft and may utilize them where the high priorities of the plant lie. It is expedient to follow this philosophy in the forecasting phase of the scheduling, but to use the daily scheduling assignments to try to keep apprentices within their craft specialties. Second, note that the scheduler and the supervisor use the term mechanic to designate a fairly well-skilled mechanic technician. They use the term technician to designate a less skilled technician in the primary craft of the crew, in this case mechanical. This use of the terms allows planners, schedulers, and supervisors to communicate regarding skill level even within a standard classification. Although the plant does not have a certification program, significant differences between the skill levels of the mechanics exist. The plant needs to ensure not to allocate too many jobs requiring highly skilled mechanics at the same time. Normally a company could distinguish overall skill level through some certification process or a progression of rank such as third, second, and first class mechanics to identify the better mechanics. However, the subject plant has only mechanic, apprentice, and trainee formal designations. Therefore, the planners and schedulers informally address the needs for jobs by using the terms technician and mechanic on the job plans. When a planner uses the term technician, the job plan does not require a more capable mechanic.

Figure 6.3 shows the availability forecast worksheet after the supervisor enters all the quantities for persons and hours. Jones only forecasts for the 2 days of vacation approved for the painter. Supervisors do not presume there will be unexpected absences due to personal illnesses or sudden vacation day requests. The advance schedule sets a goal based on current knowledge and encourages everyone to meet the schedule. Typically, management above the supervisor directs training and special meetings. Management decides and sends various persons to different training classes or schools as well as coordinates special meetings such as safety or outage planning. Management does the crafts a great favor by scheduling these types of special events at least a week ahead of time. Once maintenance has set a weekly advance schedule, management assists maintenance in building the plant's confidence in the schedule by not encouraging deviation. Jones's management has not scheduled training or meetings for anyone. Jones's estimate of carryover hours is important because the scheduler must allow the crew time to finish jobs already in progress. The scheduler must not allocate new work for these labor hours. The supervisor's estimate of the amount of time required to finish carryover work is adequate. Finally, the supervisor completes the total's line for each type of work hour. The total's line helps in several ways. First, it helps to check the entries for accuracy of addition and subtraction. It also draws attention to how many hours exist in the various categories. The total magnitude of paid hours available to the crew and the effect of lost hours due to training or carryover work often are unappreciated. In this case, 200 labor hours represent a significant company expense. Out of this 200 paid hours, the supervisor forecasts 165 available for work next week in the shown crafts and skill levels. Finally, the totals lend themselves to tracking areas for improvement.

CREW WORK HOURS AVAILABILITY FORECAST

For week of: / / to / / Date: / /
 For crew: By:

| Craft | # Persons | Paid Hrs | Leave | Train | Misc | Carry-over* | Avail Hrs |
|---------------|---------------|----------|----------|----------|----------|-------------|-----------|
| Mech | x 40 = | - | - | - | - | - | = |
| Welder | x 40 = | - | - | - | - | - | = |
| Machinist | x 40 = | - | - | - | - | - | = |
| Painter | x 40 = | - | - | - | - | - | = |
| Tech | x 40 = | - | - | - | - | - | = |
| Helper | x 40 = | - | - | - | - | - | = |
| | x 40 = | - | - | - | - | - | = |
| | x 40 = | - | - | - | - | - | = |
| | x 40 = | - | - | - | - | - | = |
| | x 40 = | - | - | - | - | - | = |
| Totals | x 40 = | - | - | - | - | - | = |

***Carryover work is any work which has been physically started in the current period, but will not be finished and will run over into the forecast period.**

FIGURE 6.2 Input of normal craft and skill level designations.

Figure 6.4 illustrates the use of the Crew Work Hours Availability Forecast worksheet for another mechanical maintenance crew. J. Field, supervisor of B Crew, has just received the availability forecast worksheet from the scheduler. The crew consists of 15 persons. The crew has two welders, two machinists, and six mechanics. Field considers three of the mechanics to be significantly more capable than the others. Two trainees and three apprentices make up the remaining five employees. Field will forecast the crew available work hours from the following information. One of the welders requested 2 days of vacation next week. All B Crew apprentices must attend an entire day of classroom training. B Crew will have a 1-hour safety meeting on Wednesday. After checking on jobs in progress, Field makes an estimate for carryover work. Carryover work will

| CREW WORK HOURS AVAILABILITY FORECAST | | | | | | | |
|---|-----------|---------------------|-------|-------|------|-------------|-----------|
| For week of: <u>5/10/99</u> to <u>5/13/99</u> | | | | | | | |
| For crew: <u>A Crew</u> By: <u>B. Jones</u> Date: <u>5/6/99</u> | | | | | | | |
| Craft | # Persons | Paid Hrs | Leave | Train | Misc | Carry-over* | Avail Hrs |
| Mech | 1 | $1 \times 40 = 40$ | - | - | - | 5 | = 35 |
| Welder | 1 | $1 \times 40 = 40$ | - | - | - | 5 | = 35 |
| Machinist | | $\times 40 =$ | - | - | - | | = |
| Painter | 1 | $1 \times 40 = 40$ | 20 | - | - | | = 20 |
| Tech | 1 | $1 \times 40 = 40$ | - | - | - | 5 | = 35 |
| Helper | 1 | $1 \times 40 = 40$ | - | - | - | | = 40 |
| | | $\times 40 =$ | - | - | - | | = |
| | | $\times 40 =$ | - | - | - | | = |
| | | $\times 40 =$ | - | - | - | | = |
| | | $\times 40 =$ | - | - | - | | = |
| Totals | 5 | $5 \times 40 = 200$ | 20 | - | - | 15 | = 165 |

*Carryover work is any work which has been physically started in the current period, but will not be finished and will run over into the forecast period.

FIGURE 6.3 Completed forecast for the A Crew.

consist of 2 days of welding needing a welder and a helper, 1 day of machine work, 1 day of skilled mechanic work, and another day of less demanding mechanic work.

As before, the supervisor classifies the mechanics according to skill describing them as three mechanics and three technicians. The supervisor forecasts five helpers including the three apprentices and both trainees. The classroom training makes only 30 hours unavailable since out of the five helpers, only the apprentices must attend. The safety meeting on Wednesday makes 1 hour for each person unavailable for scheduling in the Miscellaneous column. The specific day of the week is irrelevant to both the forecast and the weekly allocation. Only the available hours for the entire week matter. The daily scheduling routine later will take this into account. Finally, out of the 600 paid hours, 455 are available for new work.

Sorting Work Orders

In preparation of allocating work orders into the crew availability forecast, the scheduler sorts the plant's backlog. If the crew is responsible for only a certain area of the plant, the scheduler will only sort those work orders. Later after the scheduler allocates work for every crew, the scheduler might be able to recommend that certain crews assist other crews. The scheduler sorts the backlogged work orders in order to preferentially select work orders to allocate. If there are more job hours in the backlog than the forecast, obviously the scheduler cannot expect the crew to complete all the work. If the backlog has 1000 hours of jobs, then a crew expecting to have 455 labor hours cannot do all the work in a single week. The

| CREW WORK HOURS AVAILABILITY FORECAST | | | | | | | |
|---|-----------|----------------------|-------|-------|------|-------------|-----------|
| For week of: <u>5/11/99</u> to <u>5/14/99</u> | | | | | | | |
| For crew: <u>B Crew</u> By: <u>J. Field</u> Date: <u>5/7/99</u> | | | | | | | |
| Craft | # Persons | Paid Hrs | Leave | Train | Misc | Carry-over* | Avail Hrs |
| Mech | 3 | $3 \times 40 = 120$ | - | - | 3 | 10 | = 107 |
| Welder | 2 | $2 \times 40 = 80$ | 20 | - | 2 | 20 | = 38 |
| Machinist | 2 | $2 \times 40 = 80$ | - | - | 2 | 10 | = 68 |
| Painter | | $\times 40 =$ | - | - | - | | = |
| Tech | 3 | $3 \times 40 = 120$ | - | - | 3 | 10 | = 107 |
| Helper | 5 | $5 \times 40 = 200$ | - | 30 | 5 | 30 | = 135 |
| | | $\times 40 =$ | - | - | - | | = |
| | | $\times 40 =$ | - | - | - | | = |
| | | $\times 40 =$ | - | - | - | | = |
| | | $\times 40 =$ | - | - | - | | = |
| Totals | 15 | $15 \times 40 = 600$ | 20 | 30 | 15 | 80 | = 455 |

*Carryover work is any work which has been physically started in the current period, but will not be finished and will run over into the forecast period.

FIGURE 6.4 Completed forecast for the B Crew.

scheduler must select 455 hours worth of work to allocate for the week. The scheduler sorts the backlog of work orders into an overall order that will help determine which particular work orders are appropriate. Note that this presumes Scheduling Principle 4, proceeding with a preference to schedule 100% of the forecasted crew work hours, not more (120%) or less (80%). The procedure for allocating the work hours into the backlog proceeds with assigning the higher priorities before the lower priority work. The procedure also makes allowance for jobs on the same system and proactive work. In addition, the process shows how to select among jobs of equal priority and work type.

The scheduler returns to the planning office after delivering the Crew Work Hours Availability Forecast worksheet for the crew supervisor to complete. The scheduler collects all the planned work orders for a particular crew from the waiting-to-be-scheduled file and organizes them on a conference room table. The scheduler sorts them into separate piles, one pile for each priority. The waiting-to-be-scheduled file might already have separate folders for each priority to facilitate this step. Appendix J describes the priority codes for the work order system. Then, the scheduler sorts each pile into a particular order.

The scheduler first sorts the highest priority pile, priority 1 (urgent). Note there are no priority-0 (emergency) jobs in the backlog. Emergency jobs would already be under way and so are neither planned nor scheduled. By definition, all priority-1 work is classified as reactive work. Why is this reactive work sorted ahead of any proactive work? The ideal situation would be to have only proactive work in a plant. The plant prefers doing lower priority, proactive work to head off emergencies and urgent work. However, priority-1 work is urgent. It must be addressed, usually to restore lost capacity or remedy an immediate threat to production. The purpose of proactive work is to head off any reactive work, but when proactive action has failed to prevent a reactive situation, the situation must be addressed. Maintenance must first schedule urgent work to restore the plant. However, lower priority, reactive work should wait until after equal priority proactive work. In giving general preference to proactive work in this manner, the incidence of reactive situations diminishes. Therefore, the scheduler considers priority-1 work, which is all reactive and urgent, first.

The scheduler sorts the priority-1 jobs into order with jobs requiring the highest total of work hours on top. When the scheduler later allocates the work orders, jobs with more total work hours are put in the schedule first. This will allow fitting smaller jobs of equal priority into gaps of time remaining during the allocation process. This gap fitting would be more difficult if the scheduler allocated smaller jobs first. The scheduler would have to allocate only portions of larger jobs unnecessarily. The scheduler makes an exception to this sorting for smaller jobs encountered if they belong to the same system as larger jobs already higher in the group. In that case, the scheduler physically removes the smaller work order from its natural order and staples it to the work order for the larger job in the same system.

Scheduling work together for the same system is important for several reasons. Productivity increases if technicians can move from one job to a nearby job on the same system. They do not need to lose time familiarizing themselves with a different system at the start of each job. They avoid having to demobilize, travel, and move personal tool boxes to a different site to set up again. Sometimes they can use the same scaffolding or insulation clearing to get to the work. There is also a psychological boost to remaining on the same system. Frequently the time between jobs is taken advantage of as being a logical time to take breaks or "rest a moment" even when the jobs only last an hour or less. When jobs are scheduled on the same system, there is a tendency to look at the entire system as a single job through which to proceed with minimal delay. On the operations or production side, combining same system jobs also helps improve plant operations. An operator prefers to clear up a single system a single time for several jobs. A less organized scheduling effort might have the operator clear up the demineralizer on Monday and Wednesday for two jobs that could have both been done on Monday. Then on Friday, when the maintenance group

requests the operator to clear up the demineralizer a third time, the operator must refuse. The operator must explain that the plant is in jeopardy of not having enough water in its storage tanks. This scenario frequently occurs when no advance scheduling exists. The supervisor then assigns work by picking through the entire plant backlog for each next job. The scenario also can occur if the scheduler does not place the jobs together in an advance allocation. Unnecessarily clearing up a system multiple times wastes time and frustrates the operators.

Then the scheduler similarly sorts the priority-2 (serious) work orders by work order size, biggest jobs on top, with three exceptions. The first exception is that the scheduler puts all PM, preventive maintenance, jobs at the top of the pile. PM jobs are always prioritized as priority-2 jobs. They are considered serious and not simply routine maintenance with a lower priority. The scheduler sorts PM jobs by job size within themselves, larger ones first. The second exception is similar as for priority-1 work orders. If a work order is encountered that belongs in a system for which a larger or higher priority work order has already been sorted, the work order is moved up and attached to the previously sorted work order. This is done even if it means moving a work order from the priority-2 pile to the priority-1 pile to attach it to the other work order. The third exception is that for work orders of approximately the same size with the same priority, the scheduler places a proactive work order ahead of a reactive one.

Then the scheduler sorts the pile for priority-3 work orders with larger work orders on top and proactive work getting preference for work orders of approximately the same size. The scheduler physically moves any work order for a system already encountered and attaches it to the other work order, even if it is in a higher priority pile.

Similarly, the scheduler sorts each pile of same-priority work orders. Finally, there is a finished group for each priority arranged from top to bottom by size. There are exceptions for same-system work orders stapled together, exceptions for similar-sized proactive work ahead of reactive work, and PM work orders at the top of the priority-2 stack (unless a PM was moved to the priority-1 stack to be with a same system work order).

Note that the advance scheduling process does not consider aging of work orders. The concept of aging is that an older work order should get higher attention than a similar work order only recently written. That is, a low priority work order written 9 months ago might justify more attention than a serious work order written only yesterday. Aging might help a work force that does not have weekly scheduling. If a crew is only completing the high priority work with low productivity, increasing the relative priority of an older, low priority job might encourage the crew to include it as well. Aging is not as helpful if the maintenance group allocates and expects a crew to complete a proper amount of work each week. A properly sized maintenance crew is capable of handling all the work that comes up, not just the high priority tasks. That means that the crew can complete all the work so aging is not necessary to bring older jobs to the top. Scheduling keeps the crew from lowering its productivity to handle only the high priority work. Scheduling Principle 2 states the importance of correct priorities. Working lower priority jobs ahead of clearly more important jobs leads a crew to doubt its leadership. Doing the most important work first gives the plant more benefit by definition. So aging is really a tool to increase a crew's low productivity. Aging would interfere with an already highly productive crew. Aging figures that a crew is less productive than it should be. Aging figures that a crew is only doing the high priority work by choice. So aging simply raises the priority of some of the work into the higher priority work to which the crew will give attention. On the other hand, a crew already getting as much work done as it should can only give attention to another job by not doing a job already intended. So aging for the highly productive crew has just made the crew complete a lower priority job instead of a higher priority job to the plant's detriment.

Claiming that less important work should not be done ahead of more important work does not say work should never be reprioritized. If an older, low priority work order for

some reason merits more importance recently, then the priority should be increased. With the same reasoning, perhaps a higher priority work order is now less important than previously thought. The planning system should allow for changing the priority of each of these type work orders. One of the helpful additions to a planning group in this respect is an operations coordinator. This person or any knowledgeable operator can benefit a planning group by a monthly review of an extensive backlog. The operations coordinator can determine if some work orders should be reprioritized. This person has the authority to change the priority of any work order on the spot.

The scheduler receives two things from the crew supervisor a few hours after the last shift starts. The scheduler receives the completed Crew Work Hours Availability Forecast worksheet and any work orders which had been scheduled, but are now not going to be started this week. The supervisor has had time to assess the crew projected attendance for the next week as well as the status of current jobs-in-progress. In the case of an entirely paper-driven system, the crew supervisor physically hands over the work orders that the crew will not start. (In the case of an entirely computer driven system, the maintenance group might only print out the physical work orders when assigning them to the field technicians, if at all. The supervisor updates the computer changing each job to "in-progress" at the beginning of the shift or the end of the previous shift for the coming day. Therefore, the scheduler may consult the CMMS each week to determine which allocated jobs will not be started.) The scheduler takes the jobs not to be started and places them into the priority piles of work orders if they have already been arranged. The scheduler places these new work orders into the piles where they would belong if they had already been in the backlog. The actual allocation sequence can now take place.

Tables 6.1 through 6.3 illustrate sorting a plant backlog. The backlog belongs to mechanical maintenance A Crew. An earlier illustration used this crew as an example for forecasting. Table 6.1 shows the backlog arranged by work order number. The backlog consists of 243 total estimated work hours as planned. Because A Crew has only 165 work hours forecasted available, the scheduler must select the proper 165 hours to allocate for the next week. A plant also generally prefers to have 2 to 3 weeks of backlog available. This plant has less than 2 weeks of backlog. If this shortage is the normal case, the plant might not be identifying enough corrective maintenance situations to head off later breakdowns. The plant might also not be creating enough PM tasks. On the other hand, the maintenance crew might be overstaffed for the work area. Of the work orders in the backlog, work order codes as defined in App. J define certain information necessary for scheduling. First, the unit code N01 shows that most of the work orders are for North Unit 1, which is A Crew's primary responsibility. Second, within Unit 1, the system codes show that a variety of different systems need work. Third, work type codes indicate the nature of the work. Code 5 is breakdown and failure. Code 7 is preventive maintenance. Code 8 is work recommended by predictive maintenance. Code 9 is corrective maintenance that can head off failure and breakdown. Fourth, outage code 0 illustrates that the scheduler considers only work not requiring an outage of the entire unit for the normal work week.

Table 6.2 shows the backlog after the scheduler has physically grouped the work orders into different priorities. In addition, the largest work orders have been placed ahead of smaller jobs within each priority group. Note the scheduler places WO (work order) no. 012 requiring 16 total labor hours ahead of WO no. 004 requiring only 14 hours. Similarly, WO no. 004 is ahead of WO no. 002, which requires only 10 labor hours. Each priority group is similarly arranged with the only exception being for the priority-2 work orders. The scheduler must place PM work orders first within the priority-2 work orders. Work type code 7 defines the work as preventive maintenance. Therefore, the scheduler places WO no. 005 at the head of the priority-2 group even though it has the fewest hours.

Table 6.3 shows the backlog after the scheduler has adjusted the groups considering same-system work and other proactive work. First, the scheduler takes WO no. 006 from the

TABLE 6.1 Plant Backlog for the A Crew Listed by Work Order Number

| WO No. | Unit | System | Priority | Work type | Outage | No. of persons and craft | Est. hours | Est. duration |
|--------|------|--------|----------|-----------|--------|--------------------------|------------|---------------|
| 001 | N00 | ZE | 4 | 5 | 0 | 1 welder | 35 | 35 |
| 002 | N01 | CP | 1 | 5 | 0 | 1 tech | 10 | 10 |
| 003 | N01 | CV | 3 | 9 | 0 | 1 painter | 40 | 40 |
| 004 | N01 | FC | 1 | 5 | 0 | 1 tech, 1 helper | 7, 7 | 7 |
| 005 | N01 | CP | 2 | 7 | 0 | 1 tech, 2 helpers | 6, 12 | 6 |
| 006 | N01 | FC | 3 | 5 | 0 | 1 tech, 1 helper | 15, 15 | 15 |
| 007 | N01 | JC | 2 | 5 | 0 | 1 mech, 1 helper | 20, 20 | 20 |
| 008 | N01 | JX | 3 | 9 | 0 | 1 painter | 4 | 4 |
| 009 | N01 | CP | 4 | 5 | 0 | 1 mech, 1 helper | 2, 2 | 2 |
| 010 | N01 | IF | 3 | 9 | 0 | 1 tech, 1 helper | 3, 3 | 3 |
| 011 | N01 | CD | 2 | 8 | 0 | 1 mech, 1 helper | 10, 10 | 10 |
| 012 | N01 | BV | 1 | 5 | 0 | 1 welder, 1 helper | 8, 8 | 8 |
| 013 | N01 | IF | 4 | 9 | 0 | 2 tech | 6 | 3 |

priority-3 stack and attaches it behind WO no. 004 in the priority-1 group. These work orders are both in the same system, FC. Second, the scheduler takes WO no. 005 from the priority-2 stack and WO no. 009 from the priority-4 group. The scheduler attaches both work orders behind WO no. 002 in the priority-1 stack. All three are in the same system, CP. Finally, the scheduler scans the work orders to see if any of the proactive work orders besides PM should be moved up in the allocation preference. Proactive work type 8 is work recommended by predictive maintenance and reactive work type 5 is work to restore something that has already failed. WO no. 011 (work type 8) is currently behind WO no. 007 (work type 5). If WO no. 011 were closer in size to WO no. 007, say 35 to 39 labor hours, the scheduler would move it ahead. However, in this case, the relative size dictates that preference be given to the reactive work. In the priority-3 group, all of the work is proactive, work type 9 so no adjustments can be made. The scheduler will use the order presented by Table 6.3 to select work orders to allocate into the A Crew work hours availability forecast.

Tables 6.4 through 6.6 illustrate another example of sorting a nonoutage, plant backlog for B Crew at the same plant. This crew has a different backlog because it is responsible for a separate section of the plant. Table 6.4 shows the backlog arranged by work order number.

Table 6.5 shows the backlog after the scheduler has sorted the priority groups and placed PM jobs at the top of the priority-2 work orders.

Table 6.6 shows the backlog after the scheduler has grouped same system work orders. This grouping should help maintenance and operations concentrate on the most needy systems in an organized manner. Notice this grouping also allowed the scheduler to move a number of proactive work orders up into the priority-1 group. There are seven proactive work orders moved into this group, two PM work orders, three corrective maintenance

TABLE 6.2 Plant Backlog for the A Crew Grouped by Work Order Priority, Size, and PM

| WO No. | Unit | System | Priority | Work type | Outage | No. of persons and craft | Est. hours | Est. duration |
|--------|------|--------|----------|-----------|--------|--------------------------|------------|---------------|
| 012 | N01 | BV | 1 | 5 | 0 | 1 welder, 1 helper | 8, 8 | 8 |
| 004 | N01 | FC | 1 | 5 | 0 | 1 tech, 1 helper | 7, 7 | 7 |
| 002 | N01 | CP | 1 | 5 | 0 | 1 tech | 10 | 10 |
| 005 | N01 | CP | 2 | 7 | 0 | 1 tech, 2 helpers | 6, 12 | 6 |
| 007 | N01 | JC | 2 | 5 | 0 | 1 mech, 1 helper | 20, 20 | 20 |
| 011 | N01 | CD | 2 | 8 | 0 | 1 mech, 1 helper | 10, 10 | 10 |
| 003 | N01 | CV | 3 | 9 | 0 | 1 painter | 40 | 40 |
| 006 | N01 | FC | 3 | 5 | 0 | 1 tech, 1 helper | 15, 15 | 15 |
| 010 | N01 | IF | 3 | 9 | 0 | 1 tech, 1 helper | 3, 3 | 3 |
| 008 | N01 | JX | 3 | 9 | 0 | 1 painter | 4 | 4 |
| 001 | N00 | ZE | 4 | 5 | 0 | 1 welder | 35 | 35 |
| 013 | N01 | IF | 4 | 9 | 0 | 2 tech | 6 | 3 |
| 009 | N01 | CP | 4 | 5 | 0 | 1 mech, 1 helper | 2, 2 | 2 |

work orders, and one predictive maintenance work order. Without this grouping, the work force may have had a tendency to concentrate solely on the high priority reactive work for the week. A sanity check may also be needed after the forecast work hours are compared with the sorted backlog preference order. WO no. 023 is a fairly large priority-4 work order that the scheduler has moved into the priority-1 group. After reading exact job descriptions, the scheduler or operations coordinator may prefer holding it until the plant has addressed some of the priority-2 work. An obvious case might be the inadvisability of attaching a 40-hour, priority-4 job to a single 3-hour, priority-1 job. However, in the case of WO no. 23, there are already 67 hours of work to be done for system FO.

Allocating Work Orders

With the crew work hour forecast in hand and the work orders stacked on the table, the scheduler uses the Advance Schedule Worksheet, Fig. 6.5, to allocate the right work orders for the week. This worksheet allows the scheduler logically to connect the backlog with the crew time available. The worksheet form essentially consists of a blank sheet of paper with horizontal lines. The horizontal lines lie on the form at the same heights as the Crew Work Hours Availability Forecast worksheet (Fig. 6.1). The scheduler may tape or staple the schedule worksheet side by side to the availability worksheet. The scheduler places the worksheets together such that there is a long blank line immediately following the available work hours for each craft skill level. For the ease of this discussion, the scheduler does not physically attach the worksheets together, but writes the craft level and forecast available hours on the extreme left of each line. The long blank lines allow for

tabulation of remaining crew hours as the scheduler places each job into the schedule allocation for the next week.

After writing the available hours on the left of each line, the scheduler selects the top work order from the pile of highest priority work orders. The scheduler uses the long blank line beside each craft skill level to write the remaining craft hours available after the scheduler subtracts the hours required by the selected work order. The scheduler then puts the selected work order into the week's worth of work being allocated. This work constitutes the weekly schedule.

The scheduler physically places the actual work order itself into a set of folders to deliver to the crew supervisor. There is a folder for each craft skill level which is the lead for the work order. For example, if the work order requires two helpers, the scheduler places the work order into the helper folder. If the work order requires a mechanic and a helper, the work order also goes into the mechanic folder since the lead person is a mechanic. If the work order requires two welders and an electrician, the work order goes into the welder folder since the bulk of the work (and probably the lead) is welding. Later these folders will help the crew supervisor find work while assigning to the different crafts and skill on the individual crew. The craft skill level folders not only allow sorting of the work by trades or classifications, but they are also the vehicle that physically transports the scheduled work orders over to the crew supervisor. Later at the end of the scheduling period, the supervisor returns the folders to the scheduler with work orders that were not started. The scheduler places these work orders back into the backlog for possible inclusion in the next weekly schedule as the scheduler follows the advance scheduling routine.

TABLE 6.3 Plant Backlog for the A Crew Adjusted for Work on Same Systems and Other Proactive Work

| WO No. | Unit | System | Priority | Work type | Outage | No. of persons and craft | Est. hours | Est. duration |
|--------|------|--------|----------|-----------|--------|--------------------------|------------|---------------|
| 012 | N01 | BV | 1 | 5 | 0 | 1 welder, 1 helper | 8, 8 | 8 |
| 004 | N01 | FC | 1 | 5 | 0 | 1 tech, 1 helper | 7, 7 | 7 |
| 006 | N01 | FC | 3 | 5 | 0 | 1 tech, 1 helper | 15, 15 | 15 |
| 002 | N01 | CP | 1 | 5 | 0 | 1 tech | 10 | 10 |
| 005 | N01 | CP | 2 | 7 | 0 | 1 tech, 2 helpers | 6, 12 | 6 |
| 009 | N01 | CP | 4 | 5 | 0 | 1 mech, 1 helper | 2, 2 | 2 |
| 007 | N01 | JC | 2 | 5 | 0 | 1 mech, 1 helper | 20, 20 | 20 |
| 011 | N01 | CD | 2 | 8 | 0 | 1 mech, 1 helper | 10, 10 | 10 |
| 003 | N01 | CV | 3 | 9 | 0 | 1 painter | 40 | 40 |
| 010 | N01 | IF | 3 | 9 | 0 | 1 tech, 1 helper | 3, 3 | 3 |
| 013 | N01 | IF | 4 | 9 | 0 | 2 tech | 6 | 3 |
| 008 | N01 | JX | 3 | 9 | 0 | 1 painter | 4 | 4 |
| 001 | N00 | ZE | 4 | 5 | 0 | 1 welder | 35 | 35 |

TABLE 6.4 Plant Backlog for the B Crew Listed by Work Order Number

| WO No. | Unit | System | Priority | Work type | Outage | No. of persons and craft | Est. hours | Est. duration |
|--------|------|--------|----------|-----------|--------|--------------------------|------------|---------------|
| 021 | N02 | BS | 1 | 5 | 0 | 2 tech | 6 | 3 |
| 022 | N32 | UA | 3 | 9 | 0 | 2 tech | 14 | 7 |
| 023 | N00 | FO | 4 | 9 | 0 | 1 tech, 1 helper | 20, 20 | 20 |
| 024 | N00 | HA | 2 | 7 | 0 | 1 tech, 1 helper | 20, 20 | 20 |
| 025 | N00 | HC | 2 | 5 | 0 | 1 tech | 17 | 17 |
| 026 | N00 | FO | 2 | 5 | 0 | 1 welder | 3 | 3 |
| 027 | N00 | HD | 2 | 7 | 0 | 1 mach | 2 | 2 |
| 028 | N00 | HP | 1 | 5 | 0 | 1 mach, 1 helper | 8, 8 | 8 |
| 029 | N00 | FW | 4 | 9 | 0 | 2 helpers | 12 | 6 |
| 030 | N00 | HD | 1 | 5 | 0 | 1 mech, 1 helper | 1, 1 | 1 |
| 031 | N02 | DA | 3 | 3 | 0 | 1 mech, 1 helper | 20, 20 | 20 |
| 032 | N02 | DO | 3 | 9 | 0 | 1 helper | 40 | 40 |
| 033 | N00 | FO | 2 | 9 | 0 | 1 mach, 1 tech | 14, 14 | 14 |
| 034 | N00 | FO | 2 | 5 | 0 | 1 mach, 1 tech | 6, 6 | 6 |
| 035 | N00 | KD | 1 | 5 | 0 | 1 tech | 20 | 20 |
| 036 | N00 | FW | 1 | 5 | 0 | 1 mech, 2 helpers | 6, 12 | 6 |
| 037 | N00 | FO | 2 | 7 | 0 | 1 mech, 1 helper | 4, 8 | 8 |
| 038 | N31 | UZ | 2 | 5 | 0 | 1 tech, 1 helper | 3, 3 | 3 |
| 039 | N00 | FO | 2 | 8 | 0 | 1 welder, 1 helper | 2, 2 | 2 |
| 040 | N02 | FD | 3 | 8 | 0 | 1 welder, 1 helper | 10, 10 | 10 |
| 041 | N00 | FO | 1 | 5 | 0 | 1 tech, 1 helper | 4, 4 | 4 |
| 042 | N02 | FD | 1 | 5 | 0 | 2 tech | 8 | 4 |
| 043 | N31 | UA | 3 | 9 | 0 | 1 mech, 1 helper | 20, 20 | 20 |
| 044 | N31 | UZ | 4 | 9 | 0 | 2 helpers | 2 | 1 |

The scheduler then repeats the work order selection process to allocate work orders into the available craft hours. The scheduler selects the next work order from the top of the highest priority work orders. If the selected job requires more hours than the hours left on a particular craft line, the scheduler must make a decision. The scheduler first tries to "work persons down," such as using a mechanic as a helper. The scheduler might want to schedule only part of a job, such as scheduling 30 hours of a 60-hour job if only 30 hours of a particular skill are available. The scheduler might also decide the job cannot be scheduled

because there are insufficient hours available. The scheduler places subsequent work orders behind any work orders already in each folder. The scheduler continues the allocation process until either the crew runs out of available work hours or the backlog runs out of work orders. The backlog might run out of work orders altogether or just run out of work orders for which the crew has qualified labor.

After making the initial allocation grouping, the scheduler makes a final consideration of proactive work and consults operations. The scheduler considers if he or she ought to place

TABLE 6.5 Plant Backlog for the B Crew Grouped by Work Order Priority, Size, and PM

| WO No. | Unit | System | Priority | Work type | Outage | No. of persons and craft | Est. hours | Est. duration |
|--------|------|--------|----------|-----------|--------|--------------------------|------------|---------------|
| 035 | N00 | KD | 1 | 5 | 0 | 1 tech | 20 | 20 |
| 036 | N00 | FW | 1 | 5 | 0 | 1 mech, 2 helpers | 6, 12 | 6 |
| 028 | N00 | HP | 1 | 5 | 0 | 1 mach, 1 helper | 8, 8 | 8 |
| 041 | N00 | FO | 1 | 5 | 0 | 1 tech, 1 helper | 4, 4 | 4 |
| 042 | N02 | FD | 1 | 5 | 0 | 2 tech | 8 | 4 |
| 021 | N02 | BS | 1 | 5 | 0 | 2 tech | 6 | 3 |
| 030 | N00 | HD | 1 | 5 | 0 | 1 mech, 1 helper | 1, 1 | 1 |
| 024 | N00 | HA | 2 | 7 | 0 | 1 tech, 1 helper | 20, 20 | 20 |
| 037 | N00 | FO | 2 | 7 | 0 | 1 mech, 1 helper | 4, 8 | 8 |
| 027 | N00 | HD | 2 | 7 | 0 | 1 mach | 2 | 2 |
| 033 | N00 | FO | 2 | 9 | 0 | 1 mach, 1 tech | 14, 14 | 14 |
| 025 | N00 | HC | 2 | 5 | 0 | 1 tech | 17 | 17 |
| 034 | N00 | FO | 2 | 5 | 0 | 1 mach, 1 tech | 6, 6 | 6 |
| 038 | N31 | UZ | 2 | 5 | 0 | 1 tech, 1 helper | 3, 3 | 3 |
| 039 | N00 | FO | 2 | 8 | 0 | 1 welder, 1 helper | 2, 2 | 2 |
| 026 | N00 | FO | 2 | 5 | 0 | 1 welder | 3 | 3 |
| 031 | N02 | DA | 3 | 3 | 0 | 1 mech, 1 helper | 20, 20 | 20 |
| 032 | N02 | DO | 3 | 9 | 0 | 1 helper | 40 | 40 |
| 043 | N31 | UA | 3 | 9 | 0 | 1 mech, 1 helper | 20, 20 | 20 |
| 040 | N02 | FD | 3 | 8 | 0 | 1 welder, 1 helper | 10, 10 | 10 |
| 022 | N32 | UA | 3 | 9 | 0 | 2 tech | 14 | 7 |
| 023 | N00 | FO | 4 | 9 | 0 | 1 tech, 1 helper | 20, 20 | 20 |
| 029 | N00 | FW | 4 | 9 | 0 | 2 helpers | 12 | 6 |
| 044 | N31 | UZ | 4 | 9 | 0 | 2 helpers | 2 | 1 |

TABLE 6.6 Plant Backlog for the B Crew Adjusted for Work on Same Systems and Other Proactive Work

| WO No. | Unit | System | Priority | Work type | Outage | No. of persons and craft | Est. hours | Est. duration |
|--------|------|--------|----------|-----------|--------|--------------------------|------------|---------------|
| 035 | N00 | KD | 1 | 5 | 0 | 1 tech | 20 | 20 |
| 036 | N00 | FW | 1 | 5 | 0 | 1 mech, 2 helpers | 6, 12 | 6 |
| 029 | N00 | FW | 4 | 9 | 0 | 2 helpers | 12 | 6 |
| 028 | N00 | HP | 1 | 5 | 0 | 1 mech, 1 helper | 8, 8 | 8 |
| 041 | N00 | FO | 1 | 5 | 0 | 1 tech, 1 helper | 4, 4 | 4 |
| 037 | N00 | FO | 2 | 7 | 0 | 1 mech, 1 helper | 4, 8 | 8 |
| 033 | N00 | FO | 2 | 9 | 0 | 1 mech, 1 tech | 14, 14 | 14 |
| 034 | N00 | FO | 2 | 5 | 0 | 1 mech, 1 tech | 6, 6 | 6 |
| 039 | N00 | FO | 2 | 8 | 0 | 1 welder, 1 helper | 2, 2 | 2 |
| 026 | N00 | FO | 2 | 5 | 0 | 1 welder | 3 | 3 |
| 023 | N00 | FO | 4 | 9 | 0 | 1 tech, 1 helper | 20, 20 | 20 |
| 042 | N02 | FD | 1 | 5 | 0 | 2 tech | 8 | 4 |
| 040 | N02 | FD | 3 | 8 | 0 | 1 welder, 1 helper | 10, 10 | 10 |
| 021 | N02 | BS | 1 | 5 | 0 | 2 tech | 6 | 3 |
| 030 | N00 | HD | 1 | 5 | 0 | 1 mech, 1 helper | 1, 1 | 1 |
| 027 | N00 | HD | 2 | 7 | 0 | 1 mach | 2 | 2 |
| 024 | N00 | HA | 2 | 7 | 0 | 1 tech, 1 helper | 20, 20 | 20 |
| 025 | N00 | HC | 2 | 5 | 0 | 1 tech | 17 | 17 |
| 038 | N31 | UZ | 2 | 5 | 0 | 1 tech, 1 helper | 3, 3 | 3 |
| 044 | N31 | UZ | 4 | 9 | 0 | 2 helpers | 2 | 1 |
| 031 | N02 | DA | 3 | 3 | 0 | 1 mech, 1 helper | 20, 20 | 20 |
| 032 | N02 | DO | 3 | 9 | 0 | 1 helper | 40 | 40 |
| 043 | N31 | UA | 3 | 9 | 0 | 1 mech, 1 helper | 20, 20 | 20 |
| 022 | N32 | UA | 3 | 9 | 0 | 2 tech | 14 | 7 |

any more proactive work into the schedule to replace low priority, reactive work. This might be advisable for the allocation in which there is almost no proactive work whatsoever. There will never be a reduction of reactive work if there is never any proactive work performed. Both of the previous examples of backlogs contain a modest amount of proactive work and so need no adjustment. Next, the scheduler consults the operations coordinator giving this person a chance to replace any of the allocated work with work that the scheduler did not

choose. Maintenance and production schedules must be integrated even when not considering outage work. The operations coordinator understands overall constraints of operations being able to clear or release certain equipment at the present time. The operations coordinator may also make final adjustments for the best benefit of the plant. In both of the example allocations, the operations coordinator decides not to make adjustments.

The following examples use the Work Order Allocation Worksheet to combine the previous forecast examples and previous backlog sorting examples into a week's worth of work, the weekly schedule allocation.

ADVANCE SCHEDULE WORKSHEET

For week of: _____ to _____
 For crew: _____ By: _____ Date: _____

| Forecast | Available Hours Left |
|---------------|----------------------|
| | |
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| | |
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| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| Totals | _____ |

Instructions: Subtract job work hours from available line total until balance reaches zero for each line or backlog runs out.

FIGURE 6.5 Worksheet to assist the scheduler determine which work orders to allocate for the week.

Figures 6.6 through 6.12 illustrate using the scheduling worksheet to allocate the nonoutage backlog for A Crew. The scheduler first copies the craft levels and forecasted hours from the Crew Work Hours Availability Forecast worksheet for A Crew (Fig. 6.3). Figure 6.6 shows the resulting Advance Schedule Worksheet after this first step.

Then the scheduler selects work order no. 012, the first work order from the highest priority group for A Crew (shown in Table 6.3). WO no. 012 requires a welder for 8 hours and a helper for 8 hours. Therefore, the scheduler subtracts 8 hours from the 35 hours available for welders leaving 27 hours available. The scheduler writes down "27" on the welder line indicating the hours now available. Similarly, the scheduler subtracts 8 hours from the 40 helper hours available and writes down "32" on the helper line to indicate there are only 32 helper hours now available. The scheduler places work order no. 012 into a folder labeled "Welder" for eventual delivery to the crew supervisor. Figure 6.7 shows the resulting Advance Schedule Worksheet.

Figure 6.8 shows the Advance Schedule Worksheet after the scheduler selects work order nos. 004, 006, and 002. The scheduler places all of these work orders into a folder labeled "Technician" because that is the lead skill required on each.

The scheduler then selects work order no. 005 from the backlog. This work cannot be allocated into the available hours as simply as the preceding work orders. This work order requires 6 technical hours, but there are only 3 technical hours available. The scheduler takes the 3 technical hours available and then takes 3 welder hours to use as technician hours. The scheduler considers that a welder can perform the less complex mechanical tasks required by a technician. The scheduler does not wish to use a more skilled mechanic for the work because the backlog contains a significant amount of priority-2, skilled mechanic work. The backlog has more welding work, but it is priority-4 work. Next, the work order requires 12 helper hours, but only 10 are available. Therefore the scheduler takes the 10 helper hours available and takes 2 more welder hours to use as helper hours. Thus the scheduler subtracts a total of 5 welder hours from the 27 available leaving 22 available welder hours. See Fig. 6.9. These decisions of where to take hours require judgment on the scheduler's part. The exact choices are not critical. What is critical is that the scheduler realizes the ability to allocate work to other than the exact craft and skill specified by the job plan. The scheduler must remember that the job was only planned for the minimum skill level required.

Another question arises regarding splitting hours from different areas. Is the scheduler requiring different persons to perform fractions of jobs? No. As the actual week later progresses, some jobs will run over and others under allowing the crew supervisor to assign whole jobs to specific individuals. The crew supervisor may assign a welder as a helper for an entire job, but probably not for only half of a job. Actual experience has shown that this method of allocating work for the week results in a quantity of work for which the crew possesses the appropriate labor.

As the scheduler selects more and more of the backlog, more of these type decisions are made. Figure 6.10 shows the results of the scheduler allocating work order nos. 009, 007, and 011 into the weekly schedule. For both WO no. 009 and WO no. 007 the scheduler has the mechanic hours needed, but has to use welder hours for all of the helper hours. For WO no. 011, the scheduler again has the needed mechanic hours available. However, the scheduler must again use another skill level for the helper hours required. This time there are no more welder hours available. The scheduler decides to use the painter as a helper for WO no. 011. Although there is painting work in the backlog, it has a lower priority than WO no. 011. The painter would still have some hours to begin the painting job and could finish it as carryover work the following week.

Finally, Figure 6.11 shows the last work order that the scheduler places into the weekly schedule. The scheduler does not want to overschedule the crew. WO no. 003 requires 40 painter hours. The scheduler expressly states by writing a note on WO no. 003 that only 10

| ADVANCE SCHEDULE WORKSHEET | | |
|--|--|-----|
| For week of: <u>5/10/99</u> to <u>5/13/99</u> | | |
| For crew: <u>A Crew</u> By: <u>C. Rodgers</u> Date: <u>5/6/99</u> | | |
| Forecast | Available Hours Left (Work Order #) | |
| | | #12 |
| Mech | 35 | |
| Welder | 35 | 27 |
| Machinist | | |
| Painter | 20 | |
| Tech | 35 | |
| Helper | 40 | 32 |
| Totals | 165 | |
| Instructions: Subtract job work hours from available line total until balance reaches zero for each line or backlog runs out. | | |

FIGURE 6.6 Input of original labor forecast and first work order for the A Crew.

hours are being scheduled for the next week. The scheduler expects the painter to begin the paint job on the painter's last day of the week. The scheduler stops the schedule allocation process taking up all but 3 hours of skilled mechanic work hours from the forecast. There are no jobs in the backlog that take as few as 3 hours that the mechanic could perform. The scheduler has allocated 162 hours of backlog work for the forecasted 165 hours the crew has available. The scheduler considers this to be a 100% allocation. The scheduler does not want to give the crew any occasion to suggest that too much work was allocated. The scheduler now has work orders arranged in several folders, Mechanic, Welder, Painter, and

ADVANCE SCHEDULE WORKSHEET

For week of: 5/10/99 to 5/13/99
 For crew: A Crew By: C. Rodgers Date: 5/6/99

| Forecast | | Available Hours Left | | |
|-----------|----|----------------------|----|----|
| | | (Work Order #) | | |
| | | #12 | #4 | #6 |
| Mech | 35 | | | |
| Welder | 35 | 27 | | |
| Machinist | | | | |
| Painter | 20 | | | |
| Tech | 35 | | | |
| Helper | 40 | 32 | | |
| Totals | | <u>165</u> | | |

Instructions: Subtract job work hours from available line total until balance reaches zero for each line or backlog runs out.

FIGURE 6.7 Setting of columns to illustrate labor calculations with next three work orders.

Technician. The scheduler did not place any work orders in a folder labeled Helper because in this case, no work required helpers alone. The scheduler takes the work order folders over to the A Crew supervisor. A Crew supervisor Jones will use the work orders to begin establishing a daily schedule for the first day of next week.

In actual practice, Fig. 6.12 shows the actual worksheet as the scheduler would have filled in the information. The scheduler would not have listed each work order at the top of columns. Rather, the scheduler would have written in available hours left as the scheduler selected jobs and placed them into folders.

Figures 6.13 through 6.17 illustrate using the scheduling worksheet to allocate the nonoutage backlog for B Crew.

The scheduler first copies over the craft levels and forecasted hours from the Crew Work Hours Availability Forecast worksheet for B Crew (Fig. 6.4). Figure 6.13 shows the Advance Schedule Worksheet after the scheduler has selected the first 12 jobs from the previously sorted backlog for B Crew. None of these jobs requires the scheduler to consider using a craft skill level other than the ones planned on the work orders. For each work order, the scheduler merely subtracts the required work hours from each craft skill level

ADVANCE SCHEDULE WORKSHEET

For week of: 5/10/99 to 5/13/99
 For crew: A Crew By: C. Rodgers Date: 5/6/99

| Forecast | | Available Hours Left | | |
|-----------|----|----------------------|----|----|
| | | (Work Order #) | | |
| | | #12 | #4 | #6 |
| Mech | 35 | | | |
| Welder | 35 | 27 | | |
| Machinist | | | | |
| Painter | 20 | | | |
| Tech | 35 | 28 | 13 | 3 |
| Helper | 40 | 32 | 25 | 10 |
| Totals | | <u>165</u> | | |

Instructions: Subtract job work hours from available line total until balance reaches zero for each line or backlog runs out.

FIGURE 6.8 Labor calculations of available labor hours remaining.

| ADVANCE SCHEDULE WORKSHEET | | | | | | |
|---|-----|----------------------|----|----|----|----|
| For week of: <u>5/10/99</u> to <u>5/13/99</u> | | | | | | |
| For crew: <u>A Crew</u> By: <u>C. Rodgers</u> Date: <u>5/6/99</u> | | | | | | |
| Forecast | | Available Hours Left | | | | |
| | | (Work Order #) | | | | |
| | | #12 | #4 | #6 | #2 | #5 |
| Mech | 35 | | | | | |
| Welder | 35 | 27 | | | 22 | |
| Machinist | | | | | | |
| Painter | 20 | | | | | |
| Tech | 35 | 28 | 13 | 3 | 0 | |
| Helper | 40 | 32 | 25 | 10 | 0 | |
| Totals | 165 | | | | | |

Instructions: Subtract job work hours from available line total until balance reaches zero for each line or backlog runs out.

FIGURE 6.9 Allocating first work order to use other than the minimum labor skill that was planned.

line. Then the scheduler puts the selected work order into its folder for the pertinent lead craft.

After including the twelfth job, WO no. 042, the scheduler runs out of room on the worksheet. The scheduler simply labels the worksheet "Page 1" and begins a second page. Figure 6.14 shows the second page and the next five work orders selected. Similar to the first page, none of the jobs requires the scheduler to consider using a craft skill level other than the ones planned on the work orders. For each work order, the scheduler subtracts the

required work hours from each craft skill level line. Then the scheduler puts the selected work order into its folder for the pertinent lead craft.

Beginning with WO no. 25, the scheduler must decide to work persons outside of their top skill levels. WO no. 25 requires 17 technician hours, but only 9 are available. The scheduler decides to use 8 mechanical hours to make up the difference leaving 88 mechanic hours and 0 technical hours available afterward. Likewise, WO no. 038 requires using 3 mechanical hours as technical hours. There are no such decisions to make for WO no. 044

| ADVANCE SCHEDULE WORKSHEET | | | | | | |
|---|-----|----------------------|----|----|----|----|
| For week of: <u>5/10/99</u> to <u>5/13/99</u> | | | | | | |
| For crew: <u>A Crew</u> By: <u>C. Rodgers</u> Date: <u>5/6/99</u> | | | | | | |
| Forecast | | Available Hours Left | | | | |
| | | (Work Order #) | | | | |
| | | #12 | #4 | #6 | #2 | #5 |
| Mech | 35 | | | | | |
| Welder | 35 | 27 | | | 22 | 20 |
| Machinist | | | | | | |
| Painter | 20 | | | | | 10 |
| Tech | 35 | 28 | 13 | 3 | 0 | |
| Helper | 40 | 32 | 25 | 10 | 0 | |
| Totals | 165 | | | | | |

Instructions: Subtract job work hours from available line total until balance reaches zero for each line or backlog runs out.

FIGURE 6.10 Allocating next three work orders. Each uses other than the minimum labor skill that was planned.

| ADVANCE SCHEDULE WORKSHEET | | | | | | | | | | | |
|---|----------------------|----|----|----|----|----|----|-----|----|----|---|
| For week of: <u>5/10/99</u> to <u>5/13/99</u> | | | | | | | | | | | |
| For crew: <u>A Crew</u> By: <u>C. Rodgers</u> Date: <u>5/6/99</u> | | | | | | | | | | | |
| Forecast | Available Hours Left | | | | | | | | | | |
| | (Work Order #) | | | | | | | | | | |
| | #12 | #4 | #6 | #2 | #5 | #9 | #7 | #11 | #3 | | |
| Mech | 35 | | | | | | | | 33 | 13 | 3 |
| Welder | 35 | 27 | | | | 22 | 20 | 0 | | | |
| Machinist | | | | | | | | | | | |
| Painter | 20 | | | | | | | | 10 | 0* | |
| Tech | 35 | | 28 | 13 | 3 | 0 | | | | | |
| Helper | 40 | 32 | 25 | 10 | 0 | | | | | | |
| Totals | 165 | | | | | | | | | | 3 |

*Only 10 hours of 40 hour paint job assigned. WO#003

Instructions: Subtract job work hours from available line total until balance reaches zero for each line or backlog runs out.

FIGURE 6.11 Allocating a partial work order.

and WO no. 031. Each requires helper or mechanical hours which are available. Figure 6.15 shows the worksheet that results from including these four work orders.

Finally, Fig. 6.16 shows the resulting worksheet after the scheduler includes the last three jobs in the backlog. The scheduler uses the remaining 13 helper hours for WO no. 32. Since this work order calls for 40 helper hours, the scheduler also uses 27 machinist hours. This decision leaves 11 machinist hours and 0 helper hours. WO no. 43 calls for 40 technical hours of which none are available. Therefore, the scheduler uses 40 mechanical hours. Likewise, the last work order in the backlog, WO no. 22 is planned for technical hours. The scheduler uses mechanical hours instead. Now all the backlog has been allocated.

In actual practice, Fig. 6.17 shows the actual worksheet as the scheduler would have filled in the information.

Without the allocation system, the crew may have not realized it had the ability to complete the entire backlog. Instead, the crew may have only concentrated on completing the higher priority work. In addition, the allocation process identifies how many extra craft hours are left. There are 45 craft hours left, 11 mechanic, 23 welder, and 11 machinist. The scheduler has a basis to suggest using B Crew labor to assist A Crew next week. The B Crew Mechanic and Machinist could not only complete WO no. 010 and no. 013, but replace 10 of the helper hours on WO no. 007. This would free up 10 hours of A Crew

| ADVANCE SCHEDULE WORKSHEET | | | | | | | | | | | |
|---|----------------------|----|----|----|----|----|----|-----|----|----|---|
| For week of: <u>5/10/99</u> to <u>5/13/99</u> | | | | | | | | | | | |
| For crew: <u>A Crew</u> By: <u>C. Rodgers</u> Date: <u>5/6/99</u> | | | | | | | | | | | |
| Forecast | Available Hours Left | | | | | | | | | | |
| | (Work Order #) | | | | | | | | | | |
| | #12 | #4 | #6 | #2 | #5 | #9 | #7 | #11 | #3 | | |
| Mech | 35 | | | | | | | | 33 | 13 | 3 |
| Welder | 35 | 27 | | | | 22 | 20 | 0 | | | |
| Machinist | | | | | | | | | | | |
| Painter | 20 | | | | | | | | 10 | 0* | |
| Tech | 35 | | 28 | 13 | 3 | 0 | | | | | |
| Helper | 40 | 32 | 25 | 10 | 0 | | | | | | |
| Totals | 165 | | | | | | | | | | 3 |

*Only 10 hours of 40 hour paint job assigned. WO#003

Instructions: Subtract job work hours from available line total until balance reaches zero for each line or backlog runs out.

FIGURE 6.12 Realistic completed Advance Schedule Worksheet for the A Crew.

ADVANCE SCHEDULE WORKSHEET

For week of: 5/11/99 to 5/14/99
 For crew: B Crew By: C. Rodgers Date: 5/7/99

Page 1

| Forecast | Available Hours Left | | | | | | | | | | | |
|-------------------|----------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| | (Work Order #) | | | | | | | | | | | |
| | #35 | #36 | #29 | #28 | #41 | #37 | #33 | #34 | #39 | #26 | #23 | #42 |
| Mech 107 | 101 | | | | 97 | | | | | | | |
| Welder 38 | | | | | | | | 36 | 33 | | | |
| Machinist 68 | | | 60 | | | 46 | 40 | | | | | |
| Painter | | | | | | | | | | | | |
| Tech 107 | 87 | | | | 83 | 69 | 63 | | | | 43 | 35 |
| Helper 135 | | 123 | 111 | 103 | 99 | 91 | | | 89 | | 69 | |
| Totals <u>455</u> | | | | | | | | | | | | |

Instructions: Subtract job work hours from available line total until balance reaches zero for each line or backlog runs out.

FIGURE 6.13 Input of original labor forecast and first 12 work orders for the B Crew.

welder hours. Along with the 23 B Crew welder hours left over, this is almost enough hours to complete the priority-4 welding job, WO no. 001. There are two common practices to execute this assistance. One method would be for a crew supervisor to give the other supervisor several work orders. The other method would be for a crew supervisor to plan to loan the other supervisor several persons for a day or two. For example, presume that on the scheduler's recommendation, the A Crew supervisor gives the B Crew supervisor work order nos. 010 and 013. In addition, the B Crew supervisor arranges to give the A Crew one day of machinist help and two days of welder help toward the end of the week, if necessary.

STAGING PARTS AND TOOLS

Staging is not essential to maintenance planning. Planning and scheduling can achieve high productivity without staging parts and tools. Moreover, staging can be a time waster. Nevertheless, staging can significantly boost productivity for completing more work.

Staging means physically moving a part or a tool out of its regular storage place to where a technician can more easily obtain it before a job. Staging items reduces the time a

ADVANCE SCHEDULE WORKSHEET

For week of: 5/11/99 to 5/14/99
 For crew: B Crew By: C. Rodgers Date: 5/7/99

Page 2

| Forecast | Available Hours Left | | |
|--------------|----------------------|-----|-----|
| | (Work Order #) | | |
| | #40 | #21 | #30 |
| Mech | 96 | | |
| Welder | 23 | | |
| Machinist | | 38 | |
| Painter | | | |
| Tech | 29 | | 9 |
| Helper | 59 | 58 | 38 |
| Totals _____ | | | |

Instructions: Subtract job work hours from available line total until balance reaches zero for each line or backlog runs out.

FIGURE 6.14 Using a second page and allocating the next five work orders.

ADVANCE SCHEDULE WORKSHEET

For week of: 5/11/99 to 5/14/99
 For crew: B Crew By: C. Rodgers Date: 5/7/99

Page 2

| Forecast | Available Hours Left | | | | | | | | |
|-----------|----------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| | (Work Order #) | | | | | | | | |
| | #40 | #21 | #30 | #27 | #24 | #25 | #38 | #44 | #31 |
| Mech | | 96 | | | 88 | 85 | | | 65 |
| Welder | 23 | | | | | | | | |
| Machinist | | | 38 | | | | | | |
| Painter | | | | | | | | | |
| Tech | 29 | | | 9 | 0 | | | | |
| Helper | 59 | 58 | 38 | 35 | 33 | 13 | | | |
| Totals | | | | | | | | | |

Instructions: Subtract job work hours from available line total until balance reaches zero for each line or backlog runs out.

FIGURE 6.15 Allocating the next four work orders. The first two work orders use other than the minimum labor skill that was planned.

technician would otherwise spend gathering parts and tools before a job. A net reduction of time for the company comes from a combination of increased specialization, planner expertise, and reduced opportunity for delay trips. First, the person staging the part normally stages more than one job at a time, perhaps as many as needed for the whole crew. The employment of staging reduces the overall number of trips to the storeroom when handling several jobs at the same time. The person staging the items also gains a better than usual familiarity with the storeroom, further reducing time to procure any single item. Second, if

the person who plans the job also stages the items, there is another advantage. The planner who specified the item to begin with has the best idea of exactly what item the job requires. This familiarity may speed the process of obtaining the right part at the counter. Third, staging helps keep technicians on the job. Any trip away from the job to a storeroom or tool room can escalate beyond a simple delay to obtain the originally intended item.

Staging is similar to having the operations group clear a piece of equipment. The maintenance group prefers to have the equipment cleared before arriving on-site with three technicians. If the operations group did not have the equipment ready, the technicians would have to wait or lose overall efficiency finding other jobs to fill the wait time. Therefore, the operations

ADVANCE SCHEDULE WORKSHEET

For week of: 5/11/99 to 5/14/99
 For crew: B Crew By: C. Rodgers Date: 5/7/99

Page 2

| Forecast | Available Hours Left | | | | | | | | | | | |
|-----------|----------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| | (Work Order #) | | | | | | | | | | | |
| | #40 | #21 | #30 | #27 | #24 | #25 | #38 | #44 | #31 | #32 | #43 | #22 |
| Mech | | 96 | | | 88 | 85 | | | 65 | 25 | 11 | |
| Welder | 23 | | | | | | | | | | | |
| Machinist | | | 38 | | | | | | | | 11 | |
| Painter | | | | | | | | | | | | |
| Tech | 29 | | | 9 | 0 | | | | | | | |
| Helper | 59 | 58 | 38 | 35 | 33 | 13 | 0 | | | | | |
| Totals | | | | | | | | | | | | 45 |

Instructions: Subtract job work hours from available line total until balance reaches zero for each line or backlog runs out.

FIGURE 6.16 Allocating the final three work orders in entire backlog.

ADVANCE SCHEDULE WORKSHEET

For week of: 5/11/99 to 5/14/99
 For crew: B Crew By: C. Rodgers Date: 5/7/99

| Forecast | Available Hours Left |
|--------------------------|---|
| Mech 107 | 101 97 96 88 85 65 25 11 |
| Welder 38 | 36 33 23 |
| Machinist 68 | 60 46 40 38 11 |
| Painter | |
| Tech 107 | 87 83 69 63 43 35 29 9 0 |
| Helper 135 | 123 111 103 99 91 89 69 59 58 38 35 33 13 0 |
| | |
| | |
| | |
| | |
| Totals <u>455</u> | <u>45</u> |

Instructions: Subtract job work hours from available line total until balance reaches zero for each line or backlog runs out.

FIGURE 6.17 Realistic completed Advance Schedule Worksheet for the B Crew.

group might normally clear the equipment during the night shift based on a request from the previous day's scheduling meeting or schedule. The technicians then arrive and go to work in the morning without delay. Likewise, the maintenance group prefers parts and tools to be ready for work. There might be overall inefficiency if two of the technicians have to wait for one technician to check out a special tool or wait in front of the storeroom counter.

Consider several tasks by a school maintenance person as an illustration of some of the benefits of staging. The school had identified a broken easel and a broken toddler table. The maintenance person serving several schools showed up at 11:00 AM. The

school secretary handed over a bag containing a replacement bolt and plastic fitting for the easel and another bag with a washer and bolt for the table. The maintenance person took the staged items and fixed both pieces of furniture in 20 minutes. The school secretary had saved expensive maintenance service time by staging the parts needed. The secretary had determined what items were needed by simply examining the furniture and describing the problem to the appropriate school furniture supply company. This company had mailed the exact required parts the preceding week.

Consider another example from a modern electric power plant. The planner scoped the job to replace a flanged valve. The planner staged a sling, gasket material, and 48 bolts, washers, and nuts along with the replacement valve. The planner did not stage a necessary come-a-long as this device was standard issue in mechanic tool boxes. The planner placed all the items together on a pallet in the tool room. The planner identified the job as staged on the work order and attached a copy of the work order to the pallet to aid later identification. The two assigned technicians later transported the materials to the job site and expeditiously completed the work.

With staging in place, envision a technician arriving at work already knowing what job to start on from the previous day's schedule. The technician picks up his or her tool box along with a bag of parts staged the night before and heads to the job site.

The following sections discuss what might be practical to stage, where items could be staged, who should stage the items, and how to go about staging items.

What to Stage

The maintenance group should consider staging all the items the planner included in the job plan. When planning a job, the planner identifies the items that the planner anticipates the job requires. The key word is anticipated. Just as the planner includes time for only anticipated delays, the planner plans for only anticipated parts or tools. The planner estimates the anticipated job cost using these anticipated times, parts, and tools. The planner may include an equipment parts breakdown with the job plan, but this is only a list. The work plan expressly identifies anticipated items for this job. Therefore, it follows that if the job plan calls for certain items, those items could be staged.

However, a number of questions remain. What if it is uncertain what parts a job will need? Perhaps a high chance exists that the anticipated parts will be unnecessary. In addition, perhaps a high chance exists that unanticipated parts will be necessary. If there is a high probability that the technician will have to go to the storeroom for unanticipated items, why bother to stage the anticipated items the job will certainly require? Moreover, what happens to unused staged items on a job? What about time expended to return those items to stock?

Consider a technician that has already started a job where the planner has anticipated the use of several parts. The technician soon finds out the job requires only a single specific part. The technician can obtain just that item from the storeroom. Thus, there are no extra items taken to the job site and no leftover items to return. Why not have the planner just reserve the anticipated parts rather than stage them as well? Reserving through advance notice to the storeroom rather than the additional step of staging may be all that is needed.

As one can see, these questions complicate decisions regarding whether to stage items. Jobs vary just as do plant sites and plant processes such as receiving and returning storeroom items. Therefore, the following guidelines help the maintenance force make better decisions about staging.

Always stage anticipated items that are:

1. Nonstock and purchased especially for the job.
2. Certainly needed for the job and there is little likelihood any other items from the same place will be needed. Example: Job to replace air filter.

Favor staging anticipated items where:

1. There is high likelihood item will be needed.
2. There is low likelihood other items from the same place will be needed.
3. Technician time is valuable.
4. Technician time is limited.
5. Persons to stage items are readily available.
6. Equipment downtime is valuable.
7. Equipment downtime is limited.
8. Distance to the storeroom or tool room is excessive.
9. Availability or accessibility of storeroom or tool room is limited.
10. It is relatively difficult later to transport items to the site if they are not staged.
11. Item is easily returnable to storeroom or tool room.
12. Item is disposable if unused or lower in value than would be worth technicians' time to return.
13. There is some experience with planning and scheduling.
14. There is high maturity and sophistication of the planners to anticipate items correctly.
15. There is high confidence that the job will start the week or day scheduled.

Do not stage items that are:

1. For unscheduled jobs unless a nonstock item was exclusively obtained for a job.
2. Difficult or impractical to move repeatedly due to size or storage requirements.
3. Difficult or impractical to move repeatedly due to legal tracking requirements.

Scheduling is frequently the most critical factor influencing staging. Chapter 3 presented the case that if work could reasonably be expected to start in a given week, staging could be practiced. If there was no advance scheduling to tell when maintenance expected to start jobs, it might be impractical to stage parts or tools. One problem arises from taking parts or tools out of stock for a job that the maintenance crew may not start for quite a while. The staging makes the parts and tools unavailable for other jobs. The second problem arises from the physical storage of the staged parts and tools. Temporary holding places for staged items become overwhelmed and items become lost. On the other hand, if the maintenance group schedules a job for the next day or the next week, staging parts and tools can boost productivity. Staging a part or tool for a scheduled job makes sense because there is a commitment to starting the jobs. In that case, the staged items become properly unavailable for use elsewhere because they really do need to be reserved for jobs about to begin. In addition, because their jobs are about to begin, there is limited danger of overfilling a designated staging area.

Where to Stage

There are various possibilities for where the maintenance force may stage items, each with advantages and disadvantages. These possibilities include central staging areas, scattered staging areas, job sites, crew ready areas, and technician benches. Moreover, combinations of any of these approaches may be the most practical for a particular plant situation.

A central staging area would be an area where any item could be staged. The area could be part of another operation such as the tool room where technicians come to a counter to

request their items. The area could otherwise be one dedicated for staging without a counter where some or all technicians have open access. Using a central staging area gives fairly good security to keep parts from being lost. Persons have little doubt where an item is staged because there is only one possibility. A central staging area lends itself to uniform procedures, especially with a counter operation. Unfortunately, the central staging area may not be better than leaving the items in the storeroom if the technician still has to go to a counter and wait for the attendant. Despite this concern, staging storeroom items in the tool room may still be a good idea. The maintenance group may have better control over the staging area than the storeroom. Many companies place the storeroom under the control of a group other than maintenance. The storeroom management may be unwilling or unable to make its checkout procedure user friendly. In this case, having a few persons stage the anticipated items out of the storeroom to a more readily accessible tool room for the bulk of technician activity makes sense. Geographic accessibility also makes a difference. The storeroom may be more remotely located than the staging area for most jobs. There may even be several storerooms scattered about the plant site for various types of goods. Having an efficient operation to stage items to a central location might increase overall efficiency. Technicians would not have to be as familiar with the various storerooms to obtain a part if they could go to a central staging area. A central staging area has several disadvantages versus other staging options. It may be better to stage items closer to job sites to speed up work. Also, a central staging area may still require the technicians to make a side trip. Each extra trip during the day invites technicians to add unnecessary delays. Technicians might check with the supervisor or technician friends "just to see what is going on." They might run by the machine shop to use the telephone "for a minute." Then the technicians must refamiliarize themselves with the jobs when they return. Mostly due to simple human nature, the delays add up when the staging area does not support technicians staying on the job site.

Scattered staging areas attempt to remedy the shortcomings of central staging. In this arrangement, there are several designated areas for staging. They are scattered throughout the extensive plant area. The locations are close enough to the general areas of work to avoid inviting any unnecessary side trips. They are also located out of regular traffic pathways, but easy to find. These staging areas are not necessarily elaborate and may be simply formed with lines of yellow paint. One aluminum rolling mill operation outlines squares of space on the plant floor in this manner. A more complex area might involve a shed. This is how one steam plant set up a staging area for specialized turbine tools on the turbine deck. Such a secure area may have a counter with an attendant and be open only during certain turbine work. At other times, limited access is available to supervisors or certain technicians. Other variations abound in between a secure shed with a counter and a painted square space. A shed, room, or cage could exist with or without a door lock or padlock. Large wooden boxes could be placed in strategic locations. Expensive or inexpensive shelving can be utilized. A closely associated issue is having access to tools at various locations throughout the plant. A particular job on a burner might require specialized tools that the plant uses nowhere else. It would make sense to have the burner tools located in a tool box on the burner deck ready for use whether a job is in the backlog or not. It could be argued whether this is scattered staging or a scattered tool room. In either case, the objective is to have items on hand to reduce travel and delays during the job. The disadvantages of a scattered staging strategy revolve around having less control and requiring more coordination. There is less security to prevent missing parts. It takes increased effort to take items to more than a single location. Nevertheless, having scattered sites close to the work areas can reduce delays to improve productivity.

Staging material directly at a job site provides the greatest advantage of not having to move parts repeatedly and limiting reasons to leave the job site. On the other hand, this arrangement provides the least security against missing parts. It could also contribute to a more hazardous plant site with parts located every which way. There is also danger for

damaging items before they can be used if they get in the way of other plant maintenance or operations. The amount of coordination involved in finding each specific job site to receive items could be a further problem. Even with good coordination, there is a significant chance of putting an item at the wrong site and in effect losing it. On-site staging might make sense for a rotating spares program where there is a designated storage accommodation for the extra equipment. It is also practical to deliver large, nonstock equipment directly to the job site. It may also work out for items that are not readily transported later such as medium to large motors, valves, piping, and pumps. Note that the size of these items also makes it unlikely that they would be carried away from the job site. One plant makes the last duty of the day for tool room attendants to move heavy equipment such as cranes to the sites for the next day's jobs. Smaller items such as gaskets, small valves, and fittings are more practically staged in crew ready areas or on technician work benches.

The crew ready area is a likely place to stage relatively small items. Many crews have a designated area where they check in each morning. The crew may also use this area as a break room. Having a shelf or side area in this room for staged items reduces the need for an extra trip to a central staging location. This is especially true of the first job for the day and usually for a second and third job if breaks can be coordinated between jobs. The supervisor has some measure of control over such a location which may be an advantage over scattered locations or job sites. The supervisor also may be more interested in the staging operation with its visible presence there. A supervisor receives excellent feedback of how staging is working when the crew receives items in the supervisor's presence.

Technician benches cannot be overlooked as likely places to stage items. Many companies have a work area of sorts for every technician. This is especially true of many I&C technicians and electricians. It is also common for mechanics and other mechanical crafts to have work benches. These work places allow technicians a clean shop area to work on devices and equipment. Cleanliness gives a great boost to any maintenance task. Companies would rather a technician be free to concentrate on keeping gasket faces clean than to worry about where to obtain gasket material. Planning ahead to ensure parts availability and staging to deliver parts helps the technician's concentration. Technician benches are natural places to consider staging items. The technicians consider these areas their personal spaces and check in there just as they would their crew area each morning. In addition, technicians conduct many of the maintenance tasks in whole or in part on their bench. Therefore, staging items here might mean the technicians need not make any trips elsewhere. Consider a job to replace a gasket on a leaking flange. On this job, the technician needs to cut a gasket from a roll of gasket material. The planner has noted the size of the gasket needed as well as the gasket material. The day before the job, the supervisor has someone from the tool room drop off enough gasket material on the technician's bench for the job. The next day, the technician cuts the gasket, grabs rubber boots, and heads to the job site with the tools to fix the leaking flange. Drawbacks to staging on technician benches include a limitation on item size and possibly limited space available. The same coordination and security drawbacks of having multiple and scattered staging locations exist. An additional problem, unique to staging items at the technician benches, is that the person staging items must know the name of the assigned technician. The crew supervisor makes the assignments with the daily schedule. Because the weekly schedule does not identify the assigned technician, the person would not be able to use the weekly schedule to stage the items. Staging would have to be done daily from the daily schedule.

Who Should Stage

Normally the planner stages items, but there is equal opportunity for the scheduler, materials purchaser, tool room personnel, storeroom personnel, crew person, or even the supervi-

sor to perform this function. Staging must not come ahead of other planning duties if management has excessively limited the number of planners. The materials purchaser is probably the best person to stage nonstock items received. In addition, if the staging is based more on the daily schedule than the weekly schedule, the supervisor or his or her designee would be more appropriate to do the staging. For simplification, the following section calls the person who does the staging, the staging person.

The Process of Staging

After the scheduler makes up the weekly schedule, the staging person reviews the scheduled work orders. This person might review them before delivery to the crew supervisors or later in the supervisors' offices. (Alternately the planner could review, and mark, the work orders and direct the staging person.) To avoid delaying the receipt of the weekly schedule by the crew supervisor, the staging person may find it more desirable to work from the crew supervisor's office. The person would also have better access to the work orders. The staging person marks the work orders for which items will be staged and makes a copy of each work order that will have staged items. Then, the staging person takes the work order copies to the storeroom and tool room and collects the items to stage. The staging person takes the collected items to the appropriate staging locations and attaches the work order copy to groups of items for each job. The person places items in appropriate containers such as bags for bolts and loose items, each marked for the appropriate work order. If there are several containers for the same work order, the staging person marks the work order copy as having four bundles and each bundle as 1 of 4, 2 of 4, 3 of 4, and 4 of 4, each with the work order number. These activities may take one or more trips.

The staging person must relocate the original work order for any items that were supposed to be staged, but could not be staged for some reason. The person marks these work orders accordingly. The staging process might discover an unexpected problem with item availability that will impact a job. In this case, the staging person informs the crew supervisor and planning so that the job will not be assigned until planning remedies the problem. In the case where the daily schedule is utilized, the same process is followed on a daily basis.

What happens to staged items for a job that is not started in its assigned day or allocated week? The items that were staged for this job are not collected and returned. It is presumed that this job will likely be assigned on a subsequent day or allocated in the next week's work. The job is simply considered already staged. This situation could get out of hand if jobs are routinely staged that never start. Staging areas could become overrun and inventory stocks could become depleted. This scenario is more likely for the plant that stages without any scheduling. Staging accomplished after some scheduling effort keeps these problems to an acceptable level. Daily staging for only the next day's work lowers the probability of these problems even further.

One thing to realize is that there is a limited time available to stage items. The difficulty comes in the timing because the advance schedule is only an allocation of work and does not denote which day activities might begin. If the staging person waits to use the advance schedule, there is not much work time after which the schedule becomes available before the work week begins. If the crew works Monday through Friday, 7:30 AM to 4:00 PM, the advance schedule would be available Friday afternoon for the staging person. The staging person could extend the work time available by working a weekend or evening shift to stage items. If the crew works another type shift, other times may work better. Consider a crew that works Monday through Thursday, 10-hour days. The staging person could work Monday through Friday 8-hour days and have Thursday afternoon as well as all day Friday to stage. In addition, if the supervisor prepares the first day's schedule soon after receiving the weekly allocation, the staging person could first concentrate

on staging parts for that first day's work. Then the staging person could spend a small amount of time each day reviewing the next day's schedule from the supervisor and staging the appropriate parts.

In summary, staging can help improve maintenance productivity, but it is not essential to effective planning and scheduling. Furthermore, staging can become somewhat complicated to execute properly. Among a number of guidelines, scheduling control and experience dictate the successfulness of staging. Imagine a common household situation. One adult plans to hang several pictures and shock the swimming pool one night during the coming week. This person "stages" a hammer, several nails, and a bag of pool shock on a kitchen counter as the items are encountered during other weekend tasks. However, the items disappear from the counter as the week proceeds and wind up in various drawers or garage shelves. The person's spouse has put the items away to avoid clutter. The tasks of hanging the pictures and shocking the pool have become more complicated now as the location of the necessary items has become uncertain. Industry commonly experiences the same primary problems hindering these maintenance tasks, namely an improper staging area and an imprecise schedule for the work.

DAILY SCHEDULING

As discussed for Scheduling Principle 5 in Chap. 3, the crew supervisor schedules work orders on a daily basis. Formal daily scheduling assigns specific individuals to specific work orders in a manner that accounts for each labor hour available and works toward the goal of completing the work allocated by the weekly schedule.

Without formal daily scheduling, a natural tendency encourages supervisors to concentrate on higher priority work. Without something to encourage completion of lower priority work as well, most of the maintenance work started might be only the higher priority work. Supervisors might also tend to assign the more skilled technicians to this important work. This leads to a phenomenon of actually giving the less skilled technicians "busy work," many times work without a work order. These latter technicians might be sent to provide unneeded assistance on the higher priority jobs. They might also be allowed to take extra time on the jobs they are assigned. The supervisors desire to save the higher priority work for the higher skilled technicians. At the same time, the higher skilled technicians may see themselves as unfairly having to do most of the work. Consequently, the supervisors do not require schedule accountability. In short, productivity is left to the discretion of the high skilled portion of the work force to work at a reasonable pace on only the important jobs of the day.

In contrast, a formal, daily scheduling routine encourages the supervisors to focus on the completion of work orders rather than on keeping employees busy. The daily schedule routine ensures all technicians who work on work orders to be accountable to a schedule. The daily schedule makes sure everyone has a valid work order job. The daily scheduling routine encourages the supervisors to give the less skilled technicians greater challenge by not holding back jobs to save for other technicians. The daily schedule discourages the use of blanket accounts for time reporting because the daily schedule form plainly shows assignments. The daily schedule gives the supervisor a tangible tool with which to work toward the goal of finishing all the jobs scheduled for the week and showing what other work may have prevented them from meeting the goal. The daily schedule provides a means for the supervisors to keep track of all the jobs currently in progress and the jobs due to start the next day. The daily schedule requires the supervisor to consciously manage the crew. Having more jobs going on at the same time requires an attentive supervisor, as issues of personalities, working on jobs of more challenge, and more logistics problems arise.

The daily scheduling process begins with selecting work orders and assigning names, then coordinating with the operations group, and finally handing out the work order assignments.

Assigning Names

Different exact methods exist to schedule work for a single crew day. The important elements are that the scheduling method attaches particular tasks to each crew member's name and that the method fills each crew member's available work hours. For example, the crew supervisor should assign 10 hours of work to each crew member available for 10 hours. The supervisor bases the assignments on the planned estimates for the work orders. Depending on the industry, the supervisor might also denote the exact time during the day when each job should start or end. This would be more the case for a product line taken out of service with exact scheduling from the operations group. It would be less the case where operations can clear up certain areas for a day of maintenance without significant production problems. This chapter's outage section later addresses the urgency and coordination of outage work.

The crew supervisor normally schedules the daily maintenance activities for the crew. The scheduler might be able to do the operation of daily scheduling, leaving the supervisor free to manage work in progress and people issues. However, the daily scheduling is normally too integrated into the management of the crew for the supervisor to transfer away this duty.

Figure 6.18 shows a typical form that supervisors might use to assign names to work orders. The supervisor uses the form for a specific day. The form consists of a grid with spaces for work orders on the left and crew member names on the top. A single line near the bottom takes care of nonwork order time such as vacation. Codes allow identification

| DAILY SCHEDULE | | | | | | | | | | | | | | |
|---------------------|------|-----|-------------------|--|--|--|--|--|--|--|--|--|----------|--|
| DAY: _____ | | | DATE: _____ | | | | | | | | | | | |
| SUPERVISOR: _____ | | | | | | | | | | | | | | |
| WO# | Unit | Pri | Short Description | | | | | | | | | | Comments | |
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| Special Codes: | | | Special Code | | | | | | | | | | | |
| V-Vacation | | | S-Sick & Hours | | | | | | | | | | | |
| T-Training | | | O-Other | | | | | | | | | | | |
| A-Assigned Off-Crew | | | Total | | | | | | | | | | | |

FIGURE 6.18 Form for daily scheduling.

of specific types of nonwork order time. The bottom line provides a space for totaling each technician's time. These totals help the supervisor assign enough work to fill each hour of the shift for each person.

Figure 6.19 shows how the B Crew supervisor has added the name for each member of the crew. The supervisor can add the names one time and then copy enough forms for a supply of preprinted, daily scheduling forms. The company's graphics department might publish these daily schedule forms in pads.

Figures 6.20 through 6.24 illustrate the use of the daily schedule form for B Crew using the previously developed Crew Work Hours Availability Forecast (Fig. 6.4) and the allocated backlog for the week (Fig. 6.17 and Table 6.6). First, Supervisor J. Field adds the day and date for the day being scheduled. Field is scheduling for Tuesday, the first day of the work week for B Crew which works 10-hour days. Figure 6.20 also shows the craft skill level for each person: M, T, S, W, and H for mechanic, technician, machinist, welder, and helper, respectively. Such designation is normally unnecessary because supervisors are familiar with their technicians' capabilities.

The supervisor first enters unavailable hours for different crew members. The supervisor marks the crew members who are unavailable for the next day for training, leave time, or other reason. The supervisor marks the form by placing the number of hours any employee is unavailable under the employee's name along with the proper reason code on the special code line. Field had approved 10 vacation hours for welder Hunter that day. Next, the supervisor adds any carryover hours from the preceding work day. The supervisor writes down the work order number and brief title of any carryover work that will run into this next day's schedule. The supervisor marks down the hours needed during the next day for carryover on the same horizontal line as the work order, but under each involved

| DAILY SCHEDULE | | | | | | | | | | | | | | | | | | | | |
|------------------------|------|-----|-------------------|--------------|--------|--------|-------|--------|--------|-------|-------|----------|-----------|------------|---------|-------|--------|-------|----------|--|
| DAY: _____ DATE: _____ | | | | | | | | | | | | | | | | | | | | |
| SUPERVISOR: _____ | | | | | | | | | | | | | | | | | | | | |
| WO# | Unit | Pri | Short Description | Adamson | Barber | Capper | Glade | Hunter | Jensen | Johns | Jones | Kingsley | Patterson | Richardson | Sanchez | Smith | Wilson | Young | Comments | |
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| Special Codes: | | | | Special Code | | | | | | | | | | | | | | | | |
| V-Vacation S-Sick | | | | & Hours | | | | | | | | | | | | | | | | |
| T-Training O-Other | | | | | | | | | | | | | | | | | | | | |
| A-Assigned Off Crew | | | | Total | | | | | | | | | | | | | | | | |

FIGURE 6.19 Example preprinted form with crew member names.

| DAILY SCHEDULE | | | | | | | | | | | | | | | | | | | | |
|---------------------------------------|------|-----|-------------------|--------------|--------|--------|-------|--------|--------|-------|-------|----------|-----------|------------|---------|-------|--------|-------|----------|--|
| DAY: <u>Tues</u> DATE: <u>5/11/99</u> | | | | | | | | | | | | | | | | | | | | |
| SUPERVISOR: <u>J. Field</u> | | | | | | | | | | | | | | | | | | | | |
| WO# | Unit | Pri | Short Description | Adamson | Barber | Capper | Glade | Hunter | Jensen | Johns | Jones | Kingsley | Patterson | Richardson | Sanchez | Smith | Wilson | Young | Comments | |
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| Special Codes: | | | | Special Code | | | | | | | | | | | | | | | | |
| V-Vacation S-Sick | | | | & Hours | | | | | | | | | | | | | | | | |
| T-Training O-Other | | | | | | | | | | | | | | | | | | | | |
| A-Assigned Off Crew | | | | Total | | | | | | | | | | | | | | | | |

FIGURE 6.20 Input of date for the B Crew to schedule the first day of work week.

technician's name. Whenever the total hours for any individual reach ten, the supervisor writes 10 on the bottom line of the form. Figure 6.21 shows the results of these entries. Note that at this point, six persons of the 15 person crew have been assigned their entire 10 hours.

Next the supervisor must consider any urgent work that has come up since the time the weekly schedule was established. There may be several new urgent jobs that should not wait until the next week to begin. The supervisor adds to the daily schedule any urgent job that should begin that day. Such reactive work is planned, but planning on reactive work usually provides only an adequate scope and estimates of craft needs and work hours. This plan is all the crew supervisor needs to work the job into the schedule. With even a rudimentary plan, the supervisor keeps control of the schedule because planning has identified craft and time. The supervisor makes the decision to work these jobs into the current work load knowing that they will hinder the crew's completing all the weekly scheduled work. The supervisor would prefer to wait until the following week to begin all newly identified work for several reasons. First, jobs already scheduled for the current week have a greater likelihood of being staged leading to higher crew productivity. Second, waiting until next week gives the new jobs a better chance of having their items staged. Third, the current week's schedule was put together with some thought toward including all PM work plus sufficient other proactive work. The new job is reactive and will presumably keep proactive work from being done. Fourth, there is less chance to coordinate other resources such as other crafts. Management measures schedule compliance to encourage crews to get more work done. Working on the weekly allocation of work orders is a high priority for the crew supervisor. Nonetheless, the crew supervisor must redirect crew resources to work on truly urgent work for the good of the plant. The overall scheduling process is geared toward doing more work and doing more proactive work. However, the overall goal of the plant is not just better future availability, but availability in the immediate present as well. Urgent

| DAILY SCHEDULE | | | | Adamson | M | W | H | M | W | T | S | T | S | H | H | H | H | |
|-------------------------|------|-----|-------------------|--------------|----|----|----|----|----|----|----|----|----|----|---|---|---|-----------|
| DAY: Tues DATE: 5/11/99 | | | | Barber | | | | | | | | | | | | | | |
| SUPERVISOR: J. Field | | | | Capper | | | | | | | | | | | | | | |
| WO# | Unit | Pri | Short Description | Glade | | | | | | | | | | | | | | Comments |
| 016 | 0 | 1 | Boiler structure | | 10 | | | | | | | | | 10 | | | | Carryover |
| 017 | 0 | 3 | Fab pump shaft | | | | | | | | | | 10 | | | | | " |
| 019 | 2 | 2 | Vacuum pump | 10 | | | | | | | | | | | | | | " |
| 015 | 2 | 2 | Underdrains | | | | | | 10 | | | | | | | | | " |
| Special Codes: | | | | Special Code | | | | V | | | | | | | | | | |
| V-Vacation S-Sick | | | | & Hours | | | | 10 | | | | | | | | | | |
| T-Training O-Other | | | | | | | | | | | | | | | | | | |
| A-Assigned Off Crew | | | | Total | | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | | | | | |

FIGURE 6.21 Indication of craft skills. Input of unavailable crew hours and carryover work.

reactive work cannot be ignored. The crew supervisor must address those areas needing immediate attention. This reasoning is why the supervisor is responsible for daily scheduling and the immediate direction of the crew. The crew supervisor deviates from the weekly schedule when necessary and later explains such variances to management.

The supervisor does not have to consider emergency work when planning the next day's schedule. Crews always begin true emergency work immediately. If it can wait until the next day or the start of the shift, it may be urgent work, but it is not emergency. The supervisor immediately reassigns technicians from their current assignments for any emergency work. The supervisor makes note of these reassignments by marking up the current day's schedule, but there is nothing to mark on the schedule for tomorrow unless the current work will carry over. Then it is treated on tomorrow's schedule as carryover just as any job still in progress. If an emergency job were to come up in the middle of the night before the start of the next shift, the schedule would have already been completed. The supervisor simply revises the schedule as necessary to reflect the already assigned persons.

The weekly schedule still helps improve weekly productivity even when crews do not start scheduled work as a result of emergency or other urgent jobs arising. When reporting variance from the weekly schedule, it is difficult to explain why only one emergency job and three urgent jobs kept ten scheduled jobs from starting.

In the current illustration for B Crew, no emergencies or urgent jobs have come up for consideration in the current day's work or for the following day. This plant places an emphasis on preventing urgent situations. Personnel report small problems that can be handled proactively before they grow into large problems. Management discourages anyone including engineers from requesting work at the last minute that they could have identified earlier.

Next, the supervisor inspects the week's worth of work consisting of the folders with work orders. The advance scheduler had prepared these folders for each lead craft.

Generally the supervisor starts with the folder that represents the bulk of the crew. This folder has the most work since there were more persons for which the scheduler had to give work. The supervisor selects one job at a time and places the work order number on the daily schedule form along with a brief description of the work. Then the supervisor assigns the proper crew members to the job by allocating the work hour estimates under their names. The selection of jobs and assignment of persons is not an exact science. The supervisor prefers to consider higher skill work ahead of lower skill work to help keep assignment options open. Another preference the supervisor follows is to assign a large job to several persons, then keep those persons together for the day by assigning smaller jobs to fill their available hours. Selecting the larger, high priority jobs first leaves smaller jobs for fitting into schedule slots to make up a person's whole shift. The supervisor's skill in working with personalities comes also into play. This consideration is beyond the ability of the scheduler to make when creating a weekly schedule. Which crew members work best together? Which employees do not get along with each other? Which employees do not cooperate well with anyone? Which employees enjoy a certain type of work? Which employees need a challenge? Which employees possess the necessary skill to accomplish a unique, critical task? Which employees seem to need extra coaching and supervision? Which employees work best independently? Which employees need more experience working together with others? Which employees want opportunities to develop their leadership capabilities by leading larger jobs? Which employees rank high on the overtime list? These employees might be assigned to critical jobs that could run over requiring overtime. Which employees have the most familiarity with a particular system? Which employees need more experience in a certain system? Which employees need more experience developing a particular skill? Which employees most successfully knock out a series of small jobs? Which employees always seem to stretch their jobs to mid-day or to the end of the

| DAILY SCHEDULE | | | | Adamson | M | W | H | M | W | T | S | T | S | H | H | H | H | |
|-------------------------|------|-----|-------------------|--------------|----|----|----|----|----|----|----|----|----|----|----|---|---|-----------|
| DAY: Tues DATE: 5/11/99 | | | | Barber | | | | | | | | | | | | | | |
| SUPERVISOR: J. Field | | | | Capper | | | | | | | | | | | | | | |
| WO# | Unit | Pri | Short Description | Glade | | | | | | | | | | | | | | Comments |
| 016 | 0 | 1 | Boiler structure | | 10 | | | | | | | | | 10 | | | | Carryover |
| 017 | 0 | 3 | Fab pump shaft | | | | | | | | | | 10 | | | | | " |
| 019 | 2 | 2 | Vacuum pump | 10 | | | | | | | | | | | | | | " |
| 015 | 2 | 2 | Underdrains | | | | | | 10 | | | | | | | | | " |
| 036 | 0 | 1 | Unloading arms | | | 6 | 6 | | | | | | | | | | | 6 |
| 029 | 0 | 4 | Dock gutters | | | 4 | 4 | | | | | | | | | | | 4 |
| Special Codes: | | | | Special Code | | | | V | | | | | | | | | | |
| V-Vacation S-Sick | | | | & Hours | | | | 10 | | | | | | | | | | |
| T-Training O-Other | | | | | | | | | | | | | | | | | | |
| A-Assigned Off Crew | | | | Total | | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | | | 10 |

FIGURE 6.22 Input of the first two jobs from the allocated weekly backlog.

| DAILY SCHEDULE | | | | Adamson | M | Barber | W | Capper | H | Glade | M | Hunter | W | Jensen | T | Johns | S | Innes | T | Kingsley | S | Patterson | H | Richardson | H | Sanchez | M | Smith | T | Wilson | H | Young | H | Comments | |
|----------------------|------|-----|-------------------|---------|----|--------|----|--------|----|-------|---|--------|---|--------|---|-------|---|-------|---|----------|----|-----------|----|------------|---|---------|---|-------|---|--------|---|-------|---|----------|-----------|
| WO# | Unit | Pri | Short Description | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 016 | 0 | 1 | Boiler structure | 10 | | | | | | | | | | | | | | | | | | 10 | | | | | | | | | | | | | Carryover |
| 017 | 0 | 3 | Fab pump shaft | | | | | | | | | | | | | | | | | | 10 | | | | | | | | | | | | | | " |
| 019 | 2 | 2 | Vacuum pump | 10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | " |
| 015 | 2 | 2 | Underdrains | | | | | | | | | 10 | | | | | | | | | | | | | | | | | | | | | | | " |
| 036 | 0 | 1 | Unloading arms | | | | 6 | 6 | | | | | | | | | | | | | | | | | | | | | | | | | | 6 | |
| 029 | 0 | 4 | Dock gutters | | | 4 | 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 | |
| Special Codes: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V-Vacation S-Sick | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| T-Training O-Other | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| A-Assigned Off Crew | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Special Code & Hours | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Total | | | | 10 | 10 | 10 | 10 | 10 | 10 | 10 | | | | | | | | | | | | 10 | 10 | | | | | | | | | | | 10 | |

FIGURE 6.23 Input of the next three jobs into daily schedule.

shift? The supervisor's knowledge of the crew allows taking these considerations into account when assigning the allocated work on a daily basis.

The supervisor should resist assigning more than the estimated hours on the work order. For example, if the work order has an estimated requirement of two mechanics for 6 hours each, the supervisor would put "6" under two crew member names, not "8" for each to fill up an 8-hour shift. The job may end up running over, but the supervisor does not want to begin by anticipating the job will consume the entire shift. The assignment of exact work order hours would be a good check area for concerned managers. Checking the daily schedule may indicate a problem with most jobs seeming to be always planned for 10 hours or scheduled for 10 hours just because that is the shift arrangement.

The supervisor continues selecting tasks from the folders and distributing their hours among the crew. A work order may be attached to other work orders for the same system. In this case, the supervisor prefers to assign all of the attached work orders to a larger group of persons for the same day rather than assigning them to a smaller group over several days. Working all the jobs for a single system at the same time shortens the time the system must be out of service. It also contributes to a sense of accomplishment for both the crew and the operations group when they complete all the work on a system.

The supervisor continues selecting tasks until all crew members have their available work hours assigned to work orders. After assigning a number of the work orders, the supervisor has to exercise some further judgment in selecting work orders. The best persons to which to assign a particular work order may have too few hours left in the shift to complete that work order. The supervisor is free to assign technicians to start a bigger job that they will not finish in the shift. If assigning a 10-hour job to a person with only 3 hours left available, the supervisor would place a "3" under the person's name across from the

new job. The supervisor could also immediately begin the next day's schedule with the job at hand placing a "7" in the pertinent crew member box. That schedule may be adjusted later for different carryover hours when actual job progress is assessed. On the other hand, there may be smaller jobs with lower priorities, but fewer hours that could be completed on the same day. The supervisor is free to pick any of the jobs of lower priority in the week's allocation for assignment anytime during the week.

If the supervisor runs out of work from the weekly allocation, then he or she checks with planning to obtain planned work from the unscheduled backlog. This work is in the planning group's waiting-to-be-scheduled file. If there is no planned work waiting, the supervisor checks with the planner about working jobs that are not yet planned. The supervisor should resist assigning work without a work order.

The supervisor totals up each person's assigned hours under the person's name. The hours for each person should add to the person's paid work hours. For example, if 10-hour shifts are employed, then there should be 10 hours totaled up under every employee.

Figure 6.22 shows the first two jobs the supervisor has selected from the week of allocated work. The supervisor has selected the top job from the Mechanic folder. The supervisor first selects WO no. 36 requiring a mechanic and two helpers for 6 hours each. This work order has another work order attached for the same system. This second work order, WO no. 29, requires only two helpers for 6 hours each. After briefly reviewing the work order, the supervisor decides to assign it to the team of three persons doing the first job. The supervisor assigns each of them 4 hours to complete this job and makes a note on the work order. The supervisor has changed the plan of 12 helper hours to assign 8 helper hours and 4 mechanic hours. (This is a little unusual to change a plan in this manner, but it is acceptable.) Now three more persons have 10 total hours for the day.

| DAILY SCHEDULE | | | | Adamson | M | Barber | W | Capper | H | Glade | M | Hunter | W | Jensen | T | Johns | S | Jones | T | Kingsley | S | Patterson | H | Richardson | H | Sanchez | M | Smith | T | Wilson | H | Young | H | Comments | |
|----------------------|------|-----|-------------------|---------|----|--------|----|--------|----|-------|----|--------|----|--------|----|-------|----|-------|----|----------|----|-----------|----|------------|----|---------|----|-------|----|--------|----|-------|----|----------|-----------|
| WO# | Unit | Pri | Short Description | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 016 | 0 | 1 | Boiler structure | 10 | | | | | | | | | | | | | | | | | | 10 | | | | | | | | | | | | | Carryover |
| 017 | 0 | 3 | Fab pump shaft | | | | | | | | | | | | | | | | | | 10 | | | | | | | | | | | | | | " |
| 019 | 2 | 2 | Vacuum pump | 10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | " |
| 015 | 2 | 2 | Underdrains | | | | | | | | | 10 | | | | | | | | | | | | | | | | | | | | | | | " |
| 036 | 0 | 1 | Unloading arms | | | | 6 | 6 | | | | | | | | | | | | | | | | | | | | | | | | | | 6 | |
| 029 | 0 | 4 | Dock gutters | | | 4 | 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | 4 | |
| 028 | 0 | 1 | Pump impeller | | | | | | | | | | | | 8 | | | | | | | | 8 | | | | | | | | | | | | |
| 027 | 0 | 2 | Cat underdrain | | | | | | | | | | | 2 | | | | | | | | | | 1 | | | | | | | | | | | |
| 030 | 0 | 1 | Trn Pump Alien | | | | | | | | | | | | | | | | | | | | | 1 | 1 | | | | | | | | | | |
| 035 | 0 | 1 | Piping | | | | | | | | | | | | | | 10 | | | | | | | | | | | | | | | | | | 2 day job |
| 031 | 2 | 3 | Aux feed pumps | | | | | | | | | | | | | | | | | | | | | | 9 | 10 | | | | | | | | | 2 day job |
| 025 | 0 | 2 | Caustic leaks | | | | | | | | | | | | | | | | | | | | | | | | 10 | | | | | | | | 10 of 17 |
| Special Codes: | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| V-Vacation S-Sick | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| T-Training O-Other | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| A-Assigned Off Crew | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Special Code & Hours | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Total | | | | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | |

FIGURE 6.24 Completed daily schedule for the B Crew.

Figure 6.23 shows the result of the next three work orders selected by the supervisor. The supervisor decides to start none of the FO, Fuel Oil Storage and Transfer System, work on Tuesday because neither welder is unavailable. One is involved with carryover work and the other is taking vacation. The supervisor selects WO no. 28 requiring a machinist and a helper and then adds a smaller job, WO no. 27, to finish up the machinist's hours for the day. Because WO no. 030 is on the same system, the supervisor assigns it next.

Next, the supervisor has 20 technician hours, 9 mechanic hours, and 10 helper hours available. The supervisor selects the large job, WO no. 35, requiring 20 hours for one technician to begin 10 hours. The supervisor also assigns a 40-hour job, WO no. 31, to the mechanic and helper to begin a total of 19 hours. Finally, the supervisor assigns a 17-hour job, WO no. 25, to the last technician, Smith, to begin 10 hours. After this scheduling, the supervisor finds that a single person has less than 10 hours assigned. The helper Richardson has only 9 hours assigned. The supervisor sees no single-hour helper jobs and is reluctant to have a helper begin another job alone that will carry over. Therefore, the supervisor adds the helper's last hour to the cation underdrain fabrication job, WO no. 27. This will give Richardson, an apprentice, some time in the machine shop. Figure 6.24 shows the completed daily schedule form with names for all crew members assigned to work orders with all shift hours accounted for, adding up to 10 hours each.

Coordinating with the Operations Group

With the schedule filled out, the supervisor then coordinates with the operations group. The supervisor must communicate with operations for two reasons. The supervisor first requests that the operations group clear the pertinent equipment for the next day. The supervisor must also determine if any testing is advisable as the maintenance crew returns equipment to service. Many plants conduct a daily schedule meeting each afternoon to coordinate the next day's work between these two groups. The meeting consists of the crew supervisors and the operations supervisor. At this meeting, maintenance may also advise regarding the progress of on-going work in addition to coordinating the start and testing of new work.

Clearing means that the operations group is making the equipment available and safe for maintenance work. For example, the operations group may clear the equipment by draining process lines and closing necessary valves and electrical breakers. Then, depending on particular plant policy, the maintenance personnel may follow behind and lock out valves and breakers to their own satisfaction and security. For simplicity, this book presumes the operators do all clearing and maintenance personnel do not perform separate locking. Companies with additional requirements would simply add their required procedures to the illustrative process described here. The company should have a standard process for the maintenance group to notify the operations group of clearance needs. With a daily schedule meeting, maintenance can hand over a printed clearance request form. The maintenance crew could also deliver a clearance request form at any time to the operations group. However, maintenance should keep in mind that the operations group also schedules their activities and desires timely advance notice. Plant policy might allow less formal notice as phone calls or emails to the operations group. The plant might utilize a CMMS computer to flag the backlogged work orders needing clearance for the operators. In a daily scheduling meeting, each crew supervisor gives operations a copy of the crew's proposed daily schedule and a printed clearance request form for each work order needing clearance. The clear request form should describe the work proposed along with times needed for clearance. A copy of the work order form with special clearance instructions makes a good clear request format because the operators see the actual, maintenance work document. The supervisor has the original work order forms in hand at the meeting instead

of just the schedule sheet to allow reference to any planner notes regarding special circumstances. The face-to-face daily meeting allows the operators to commit to clearing up the necessary work areas during the evening shift for an around-the-clock operating environment. Otherwise, the operators can commit to when they would clear and have ready equipment the next day if they would not accomplish it during the night. At this meeting the operations group would also explain any particular requirements if it could clear the equipment for only part of the day. The supervisors also record feedback on the pertinent work order forms for new information regarding special requirements. The crew supervisors also note restricted times for maintenance work on the daily schedule forms and the work order forms which they will give to the field technicians. The operations group can also give immediate feedback for any jobs that it would not be able to clear at all. The supervisors make changes to the daily schedule if needed. The supervisor also has brought the weekly backlog of work to the meeting in case a new work order or two needs to be selected as replacements for jobs that would not be cleared.

During the daily scheduling meeting, the operations group and the crew supervisor agree regarding any special testing after job completion. For example, a particular strainer that has shown a past tendency to leak after maintenance should be tested before the technician has completely demobilized from the site. The decision of which jobs to test really depends upon the type of work done and the confidence in the maintenance skills and so would vary from plant to plant. The operations group or the maintenance group may have definite preferences for particular work orders to test. The planning group may recommend by noting within the job plans if the jobs should receive special attention. Management should establish a clear policy when possible regarding testing. The crew supervisor makes appropriate notes on the work orders which require testing after completion.

Handing Out Work Orders

After the daily scheduling meeting with the operations group, the crew supervisor publishes the daily schedule with any necessary revisions. The supervisor might do this by posting the daily schedule form on a crew area bulletin board or outside the supervisor's office. This allows individuals to think about their assignments for the next day. Spreading the news keeps crew members feeling more a part of a team. If published in time, there may be productivity improvements as well because technicians finishing their current jobs could take their tools and somewhat set up for their next assignments. The technicians could also review the job plans or technical manuals to familiarize themselves with the equipment. Technicians could even start to gather parts and special tools if they were not going to be staged. In effect, the technicians can stage their own jobs because they have advance notice.

The handing out of the physical work orders may depend on the plant's policy with respect to work permits. The operations group issues a document called a *work permit* that certifies that it has cleared the necessary equipment to allow safe maintenance work to begin. (Some jobs do not require clearance and work permits and the supervisor marks this information on the work order form if the planning group has not already done so.) There are different ways to accomplish permitting work areas, some less formal and some more formal and rigorous. The exact procedure would be dictated by company policy. The exact policy does not appreciably affect the enhancement to crew productivity of planning and scheduling. Some plants allow individual technicians to pick up the work permits for their assigned jobs. Other plants require the crew supervisor or a special designee to pick up the work permits. The process presented here of supervisors collecting work permits shows where the clearing and permitting of work fall into the overall planning and scheduling flow. This plant's supervisors do not hand out the physical work order forms yet because they do not yet have work permits for the jobs.

After the operations group clears the necessary areas, the operators write a work permit for each cleared work order. Then, it places the permit into a control room folder, box, or wall pocket for the crew supervisor to collect. The operations group removes a carbon copy from the back of each work permit to post on a control room bulletin board to provide the operations group with a visible board of jobs-in-progress.

At regular times the crew supervisors check the control room to pick up the approved work permits. The supervisors check for permits at the beginning and end of each day. Usually the supervisors arrive at the plant ahead of the crew to gather new work permits so that they can hand out respective work orders. They also check for permits as they return previously issued work permits from jobs completed during the day. The supervisor hands out the work order forms, but keeps the permits either in the supervisor's office or on his or her person.

The supervisor may physically hand the work orders out in a number of ways. A common practice is through a morning check-in meeting. The supervisor meets with the whole crew at shift start. The supervisor physically hands out work orders to the lead technicians making sure everyone knows where they will be working for the entire day. The supervisor may hand out all the work orders of the day or just the first ones, planning to distribute the rest of the work order forms as individuals, pairs, or groups of technicians near completion of their first jobs. The advantage to handing out all the work orders for the day at the beginning is that technicians can plan their pace for the day better. They understand the goal for the day. This factor probably outweighs a slight disadvantage for them having to keep track of the paperwork. A lost paper work order form would be a significant problem in an entirely paper system with no other record of the work. Arrangements where a computer database has at least a record of each work order make the problem of lost forms less important. Fully utilized CMMS computer systems have the least worry over lost paper forms where the computer record of the work order is the master and any paper copy serves only as a field device for the technicians. Of course, the trade-off becomes the risk of having the computer system available and functioning. Paperwork would be that much harder to keep up with, if emergencies frequently seem to interrupt work. Another common practice is for supervisors to pin work orders under lead technician names on a crew area or supervisor office bulletin board. Cubbies, file folders, or special mail slots can also be used for this purpose. Alternately the supervisor could write work order numbers on a dry erase board with lined columns and rows. Some supervisors, whether they have daily crew meetings or not, prefer personally contacting individual technicians throughout the day making sure each technician has the right work order and knows where the next assignment is.

Figures 6.25 and 6.26 illustrate possible aids for handing out work orders by placing them in slot or box structures. Everyone should be aware of work permit policies when setting up a system for technicians to have access to work orders. The following arrangements might be duplicated by writing work order numbers on dry erase boards. Figure 6.25 shows a cardboard, wooden, or metal mailbox arrangement. A supervisor might create tentative daily schedules for the entire week and distribute the entire allocated backlog. The supervisor might also distribute work orders for only one day at a time. One problem with a mailbox system is that a paper work order could only be placed in one box under a single name, usually the lead technician. Each column might be headed by a group of names or only lead technicians for teams. However, this presumes the same groups of persons would remain together throughout the week or longer. A dry erase board avoids this problem because the number of a work order could be written under several names at one time. The supervisor might keep the actual work order forms to hand out when teams are ready for them. Technicians themselves might print each work order form from a CMMS computer when ready. Figure 6.26 would be applicable to maintenance environments where technicians work as individuals (or on stable teams) and where specific start times are important. Each technician has a column of mailboxes or slots where the supervisor inserts work orders for different times of exe-

| | Adamsn | Barber | Capper | Glade | Hunter | Jensen | Johns | Jones |
|-----|--------|--------|--------|----------|--------|--------|----------|-------|
| Fri | | | | | | | | |
| Thu | | | | | | | | |
| Wed | | | | | | | | |
| Tue | 19 | 16 | | 29 36 | | 15 | 27 28 | 35 |
| Mon | | | | | | | | |

| | Kingsly | Pattersn | Richdsn | Sanchez | Smith | Wilson | Young | |
|-----|---------|----------|---------|----------|-------|--------|-------|--|
| Fri | | | | | | | | |
| Thu | | | | | | | | |
| Wed | | | | | | | | |
| Tue | 17 | 16 | | 31 30 | 25 | | | |
| Mon | | | | | | | | |

FIGURE 6.25 Optional mailbox arrangement to distribute paper work orders to lead technicians.

cution. At the beginning of the shift, the supervisor changes the heading of the previous shift to the following day of the work week. For example, at the beginning of Monday, there are headings for Monday and Tuesday. At the beginning of Tuesday, the supervisor changes the Monday heading to read Wednesday.

One method is not advised for assigning or handing out work orders. Some supervisors take the entire backlog of work from the computer whether or not it has been planned or scheduled and immediately assign technician names. In this manner, supervisors distribute their entire backlogs within their crews giving everyone a share of the plant work orders. This procedure generates the problem of not having any schedule expectations. Everyone has an individual backlog to work. When they finish one task, they should move on to the next. However, a major point of planning and scheduling is setting schedule expectations. Supervisors that assign individuals unplanned or even unscheduled work orders lose these advantages. Moreover, a CMMS computer has worsened this problem. Assigning a technician a work order in parallel to the planning process many times may result in a technician printing out the work order before a plan is available. With a pure paper system, at least the work stays in the planning channel unavailable for the technician to work prematurely.

| Monday | | | | | Tuesday | | | | |
|--------|------|-----|-----|-----|---------|------|-----|-----|-----|
| | Dave | Jan | Max | Rex | | Dave | Jan | Max | Rex |
| 7-8 | 119 | 120 | 121 | | 7-8 | | | | |
| 8-9 | 123 | | | 122 | 8-9 | | | | |
| 9-10 | | 124 | | | 9-10 | | 131 | | |
| 10-11 | 125 | 126 | | | 10-11 | | | | |
| 11-12 | | | | | 11-12 | | | | |
| 12-1 | | | 127 | | 12-1 | | | | 132 |
| 1-2 | | | | | 1-2 | | | | |
| 2-3 | | 128 | | | 2-3 | | | | |
| 3-4 | 129 | | | 130 | 3-4 | | | | |
| 4-5 | | | | | 4-5 | | | | |
| 5-6 | | | | | 5-6 | | | | |

FIGURE 6.26 Optional slotted board arrangement to distribute paper work orders to individuals for specific start times. The second day was still being established.

During Each Day

Daily scheduling is a continual cycle. During each shift as technicians work jobs, the supervisor manages from the current day's schedule and creates the next day's schedule. As technicians finish jobs, they return the work orders to the supervisor who in turn takes the work permits back to operations so operations can begin to put the equipment back into service.

Even if there are no special testing needs, the technicians and supervisors must not wait until the end of the shift to turn in work orders and return work permits. Informing the operations group promptly upon completion of individual work orders allows more time to return equipment to service and restore plant capacity. Operators can operate the equipment sooner after completion of maintenance. If initial operation reveals problems or concerns, technicians are then also still on shift to return to jobs and make corrections or advise. Were maintenance to wait until shift end to return all completed jobs, operators would also not be able to unclear all the jobs at once. Allowing operators to work throughout the shift restoring equipment to service levelizes the operations group's efforts.

In addition to coordinating with the operations group, some jobs naturally run over or under estimated times. The supervisor ensures that the technicians give feedback to help the planners estimate future jobs and the supervisor adjusts the daily schedules for today and tomorrow as needed. Other situations may arise and cause the supervisor to adjust the schedules, such as plant emergencies or unexpected meetings.

Daily scheduling is not simply a form filled out at the end of the day for the next day's activities. Even more important, it is not simply handing out work orders at the start of the shift. Throughout each day, crew supervisors use the daily schedules as a tool to control work.

OUTAGE SCHEDULING

Although routine maintenance provides the greatest opportunity for improvement and so is the focus of this book, this section gives the associated keys to understanding the concepts of outage scheduling.

The vast majority of plant work orders are tasks for the standing work force. The standing work force at the plant maintains the plant day in and day out continuously. Planning leverages that day-in and day-out maintenance work. Plants frequently overlook the opportunities within routine maintenance because outages receive so much attention. Managers view outages as extremely important. They see unscheduled outages as tragedies and extended outages as fiascos. In fact, plants organize outage events so well that they efficiently accomplish large quantities of work leaving everyone impressed with how much work can be done. They often attribute this great amount of work to extra effort based on the obvious urgency of the situation. However, the success is also due to the organizing effort, primarily the advance allocation of a specific quantity of work to complete. Similarly, planning and scheduling for routine maintenance can help accomplish an amount of work that can equally impress plant management. Planning and allocating a week's goal of work to a crew not only creates the same sense of urgency as for an "important" outage, but provides tools to manage and improve upon past problems. Nonetheless, it is worth discussing two keys to outage scheduling. First, planning provides accurate time estimates for larger jobs because larger jobs consist of a multitude of small jobs. Second, the scope of the outage must be controlled by managing the identification and inclusion of the small jobs.

An outage is normally considered the taking of an entire unit out of service. An outage is not simply shutting down a redundant process line or piece of equipment. Technicians many times can perform maintenance without taking any equipment out of service. Sometimes, technicians require taking only certain equipment or areas of a process out of service for only a brief period in such a manner that allows the unit to continue producing product. For example, operators might briefly take makeup water equipment out of service provided the plant has reserve tanks of water available. On the other hand, technicians cannot perform some maintenance tasks without causing the plant to make some or all of a unit unavailable for service. Maintenance may be able to complete some work while the plant runs at a reduced capability. For example, technicians may be able to work on one of two boiler feed pumps while a unit runs at half load. Maintenance situations may require shutting down an entire unit, require no shutdowns at all, or require varying in between unit conditions. Even with a requirement to be off-line, many plants can shut down an entire unit with hardly any advance notice or appreciable problems, operational or economical. Perhaps the company has not sold out its product line leaving open time. Perhaps technicians can complete maintenance during one shift and the unit can operate another shift during the same day. Plants normally call the taking of an entire unit out of service an outage. Outages may be major outages scheduled every so many years to overhaul major pieces of equipment on a routine basis or they may be short outages, either scheduled or unscheduled.

Some persons also call major outages overhauls or turnarounds. Major outages are when a plant schedules one or more major process systems for extensive routine replacement, refurbishment, or other maintenance. The work requires shutting down the entire unit.

These maintenance activities cannot be accomplished when the unit is operating and are often too large in scope to be done during shorter outages whether scheduled or unexpected. Many companies utilize set schedules for these events such as once every 5 years. However, the advent of predictive maintenance programs many times allows systems to run longer. Plants can then schedule major outages when sophisticated inspection methods predict the process system equipment needs attention.

On the other hand, a short outage is an event between major outages requiring taking the entire unit out of service. Short outages may be unscheduled, such as the sudden requirement to repair a burst boiler tube. The unit cannot run with the boiler tube losing process water, so the plant must take the unit out of service almost immediately or within the next few days. The plant strategy may also be to schedule short outages to take a unit out of service to perform maintenance tasks that do not require immediate attention. The plant performs these tasks in anticipation that they will lessen the likelihood of later unscheduled or surprise outages.

An evolution in the timing of short outages takes place as a plant increases its reliability through proper maintenance. A plant with fairly poor reliability usually has something break just when the plant otherwise needs a short outage. A number of work orders sit in the outage backlog. Yet rather than plan for a time to bring the unit off-line, the maintenance group knows the unit will "trip" or otherwise require shutting down for some unforeseen need on a regular basis. Take the example of a steam plant with poor water chemistry control. Boiler tubes burst periodically requiring shut down for repair. When a tube bursts with an estimate of, say, 12 hours to repair, the maintenance group springs into action also working the other outage jobs. The crew starts all jobs in the outage file with estimates of 12 hours or less. The crew may start longer jobs if the unit is not again needed immediately or management desires the unit to return in as good a shape as possible. Longer jobs that management decides not to start would wait for a future outage.

As a plant evolves from total reactive maintenance to more proactive maintenance, short notice outages begin to become less frequent. As fewer unscheduled, short notice outages appear, plant reliability improves. Yet the outage backlog first increases in size because fewer outages naturally occur. As plant reliability improves, the plant finds fewer opportunities to execute waiting outage work orders. Then the plant experiences some short notice outages occurring for new reasons. Previously, the maintenance group would have taken care of certain situations before they became too serious by doing some work during a short outage. However, when no outages come up, these situations worsen and themselves bring the unit off-line. For example, if technicians always repacked certain valves during outages, frequent unscheduled outages were available for this work. As reliability of the rest of the unit rises, the valves themselves begin to cause outages because the unit cannot wait. The evolution of the maintenance department's effectiveness continues until there is a predictability that the unit should be brought down for maintenance. At this point, management commitment for continuous reliability brings the operations and the maintenance groups together to schedule short, regular outages for routine maintenance in addition to the standard, infrequent major outages. The entire plant including operations and maintenance must adapt to a strategy of planned short outages to execute SNOW (short notice outage work). The plant must accept scheduling an outage in advance when there are a number of serious work orders on the SNOW list or there is a sufficient amount of SNOW work. The timely execution of the outage work prevents unscheduled outages. Overall plant reliability and availability increase through the strategy of short scheduled outages reducing the occurrence of infrequent, but serious, unscheduled ones. The evolution continues as maintenance and plant engineering perform defect elimination work to identify and replace equipment that requires excessive routine downtime. Moreover, maintenance, plant engineering, and the corporate project group perform defect elimination work to install plants or systems that incorporate lessons from the past. The

evolution results in a superior performing plant capable of full capacity as needed and having minimal outage requirements for maintenance.

The evolution of the maintenance department's effectiveness changes with how it approaches short outages. As a plant rises from routinely having poor reliability to become a superior performing plant, fewer unscheduled outages become available for work. Therefore, regular, scheduled, short outages become more frequent.

Planning Work Orders for Outages

Many plants have work orders that they can only execute during an outage. To help the scheduler quickly select the outage jobs, the plant keeps a SNOW list or SNOW grouping of work orders. The SNOW list or grouping identifies or even keeps together the work orders that must be done on an outage, but not necessarily the next major outage.

There are only a few differences between planning work orders for short outages and for routine maintenance. Because technicians have limited time during the actual outage to gather parts and information, the company puts more emphasis on planners identifying and reserving anticipated parts. The planner has time to do this for even reactive jobs when an outage has not yet started. On the other hand, planners place a high priority on quickly planning outage work orders. They never know when an unexpected outage may suddenly occur requiring finished plans.

Individual work orders may make up some of the work for major outages, but not necessarily all. Large tasks such as certain turbine work may instead involve special outage books of notes from previous outages. The planners should take advantage of requesting help from the specific supervisors and technicians that worked particular areas of previous major outages to determine estimated times and labor requirements. The outage books should also identify parts and tools from previous outages.

Key Concepts in Scheduling for Outages

Many individual work orders of jobs make up outage work. Therefore, the scheduler can utilize the concepts of advance scheduling developed for routine, weekly scheduling. This allows the scheduler to make accurate enough assessments of time frames for the large quantities of work involved in outages. This concept provides the first key to understanding outage scheduling.

Because outages consist of many individual jobs, the scheduler can apply the concepts that make weekly work allocations an accurate tool. A scheduler can use planned work order estimates to determine accurately the duration and labor hours for major outages. In a routine week of maintenance, a scheduler can allocate the right amount of work even though the time estimates for small jobs have a tremendous amount of variance in individual accuracy. For example, the planner's estimate for replacing a single control valve may vary considerably. Yet a weekly schedule allocation of 100 jobs smoothes out any variations of individual jobs. The work force might therefore have confidence that it could accomplish the overall amount of work in the scheduled week. The scheduler may similarly consider a single large job to consist of many small work orders and therefore accurately estimate labor requirements for the large job. The scheduler and planners together can therefore estimate the total duration and labor requirements of overhauling 20 control valves with a satisfactory degree of precision. A major outage consists of many large jobs and the handling of each large job can be approximated to the weekly scheduling process. Consider the major overhaul of a large steam turbine consisting of many individual tasks on many individual systems. The scheduler and planners together can reasonably estimate

the total duration and labor requirements of restoring the turbine itself. The restoration involves many small tasks such as disassembly, inspection, lifting, transporting, machining, coating, polishing, transporting, lifting, assembly, fastening, and alignment. There is also a myriad of miscellaneous work orders that the plant identified over the past few years that could only be done during the overhaul. The planners have already planned these work orders. The scheduler can group them to determine their group labor requirements. Overall, the scheduler uses the concept of the grouping of small tasks allowing overall estimate accuracy.

Note that during routine maintenance, the crew forecast of labor available for a single week determines how much planned work the scheduler assigns. For a major outage, the amount of work is the independent variable. That means the amount of work determines the length of the outage considering basically a set amount of labor each week. After determining the initial estimate of the outage duration, management can evaluate options to increase the work force. Management may supplement the regular labor force using 24-hour, around-the-clock work shifts or contract labor. Many plants have labor sharing agreements to help each other during major outages. For outage maintenance, the scheduler adjusts the outage time to match a given amount of work, then considers special labor arrangements. For nonoutage, routine maintenance, the scheduler adjusts the amount of work to match a given amount of labor hours.

The overall outage can be managed through CPM's and other special scheduling techniques. However, these techniques show the large groupings, not the minute, individual maintenance tasks. That is why these techniques can be successfully used with the outage.

Because a major outage consists of many individual jobs, the crew supervisor must create daily or shift schedules as the outage proceeds. A scheduler can set the major activities and overall times for the outage, but cannot control individual jobs. At the beginning of each shift, the crew supervisor must ensure persons understand their assignments based on the progress of the previous shift. The supervisor must provide this coordination during a major outage even though technicians usually stay on the same equipment and do not move around too much between different areas. An entirely different group of technicians may have worked the previous shift. In addition, the technicians may be executing work that the plant performs only once every 5 or 10 years. That means the average technicians may have drastically limited experience with the work over their entire employment at the plant. On the other hand, the often older crew supervisor may have critical personal experience.

The scheduler gathers appropriate SNOW work orders and sets the labor requirements and duration for a short, scheduled outage in a similar manner to a major outage. The scheduler and management determine the best crew and time arrangements considering labor availability and shift options.

A single event often drives a short outage. Consider first an unscheduled short outage. Consider again the boiler tube that erupts and causes a unit outage. Maintenance must repair the tube. This single task causes the unit to be on outage and unavailable. For such a task, the pertinent crew supervisor and management estimate the duration of the outage, say 18 hours. The scheduler then takes all of the work orders that have been waiting for an outage and selects the ones that can be done in 18 hours or less. Maintenance crews then complete as many of the jobs as possible. So for a short, unscheduled outage, the primary job sets the time frame. Labor availability determines how many jobs the crews can accomplish. The scheduling consists of the scheduler or supervisor taking all the outage backlog jobs with an estimated duration within that time frame and then considering the persons needed to work the jobs. If there are any backlog jobs that have not yet received planning, the supervisor guesses the time requirements and includes suitable ones in the outage scope. The supervisor writes down all the jobs on a daily schedule sheet with hours for each of the crew members. This is very similar to the regular weekly and daily scheduling routine except for one difference. The amount of hours the crew has for the week does not drive

the schedule, the outage backlog selected from the outage file by duration does. The supervisor reassigns persons from their nonoutage tasks currently under way and plans overtime as needed to get the work done.

The second key in outage scheduling is that the scope of the outage must be controlled. If the scheduler has a specific amount of work, the scheduler can develop specific time schedules and labor requirements. If the company allows the amount of work to vary, the time schedules and labor requirements cannot help varying as well. Although the techniques of accurate scheduling are important, the overwhelming key ingredient in making an outage go well is agreement on the scope. The scope itself is less important than agreement on the scope. Many times an outage will start with one scope of work, but as soon as the plant takes the unit off-line, the scope doubles.

This is a simple concept to apply to an outage consisting of 100 work orders. The scheduler can reasonably set the labor time requirements from reviewing the job plans. Then the scheduler can establish the overall schedule based upon management preference of crew shifts. However, suppose the amount of outage work orders suddenly jumps to 150. The scope of the outage has changed. It has increased by the 50 new work orders. The scheduler must change the schedule.

This consideration is especially important for major outages where the initial part of the outage may consist of inspections of major machinery. If the inspections reveal more serious damage than anticipated, the sudden inclusion of more work may extend the entire outage. This is through no fault of the scheduler. After the inspections determine the extra work, the scheduler must then analyze options of labor or critical path changes for management review. This is why outages including major inspections are difficult to schedule precisely. The advent of predictive maintenance technologies has greatly assisted scheduling for major outages. Through sophisticated technology, PdM allows more precise determination of maintenance needs before the plant shuts down major machinery to begin outages.

Knowledge of the scope of work provides only part of this second key to outage scheduling. The rest comes from understanding that the scope must be controlled. The plant must identify work as far as possible in advance. The plant must not include new work on the eve of or even during the outage whenever possible. Late announcements of work destroy schedules and labor arrangements. Late inclusion of work causes that work to be poorly planned. The ensuing confusion may also cause incomplete execution of new work hastily identified. It might also contribute to hasty decisions to delete other work from the schedule. The company may have already used the set schedule to make arrangements for production and sale of product which may become expensive to change. Additional labor necessary to maintain a set schedule with an increased scope may be more expensive or less qualified than could have otherwise been arranged. Finally, there may be insufficient advance lead time to procure material necessary to execute the work. The maintenance group would not be able to execute that work.

To reduce these changing scope problems, the scheduler first begins identification of future outages as far as possible in advance. Many companies have 1-, 5-, and 10-year outage plans. These plans give approximate periods of all anticipated outages. The 1-year plan might set specific days or weeks, whereas the 10-year plan may set specific months or seasons. As the outage time approaches, management allocates preparation time for the schedulers and key company personnel to begin defining the work scope and time frames. The particular scheduling horizons depend on the specific type of outage, equipment lead times, and labor resources. Most of the scope definition work for a larger outage is straightforward 6 months to 1 year before the scheduled outage starts. The initial project team makes use of outage files and books. Even work completed every 5 or more years is still repetitious work. Crews executing outage work must record feedback to make files most useful. The period of about 3 months before an outage starts is when scope additions multiply if left unattended. During these 3 months, it seems almost everyone knows about new work

requirements. However, with less than 3 months before the outage, there may not be enough material lead time or other time to prepare adequately for the new work. Therefore, the scheduler must pay close attention to the control of the outage scope.

Schedulers commonly control the scope of outages through the use of lists. The scheduler may issue a list of known work with a stated main purpose for the outage 6 months to a year before the start date. The scheduler has an initial meeting with supervisors to identify maintenance needs. Then, with increasing frequency until the start of the outage, the scheduler continues to meet with the supervisors and issue lists of identified work. Planners or special outage planners finish planning the identified work tasks as necessary to have them ready to execute during the outage. An outage project manager ensures this cycle of publish, identify, and plan continues up to the start of the outage. Management support and organizational discipline help ensure giving serious attention to timely identification of work. Management should not appreciate late identification of outage tasks. If managers do not wish to have an unexpected outage extension, they must be willing to freeze the outage scope and not allow routine additions at some point before the outage begins. The scheduler might issue a statement at some point before the outage that "Any work identified after this week must be arranged and managed by the originator of the work." The early start of giving attention and listing the work greatly reduces the occurrence of later scope additions.

During the course of an outage, the scheduler continues to meet with the crew supervisors to identify completed work. The scheduler also continues to publish lists of work remaining. The scheduler compares actual completion of blocks of work against expected completion to measure the progress of the outage. In order to encourage supervisors to attend meetings during the execution of the outage, the scheduler should limit the meetings to only 15 or 20 minutes.

After the outage is over, the scheduler should still schedule one or two meetings with the crew supervisors, planners, and other personnel, possibly even including technicians. Just as a planner needs feedback to improve future plans, the scheduler and planners seek information to improve future outages. The final meetings should address what went right as well as identify where the team could make improvements. These meetings should occur soon after the outages before personnel forget information and ideas.

The plant handles scheduled short outages very similarly to major outages in regard to work scope. Smaller outages that the plant determines are necessary only months, weeks, or days before starting, and have similar but less extended preparations made. The operations and maintenance groups together arrange to have a short outage at a future scheduled time to maintain the plant's capability of operating at full capacity. This is not a recovery from a trip or loss of capacity. The key to how much work the maintenance group will accomplish for a short scheduled outage is the plant decision on the scope of work. The scheduler must continually encourage the routine identification of work even if the work can only be done during an outage. This ensures the backlog contains the necessary work orders for an outage before the last moment. The scheduler assesses what routine preventive maintenance to include. The scheduler reviews any predictive maintenance recommendations or other corrective maintenance in the backlog. With this information, the scheduler prepares a preliminary scope of all jobs to include in the outage for review by the maintenance crew supervisors and plant management. The scheduler takes the scope of work and then assesses how long the outage should last based on discussions with crew supervisors for crew availability and management preferences for off shift and overtime work. The crew supervisors create a daily scheduling sheet(s) for the outage to get all the work done.

As previously discussed for unscheduled short outages or trips, the primary failure is often the item that determines the length of the outage. The scope normally consists of all SNOW work orders that the planners estimate have a duration of equal length or shorter.

Management must be willing to set a freeze on the scope of even short outages. It must resist the addition of new work after an unscheduled short outage begins or after setting the scope of a scheduled outage. Otherwise, management must accept the responsibility for outage schedule changes.

A final necessary note includes the involvement of the operations group. Timing governs the success of outage work in such a way that one must not forget the time involved for operator tasks. Operators must not only clear equipment, but return equipment to service. Managers and schedulers must include the operations group in all outage meetings to discuss clearance and restoration to service of individual components as well as overall unit shakedown. Operators may have a preference for the timing of the return of specific components to levelize their activities. Their knowledge may also profoundly affect the overall scheduling of the outage. For instance, a major steam plant may sometimes require days or weeks to clean boiler water to allow return to full capacity. As with any maintenance work, the maintenance technicians are responsible for delivering equipment that is ready to run. However, the operators have the responsibility of testing and returning the equipment to service. Schedulers must include the operators when considering maintenance work.

Two key concepts help the understanding of the scheduling of outages. The first key is realizing that the scheduler can only have great accuracy when scheduling *blocks* of work orders. Grouping of many tasks into blocks of work for an outage tends to smooth out the inaccuracies inherent in the estimates of individual tasks. The second key is realizing that the overall ability of being able to schedule outage work accurately lies in the control of additional work to the original outage scope. Schedules or resources must change if the work scope changes. A scheduler can schedule the work scope of an outage. The plant must control the scope.

QUOTAS, BENCHMARKS, AND STANDARDS ADDRESSED

The terms quota, benchmark, and standard see frequent usage in maintenance and should be addressed in light of the current scheduling context. The normal concepts implied by these words do not lend themselves very well to a planning and scheduling operation.

Quotas establish amounts of work that a crew must do. For example, management might dictate that a certain maintenance crew must always complete 60 work orders every week. At first glance, the development of a planning and scheduling system seems to have that very thing in mind. However, a quota is more of a mandatory figure that does not allow very well for consideration of current events, quality, or actual jobs ever being different from the plans. Quotas do not provide the answer to superior maintenance. Rather, proper planning and scheduling set schedule expectations and realistic goals based on current conditions as well as provide the means to improve upon past jobs. A technician must be able to point out why a job should be extended in the case of special circumstances. There may be valid schedule pressures and there may be times a technician cannot be the sole judge to delay a job. However, these factors must be maturely worked out for the optimum benefit for the plant as a whole. Rather than setting a strict quota of work orders to complete, management should consider how many technician work hours the crew has available and assist the crew to select that same amount of estimated work hours of backlogged jobs that would most benefit the plant. To emphasize that a planning and scheduling operation does not promote quotas, consider the following. If it is not a quota to assign two persons to a job, why would it be a quota to assign 2 hours to a job or two jobs to a person?

Compensation arrangements that take into account production amount without regard for quality form a type of quota. Management should avoid these situations or watch them

very closely. For example, wages based on number of jobs or number of "book hours" might encourage a technician to pay insufficient attention to quality. It is true that the supervisor has less need to motivate such piece workers; but are they performing proper work? Instead, paying technicians by the hour, but giving them sufficient amounts of work to do requires more supervisor effort, but appears to keep quality higher in focus.

Benchmarks are self comparisons to how other facilities perform in certain areas in which one has an interest to improve. For example, management may compare how much it spends yearly on maintenance versus the most profitable companies in similar or dissimilar industries. The comparisons may let management know if its own maintenance department is relatively effective. However, a comparison itself may not tell management how its own company can improve. The other facilities may have certain factors that provide for their particular success. Simple benchmark comparisons do not readily reveal these factors. The other facilities must be carefully studied for benchmarking exercises to become most useful. How similar is the other facility? Perhaps the other plant has a greater abundance of skilled labor available. Perhaps the other plant has already made the transition from reactive to proactive maintenance. Perhaps the other company invests regularly to replace troublesome equipment. Perhaps the company has an active program for maintenance personnel input into new plants being built. The point is that simple benchmark numbers may not tell why plants perform differently. There are often key factors that must be understood beyond the benchmark number. So it is with planning and scheduling. A benchmark comparison that shows a plant has a planning department and schedules its maintenance does not tell if or why those programs are beneficial. A benchmark telling that wrench time is different does not tell why it is different. The planning and scheduling principles in Chaps. 2 and 3 embody obvious factors that influence how well planning and scheduling work. In addition, the entirety of Chap. 1 points to other factors necessary for planning to function. A simple benchmark would be difficult to use among different plants in many of these regards. Consequently, benchmarking among plants to control a planning operation may not be as beneficial as closely adhering to the planning and scheduling principles and other guidelines presented in this book. Nevertheless, the principle underlying benchmarking—to visit other plants to pick up good ideas—may invaluablely assist to improve any aspect of plant operation and maintenance. Benchmarkers should try to visit best performers. They should attempt to understand how, not just how much.

Another use of the word benchmark implies less of a cross-company comparison and more of a simple goal or idea of what one's performance should be. The planner's estimate of a job's labor hours do set somewhat of a benchmark in this regard for the technician's consideration.

Standards present a combination of quotas and benchmarks, but on an individual job level. A real standard applied to a specific job would dictate beyond any doubt how long a job should take. One way an engineer or analyst would establish a standard would be to study a task as it is repeated many times by different technicians. The analyst or engineer together with some of the technicians might then decide the best way to perform the work. Then technicians trained to perform the work in this best manner would be timed. The resulting labor hours and duration would become the official job standard. This approach may be practical for an automobile repair shop where industrial engineers have studied specific tasks repeatable on identical vehicles maintained in similar shops. This approach is less applicable to an industrial plant where technicians may repeat specific jobs only once or twice over the course of a year. There is limited opportunity to observe and study such work. The manufacturers may have some ability to specify standard maintenance tasks for their equipment. On the other hand, manufacturers may be better qualified in the manufacture of the equipment rather than in its maintenance. In addition, the great diversity in the shop arrangement and personnel skills of the persons using the equipment may make generic standards useful for a starting point, if practical

at all. Preventive maintenance tasks may lend themselves to locally developed standards because technicians may execute them on a more frequent basis than once or twice a year. Nonetheless, the great productivity improvement available through planning and scheduling comes from having some schedule control, not necessarily incredibly precise estimate accuracy. Typically, the introduction of proper planning and scheduling in a maintenance organization dramatically improves productivity. Addition of precise job standards contributes a relatively smaller productivity gain. Normal job planning simply does not study jobs thoroughly enough to set precise time estimates. The planned estimates are accurate enough for scheduling work, but not for establishing official job standards. Fortunately, the ability to schedule the work in a reasonable fashion is all that is necessary.

Nonetheless, when used less formally, the term standard is somewhat applicable to the planner's estimate of a job's labor hours. The planner's estimates are said to be the job standard. One must keep in mind, however, that these are not engineered standards. They are simple, initial determinations of a skilled planner.

Setting estimates and assigning work through planning and scheduling does not necessarily involve engineered standards, production quotas, and cross-company benchmarks.

SUMMARY

This chapter described the specific activities that accomplish weekly and daily scheduling. For advance scheduling, a scheduler simply allocates an amount of work orders for a week. The scheduler does not set specific days or times to begin or complete each work order. The scheduler works with the crew supervisors to establish forecasted labor hours and then selects that quantity of work order hours for the allocation. Specific methods, routines, and forms help the scheduler select the best mix of work for the plant. For daily scheduling, the crew supervisor selects work orders mostly from the weekly allocation. However, the supervisor also maintains the flexibility to reassign the crew for emergency and other urgent work that may arise. The supervisor may follow different methods and procedures to select and assign the appropriate work each day. All of these methods and procedures have certain elements in common, primarily giving each crew member a full shift of work based on planner job estimates. As plants gain experience with planning and scheduling, staging certain job items may further improve labor productivity. These techniques of scheduling greatly assist maintenance in improving its labor productivity. This chapter described the exact steps of scheduling to clarify the concepts of scheduling. After understanding the concepts, readers may implement alternative steps than the ones prescribed. This chapter should allow companies to implement their own effective scheduling.

Routine day-to-day maintenance offers the greatest opportunity for planning and scheduling to make a difference. On the other hand, companies typically execute maintenance outages with much success already. Consequently, this book does not dwell on the actual scheduling of outage maintenance. However, the scheduling of outage maintenance relies on particular concepts inherent in the practice of routine maintenance scheduling. One concept is the increased accuracy of time estimates achievable for blocks of work made up of smaller jobs with less precise time estimates. Another concept is the control of inclusion of the smaller jobs that make up the larger blocks of outage work. If the scope of work continually changes for an outage, the overall outage schedule must change as well. The chapter addresses these concepts as keys to outage scheduling in addition to describing the routine scheduling of maintenance work.

documents may be an option if an original had to be replaced later. Similarly, computer scanning may be an option that might also enhance researching and planning jobs, especially from remote locations. Night time access is restricted because the planning offices are normally locked at night. Maintenance supervisors have the only other maintenance key rights to this area. Other persons requiring access during the night time would at least have to register their entry with operations supervisors that have keys. Some plants do not hesitate to place planners on call to respond to night time emergencies to help facilitate file access and security. Some plants have enabled planners to access computer files from home to assist supervisors or others who call with information needs making planner office entry unnecessary. Finally, management commitment and organizational discipline must consider the offense of being careless with taking or returning a file as a serious matter.

SUMMARY

Rather than just rely on the often superior technical skills a planner possesses, a planner also has many resources available to help with planning work. Most of these resources revolve around making the minifiles as useful as possible over time. Forms including datasheets help collect information and the planner makes frequent use of them. In developing the minifiles, planners perform another valuable plant service; the planners institutionalize plant knowledge. The planners gather the day-in and day-out information that the maintenance group uses to execute jobs. The planners ensure that this information becomes linked to the equipment itself in the planning process to aid future work.

Perhaps the biggest resource in many plants is the CMMS or computerized maintenance management system. All in all, the computer can be thought of as a set of minifiles and forms. The CMMS electronically links forms to equipment to make data and other information available as needed regarding that equipment. The following chapter covers the use of a CMMS computer.

CHAPTER 8

THE COMPUTER IN MAINTENANCE

Some persons think that planning work orders consists of handling parts and tools before jobs start. Other persons think that it consists of developing detailed procedures for jobs before they start. Still other persons think that it consists of utilizing a computer or CMMS (computerized maintenance management system). None of these concepts quite reaches the mark. The preceding chapters have set forth maintenance planning as a process, one that gives maintenance managers an increase in productivity. The process gives technicians a boost on the learning curve from past jobs. The process also gives supervisors job scopes and time estimates allowing them to assign sufficient daily work toward weekly work goals.

Nevertheless, more than a few persons describe their maintenance planning function by how well their CMMS works. Many of these persons profess that "everything will be perfect" when they fully implement their CMMS. Similarly, many persons wonder why planning "does not quite seem to be working" even though they have installed an expensive CMMS. Unfortunately, planning is not simply using a computer, and just because a company has a computer does not mean it even has a planning function. The CMMS can be a tremendous resource for planning, but it is not planning itself.

Perhaps unreasonable expectations contribute to disappointment for many purchasers of maintenance computer systems. Larry Beck (1996) relates survey results of manufacturing executives that indicate they typically require minimal cost justification before implementing such systems. Many of these executives expect productivity gains, but may not have specific reasons why the CMMS should deliver such improvements. David Berger (1997) says that the failure rate of CMMS package implementation is commonly thought to be about 50%, depending on one's definition of failure. Christer Idhammar (1998) places the success rate for CMMS packages at only 18%.

Companies must look at computer systems as simply another tool. They are certainly not the ultimate remedy to one's maintenance troubles nor the ultimate solution to provide improvement. Nevertheless, a CMMS is an important tool, an information tool. Moreover, a CMMS is not a tool for just the maintenance force; it is a tool for the entire plant or company. Many companies call their computer system an asset management system rather than a maintenance management system. The system helps with information for more than just the maintenance staff. In addition, the term maintenance has a bad connotation from the prevalent culture that thinks of maintenance as merely repair of broken equipment. With regard to maintenance, this information tool is one key to further improvement after the basic processes are correctly in place. The CMMS does not provide a step improvement as does implementing the basic process of planning and scheduling, but the improvement is significant.

Planning is also a tool, not the ultimate maintenance solution. The CMMS extends beyond planning, and even maintenance itself. However, the planning system also extends beyond the

CMMS. Examine the six planning principles against this information tool. The CMMS does not dictate that planners should be separate from crews. It does not dictate that planners should concentrate on future work. The CMMS does require component level equipment designations for recording information. The CMMS does not emphasize the technical skill of the planner in setting scopes and estimates. The CMMS also may not count on craft skills. The CMMS certainly cannot measure wrench time as only statistical work sampling is adequate. On the other hand, one goal of the CMMS is the same as the planning system, to help reduce delays. Examine the six scheduling principles against the CMMS. The CMMS does not dictate that plans should be made for the lowest possible skill level. The CMMS may presume that priorities and schedules are important, but may not dictate that schedules should not be interrupted nor enforce organizational discipline against setting false priorities. The CMMS does become involved in forecasting availability of personnel. The CMMS may allow sensitivity to examine scheduling work hours for 80%, 100%, or 120% of a crew's available hours. On the other hand, the CMMS would not dictate the principle of 100% as a weekly goal. Neither would it normally dictate the principle of working persons below their skill levels to match job hours to crafts available. Instead, the CMMS may blend the weekly and daily scheduling routines into setting weekly schedules on a daily basis by the computer operator who is a planner, scheduler, or crew supervisor. The CMMS may help measure schedule compliance, but it could not on its own first define what activity would constitute compliance. Finally, the CMMS may not differentiate planning's different responses to different degrees of job reactivity. One sees the principles that embody a successful planning program do not come from the CMMS. To a large extent, a CMMS is a database manager where planning may seek information. The CMMS contains information; it should not dictate planning strategy.

Regardless of planning not being synonymous with a CMMS, planners are the major users of such a system when in place. A CMMS soon becomes one of their most valuable tools. In this perspective, a chapter on the computer's role in maintenance is most justified. This chapter cannot be all inclusive of the role a CMMS would play in an entire maintenance organization or plant because this book is about maintenance planning. The influence of a CMMS extends beyond maintenance planning. Nonetheless, the involvement of planning with a CMMS must be addressed.

In the context of maintenance planning, the computer helps in two ways. First, it automates and facilitates existing processes to improve efficiency. Second, the computer can add value to produce benefits otherwise not practically achievable. On the other hand, the computer may not affect certain maintenance functions at all or it may add complications to certain functions in the maintenance process.

The previous chapters of this book establish specific strategies and techniques of planning. In this context, the following sections address computerized maintenance management systems. The first section covers what is meant by computerization. The next section addresses the relative value of computerizing different areas of maintenance. Then the use of templates or "canned" maintenance solutions is covered. The logistics of becoming involved with a CMMS and having a user friendly system is discussed. The last section provides suggested CMMS features applicable to this book's philosophy of planning. These sections also make reference to App. L, which gives examples of several of the points of discussion.

TYPE OF COMPUTERIZATION

To establish a framework for discussion, it is helpful to review the basics. There are two major issues with a number of associated minor issues. The two major issues are what type of computer system is involved and who creates the software.

There exist a wide variety of types of computer systems. The first computers were mainframes, and many company software applications today still operate on them. Mainframe computers themselves are expensive, as are the in-house information systems (IS) groups staffed to develop and maintain the software for them. Some mainframe maintenance applications are fairly sophisticated and helpful. However, in-house information systems groups usually prioritize the handling of basic company applications such as payroll, human resource systems, and general ledger accounting ahead of computerization of maintenance functions. Many organizations with only mainframe computer capability do not have much of a maintenance computer system. These maintenance groups may have certain codes tied into the payroll system and can use this limited information for certain analysis. With the advent of personal computers, many maintenance groups began to use maintenance applications on individual computers not tied into any company-wide systems. A single individual that operates the CMMS for everyone keys individual computer applications. With networked personal computers, maintenance applications allow more than a single person to review or manipulate information. Networks may be LAN (local area networks) at the single plant site, or WAN (wide area networks) covering multiple facilities over a large geographic area. Many companies are transferring their software away from mainframes to networked computers using client-server structures. With the evolution of more powerful personal computers and networks, client-server structures allow large databases and programs to interact from central computers with local computers. Small systems run from individual personal computers and simple networks may not need IS support. More complex networks and client server applications require IS support.

The developers of maintenance software may be in-house personnel or vendors. The advantage of using in-house personnel is having control over the customization of the system. Unfortunately, as mentioned above, in-house IS personnel may give maintenance work less attention than desired. In addition, in-house IS and maintenance personnel even working together may not possess as much knowledge or skill as could be obtained commercially. Then, once IS writes a program, it may have limited resources to upgrade the software continually to take advantage of new computer technology or maintenance practices. CMMS vendors are usually in a position to incorporate the most successful maintenance practices across a number of companies and even industries. The market also drives CMMS vendors to keep up to date with computer technology. Theoretically, instead of a small, in-house IS staff developing software for a single maintenance group, a CMMS vendor can maintain a large staff developing the best software and sharing the cost over many maintenance groups. Moreover, the CMMS vendor specializes in the software, whereas it may not be a central concern to an in-house staff. Finally, an in-house staff generally appoints a single individual to the maintenance of maintenance software. If this individual was the developer and left employment at the company, the maintenance group may suffer due to few persons being able to pick up the software issues. Contrary to this situation, if the in-house individual left a vendor-supplied CMMS, the CMMS vendor would be able to provide assistance for continuity.

The conventional wisdom in the maintenance industry appears to be working with the IS group and selecting a vendor CMMS that closely mirrors one's current maintenance process. A company would pay the vendor to provide some initial customization. Then, ongoing management of the software would be by maintenance fee with the vendor with in-house personnel performing some ongoing customization. Under no circumstances would the in-house group receive the source code from the vendor and make modifications that might render the system unrecognizable to the vendor's specialists. What a maintenance group desires is a system that automates how it currently conducts maintenance. The maintenance group also desires some value added functionality that allows accomplishing certain tasks not practical without a computer. It does not want to procure a CMMS in the

hope that the computer will teach it how to conduct maintenance properly. If a company does not already have a good maintenance process, it should wait to computerize.

In contrast or opposition, the maintenance planning group may benefit from computerization without buying a CMMS. All planners should have access to the Internet and email. One mechanical maintenance planner helped an electrician find an exact procedure for replacing a faulty device manufactured by a company that had been out of business for over 10 years. The planner searched the Internet and had a vendor email him an exact replacement procedure within a half hour of looking. Finding information and parts and even purchasing items on the Internet may boost a maintenance organization. Searching for MSDS information may be practical although legal requirements may dictate having on-site records. Other computer programs without a CMMS may help maintenance. A simple database program may adequately store nameplate equipment information. A clerk may easily be able to type and print work orders for PM's with a simple spreadsheet and word processor. A company should not purchase an entire CMMS with the sole benefits expected to be the automatic printing of work orders and the replacement of a single clerk.

BENEFITS WITH THE CMMS

Arguably, these are the benefits of having a computer system mostly from a maintenance planning perspective.

Computerizing the inventory system produces the overwhelming largest value added benefit. Knowing part availability and allowing economic order quantities to maintain part availability give a major financial saving. It is not unheard of that computerizing inventory might reduce a \$5 million inventory level to \$1 million in a single year. The company savings from inventory alone justifies the purchase of a CMMS. On the other hand, many company storerooms have already computerized their operations with inventory-only software without the purchase of a CMMS. The value of the benefit of converting an existing computer inventory system to one contained in a CMMS package is less significant. Nonetheless, many computerized storerooms utilize mainframe systems and must convert to nonmainframe systems for financial reasons. Early involvement of maintenance management with storeroom management may help the company make a strategic decision to procure a CMMS for everyone to utilize. Regardless of whether the inventory system is standalone or part of a CMMS, planners should be able to locate and reserve parts for specific work orders.

Simply providing easily obtainable reports gives the maintenance group its second largest benefit from a CMMS. This is another value added opportunity and not merely an automation of an existing process. Management and others need information to work within and improve a maintenance organization. A CMMS provides valuable information often not otherwise available. How much did a particular piece of equipment cost the company over the last 5 years? What are the most costly systems in terms of maintenance expenditures? What is the current backlog of work orders? What is the current backlog of work waiting on parts? What is the current backlog of work for electricians in terms of work hours? What work orders caused lost availability over the last week? Is this trend rising? What work orders could be worked tonight if there was a short notice outage? What is the trend in percentage of reactive versus proactive work orders over the last 2 years? How much have failure and breakdown work orders been reduced? Which crew has the greatest amount of failures occurring in the systems it maintains? Which work orders are waiting for planning? Which work orders have been completed, but not closed because of drawing revisions needed? Are there any planned work orders that can be worked along with the emergency job just started in this system? How many hours are spent for PM? How many hours are spent for corrective maintenance that is generated from PM work? Just

knowing that there are 651 open reactive work orders may cause management to take more decisive action than a previous feeling that the backlog was around 50 work orders. As one can see, management can determine the degree of success of the maintenance program's efforts with information readily available from a CMMS. To make the CMMS information usable requires effort on the part of the planning organization. The planners normally code work orders to allow future reporting or analysis. Codes such as type of outage required, type of work, and equipment system are necessary. The planners are the persons most familiar with the plant coding structure and provide consistency when they assign codes to new work orders each day. Whenever they handle them, planners should also scan work orders for "sense" and correct inaccurate information.

The next most valuable benefit of the CMMS is the finding of work orders. This includes work order loss prevention and determination of current work order status. It also includes sorting work orders, a benefit similar to the report benefits. First, the manual method of assigning paper work orders to crews involves a risk of lost work orders. If the physical piece of paper becomes misplaced, the work request might be forgotten. This might not appear to be a problem for the plant management used to thinking of maintenance assignments as missions to correct obviously failed equipment. How could these work assignments be forgotten? However, the maintenance group accomplishes its critical objective of preventing problems from happening in the first place through regular identification and correction of minor deficiencies. If one of these paper work orders becomes misplaced, its loss may go unnoticed until the minor deficiency becomes a glaring problem that maintenance could have avoided. A maintenance crew that normally focuses upon urgent work orders may tend to put off working less urgent work. Even a good filing system may occasionally lose paper work orders that maintenance does not immediately execute. The CMMS avoids this problem because the work order is not ever considered to be the physical document in the first place. A work order is literally what the term suggests, an order to do certain work. That identification of work resides in the computer as the actual work order. Anyone can run a report showing a listing of all work orders at any time. If a technician loses a printed out document describing the work, the computer still shows the work required. The technician or supervisor can print out another copy of the work description if desired at any time. This benefit does not require a CMMS and could be derived from a simple database of work orders recorded by a clerk each day. The management commitment required under such an arrangement would be the insistence that supervisors are responsible for the work on the database listing, not the physical documents they have in hand. In addition, if a paper work order is lost, someone would have to recreate the document from the database. These arrangements usually run into some difficulty with paper documents lost after work completion either in the field or the minifiles without the clerk registering their completion. Then, the database is obviously less current than the actual holding of paper work orders as an indication of work not completed. On the other hand, once the maintenance group adopts a more complete CMMS, supervisors seem to take better ownership of helping update work order status. The supervisors begin using the CMMS database to organize and manage their own work. Management's claim that the CMMS has the real work order and its status also appears more credible. The second part of this benefit is realized for the entire plant as the status of each work order on a CMMS begins to have real value. Before the CMMS utilization, the originator of a work order had few means of determining if the work requested had been done or would be done. If written a month before, the originator might well presume the maintenance group had put off the work order for the indefinite future. The work order had gone into the black hole. With most network CMMS packages, the originator can easily find the pertinent work order through a number of different search options. The originator might be able to hunt by work order number, originator name, date of approximate entry, equipment number, or any number of choice key words of problem description. After finding the right work order, the status of the work order is evident,

whether waiting for approval, planning, scheduling, or closing of the paperwork. One major power station bought a sophisticated CMMS package for the sole reason of allowing operators to find work orders and their status. The planners, schedulers, and supervisors also use the CMMS package's ability to find work orders to sort out certain work orders. A planner might easily find all the new reactive work orders to plan for the day. A scheduler might sort all the work orders that have been planned in order of priority, system, and job size to facilitate scheduling work for a crew. A supervisor might sort out all the work orders already assigned and in progress as a listing to help manage the day's activities. Reports and better visibility of equipment work orders help the plant optimize equipment maintenance and capital investments timing as well as make better repair versus replace decisions. The ability of a CMMS to give a view of what is out there in real time is an important benefit.

A very closely related benefit to making reports available is the linking nature of the CMMS. The CMMS is an automation of the minifiles linking history, parts, procedures, safety data, tools, and other information directly to specific equipment. Operators can keep track of standard clearances. Maintenance personnel can keep track of warranty and service agreements. Planners and engineers can keep track of cost. The CMMS connects all this different plant data to the equipment.

Beyond this joining benefit, the CMMS provides another plant advantage. In the past, different plant departments kept various independent records of important equipment information, many times duplicating the work of each other. For instance, three different groups might have a record of nameplate equipment data. One problem from this arrangement was when the maintenance or project group replaced the physical equipment. Not all of the plant departments might update their nameplate data. In time, the different departments ended up with conflicting information in their records. The advent of computerization made this problem of conflicting plant information worse. Personal computer spreadsheets and databases allowed easier organizing of data, and departments began to collect more information. A hodgepodge of plant data resources exists at many plants. The network CMMS provides a solution to this situation when everyone can access a common database for different types of equipment information. Authorized persons in each department can update a common database a single time with the latest information. The database should represent the latest information any of the departments possesses. Work order and equipment information can also be remotely viewed through the CMMS. Instead of journeying to the planning department to review minifile contents, engineers and others can find what they want on the computer. Instead of going to the engineering department to review equipment technical data, planners can find what they want on the computer. A plant should consider implementing a CMMS ahead of the proliferation of multiple databases around the plant if possible.

The CMMS provides another benefit to the planning department with regard to manipulating scheduling information. An advance schedule should normally be a simple allocation of work, and a daily schedule should involve the supervisors' personal knowledge of crew individuals for best work assignments. Nevertheless, a CMMS might facilitate some of these efforts. In addition, the CMMS allows easy "what if" reviews of different alternatives. The CMMS also allows easy publication of the schedule to anyone interested. This promotes better craft coordination as well as operations group equipment clearance arrangements.

Next, the CMMS helps the maintenance department by automating the PM generation of work orders. A small plant may avoid having a clerk to generate PM work orders manually from a master spreadsheet. The cost of having a clerk generate PM work orders manually may not be significant for a bigger plant. However, the volume of PM work orders for a bigger plant may be large enough to cause some concern over having them correctly issued and assigned. The CMMS precisely sets the PM work orders each time they are issued. Although these PM logistical advantages may seem slight, the importance of correct preventive maintenance to the maintenance group's mission is significant.

CAUTIONS WITH THE CMMS

Of course, the most obvious downside of computerizing is thinking that a computer will correct a faulty maintenance process or philosophy. Computerizing a poor maintenance process will not help maintenance. Karl Kapp's (1996) "USA" admonition must be heeded: "Understand, then Simplify, then Automate." The computer may create the illusion of progress and maintenance advancement when equipment performance has not improved. One must guard against the computer becoming a distraction to real maintenance improvement.

There are also other considerations to be made when computerizing. One of the foremost concerns is the reliability of the computer system which may be a function of the particular CMMS package, the plant computer equipment, or both. The more a plant counts on the CMMS to assist with daily maintenance functions, the more the CMMS has to be available. It is not acceptable for the computer system to crash routinely as planners and others utilize the CMMS to perform their jobs. If the operators write work orders in the middle of the night, the CMMS should routinely work in the middle of the night. If the planners report to work at 6:30 AM to code work orders, the CMMS should routinely begin work at 6:30 AM. The IS department must accept the same philosophy as the maintenance department that its job is to provide an operating machine, not provide a repair service when called.

On the other hand, the planners and the maintenance department should understand their jobs well enough to be able to carry on in the sudden absence of the computer system. There should be a backup plan such as allowing operators to submit emails in the absence of the CMMS and phone calls in the absence of the email. Planners should be able to scope jobs and prepare work orders with plans in the absence of the computer. Those paper minifiles also become very useful in the middle of the night when technicians with little inclination to log on need a simple piece of information on certain equipment. Do not be too hasty in discontinuing the collection of paper documents.

Another area of caution is cost assignment. The planner's estimate, the job hours recorded on employee timesheets, and the hours recorded on the returned work order itself may all differ. In addition, none of those three amounts may accurately reflect the hours the technicians did spend on the job. Computerization only automates what data is entered. Users of reports must be familiar with the possible shortcomings of analysis made from computer data.

Another new problem potentially arises after computerizing, especially when a company fully implements a sophisticated CMMS. Before having the CMMS, paper work orders moved sequentially from originator to planner to scheduler to supervisor to technician. There was always the occasional urgent work order that went from originator straight to the crew supervisor, but normally technicians did not receive unplanned work orders for routine maintenance. The work flow system kept the technicians from even knowing about the work prematurely. However, this changed with the advent of the information sharing CMMS. Now technicians and supervisors can routinely view new work orders for equipment in which they have an interest. A common scenario as this presents itself: A work order is written Thursday night, and on Friday morning a technician views the work order, prints it out, and completes the work, all without changing the computer status. Also on Friday, a planner views the work order, but because of the work order's low priority decides to plan it on Monday. On Monday the planner completes the plan and changes the status of the work order to waiting-to-be-scheduled. On Tuesday, the planning department clerk receives the completed work order papers from the field crew and changes the work order status to closed. The planner reviewing the work order paper is frustrated that the technician worked the job on an unplanned basis. Later when reports are run, because the computer indicated the job was planned, the crew gets credit for completing planned work. This type situation is not uncommon and requires management commitment and organizational discipline to manage. A successful

planning effort aiding technicians with information from past jobs and aiding supervisors with scheduling control information both encourage crews to seek job plans before beginning work. A proactive, professional maintenance organization also helps.

Finally, computers add to the temptation to compile unnecessary metrics. Computers allow collection and arrangement of data much more easily in many cases, but certain metrics are unnecessary for proper management. The compilation of them wastes the time of analysts and managers. This is part of the distraction capability of a CMMS.

LESSER IMPACT WITH THE CMMS

Considering the CMMS an umbrella program that allows everyone to use common databases, there are certain maintenance functions that may not be major parts of the CMMS system. Some of this may be due to the impracticality of computerizing and some may be due to the avoidance of wanting "to reinvent the wheel."

First, there may be some areas that are impractical to computerize. For example, some maintenance practitioners profess wanting to eliminate paper documents totally. Many companies have paper morgues bursting with old documents. Yet, is paper elimination a practical objective? It seems that there should be room for a 1-2-inch minifile for each of 10,000 pieces of equipment. Is it also practical to scan entire O&M manuals into computer or microfilm archives and expect easy retrieval? Would the additional step of searching discourage planners from utilizing this resource? It may be best to allow planners easy access to fast scanners to scan specific sheets as they find them in O&M manuals and attach them to specific work order plans for jobs. In this manner, the planner builds the computer files while building the paper minifile with particular O&M pages.

Second, a single computer program that does everything may not do any one thing particularly well. CMMS programs tend to handle certain areas fairly well, such as equipment and work order history databases. However, other portions of the overall CMMS program may simply be focused on "providing a complete product." Areas where the CMMS vendor may have less expertise may be tool management, predictive maintenance, and document scanning and retrieval. Many CMMS packages deal acceptably with their limitations and form alliances with other software vendors. A CMMS vendor with less experience with imaging may incorporate the successful abilities of an imaging software developer. In this manner, the CMMS package is able to bring a best-of-class performance together under a single-umbrella program. In addition, some CMMS vendors are more adept than others at allowing their programs to communicate and integrate with existing software and programs that a plant already utilizes.

Predictive maintenance might be one area best left separate from the global CMMS. Predictive maintenance software has evolved to a high degree of performing trend analysis, analyzing fairly complex data. Many plants best leave the predictive maintenance group running its own software and keeping its own database of trends. However, the plant should insist that the PdM group should utilize the plant CMMS for maintaining equipment nameplate data and writing work orders. The PdM group should also utilize the same equipment identification numbers in its software. In effect, the PdM group functions as an independent laboratory providing specialized service to the plant.

TEMPLATES

Templates warrant a special comment with regard to the planning principles set forth in this book. Templates provide quick and easy solutions to common equipment problems. For

example, a planner might have a pump with a problem. The planner might search a CMMS package's template function for pumps. The CMMS would show the common problems a pump might experience. Then the person might select which problem the pump has symptoms for and the CMMS would list common solutions for that problem. The planner could then select the desired solution and the CMMS would deliver a procedure for the job plan. The CMMS provides a master generic troubleshooting guide to boost planner efforts. In general, the problem with this approach is that the planner usually has adequate information to help determine the equipment problem. For one thing, the planner is a superior technician with specific experience with the plant's equipment. For another thing, individual equipment usually fails in only one or two favored modes that the minifiles should have well documented after even only a short time. For another thing, the technicians are usually skilled enough to make many repairs without having a generic procedure. What the technicians need are specific part numbers and other information recorded from previous jobs to avoid past delays. Generic repair procedures cannot contain this information because this information is specific to individual pieces of equipment, not types of equipment. Specific troubleshooting guides included in specific equipment O&M manuals are more helpful than generic templates contained in some CMMS packages. Overall, most templates are too general in nature.

LOGISTICS

Unfortunately, the decision to utilize a CMMS does not result in a computer being up and running the following morning with everyone fully familiar with how to use it. Will everyone use the computer after it is installed? Who should be involved with selecting a system and what is involved? What is some helpful advice on planning with a computer? This section addresses these issues.

First, whether everyone will use the CMMS depends on how user friendly the system is and the interest of the work force. With the advent of email to disseminate company-wide information, all levels of many companies are rapidly becoming computer literate. The rapid acceptance of using a CMMS may surprise many persons. One plant installed a CMMS at first only to track paper work orders and to provide equipment data for planners. Management at the plant decided that everyone should have the option of writing their work orders directly into the CMMS. The person actually responsible for implementing the system expected only 10 to 20% of new work orders to be directly entered. It was a great surprise that over 95% of the subsequent month's work orders were entered directly. The plant soon made the direct entry mandatory and eliminated the need for a clerk to enter work orders each morning.

One thing that seems to make a difference is having a special, user friendly screen that walks originators step by step through the process of entering the work orders. Another aid to helping persons utilize a CMMS is providing a slimmed down user's booklet. The typical thick volume published by many CMMS vendors contains more information than the typical person needs. The plant can publish its own versions of specialized instruction booklets for specific users. Appendix L contains sample slimmed down versions for planners and other users. Brief training showing specific helpful uses of the CMMS should be conducted by plant personnel familiar with the system. Training provided by the CMMS vendor on vendor supplied databases typically does not represent the screens as the plant has customized them nor does it utilize representative enough equipment. The vendor training may also dwell on modules the plant does not intend to implement. In addition, the vendor training may presume a maintenance approach not utilized by the plant. Key plant personnel, such as the plant individuals who understand the maintenance process and are leading the implementation of the CMMS, should take as much of the vendor supplied

training as possible. Then these persons should train the different persons at the plant for their planned usage using actual plant databases and customized screens. Appendix L contains a sample plant-wide training outline. The planners will be the major users of the system, and the training for them will usually include much hands-on time from the plant persons implementing the system. Planners themselves will help develop the usage and customization of new modules to suit their needs. There should always be one or two persons at the plant site who can answer most questions of plant persons.

The second major issue concerns who and what is involved with selecting a system. The system is usually selected by a team following a usually predictable selection routine. The actual installation may proceed all at once or in predetermined phases over several years.

The persons involved in selecting a CMMS tend to be the planning supervisor and a representative from the IS group being led by a plant engineer. This group has frequent interaction with the maintenance manager. The maintenance manager may have to ensure that the IS group does not overwhelm the selecting group with inadequate maintenance process knowledge. It is also important that the plant engineer understands the planning and maintenance processes. Another person on this team should be a person that will become the system administrator. This person will set passwords and grant other rights to users. This person may also create standard reports and do some screen customization. It is preferred that the system administrator be a plant engineer or maintenance representative rather than an IS person for several reasons. The plant needs a local representative available to answer questions who understands the plant maintenance organization and processes. The system administrator choice should provide a person who will fulfill the role for years to come rather than as a current IS assignment. Many persons feel that it is better to have as a system administrator a maintenance person who develops an interest in computers rather than a computer person who becomes interested in maintenance. The system administrator should coordinate larger tasks of modification with the IS department or the CMMS vendor. Planners play a major role in utilizing a CMMS, but being a system administrator consumes a lot of time. It may be practical to have a planner fulfill this role if there is an abundance of planners, but this is usually not the case. Of course, for standalone, single user versions, planners may be the only users that directly enter or extract information. A planner would naturally be the choice system administrator. With this team of persons, the company might begin to select a CMMS. Teams such as this also frequently employ the use of a consultant to do much of the legwork and supply more familiarity with CMMS systems during the selection process.

The actual selection process tends to be somewhat the same for many companies. This is a very simplistic overview. Obtain a clear idea of the objectives of why management wants to buy a CMMS. Assemble a team for the selection. Obtain internal views of what system features are desired. Determine initial selection criteria. For example, some companies desire a CMMS vendor to be an established company that will stay in business. Some companies want specific industry experience. Some companies want geographical closeness for support. Some companies require a specific operating platform. Survey technical magazines for summaries of systems. List likely systems. Gather literature from these companies. Call and ask questions to see how they view maintenance. Expect to establish a long term relationship of support and continuing improvement. The ability of the company and vendor to work together as a team in the future should be evaluated along with the other technical requirements. Develop ideas of prices to review with management because complete systems range in price from under \$1000 to well over \$250,000. Invite vendors to make presentations and demonstrate systems. Refine and weigh selection criteria. Investigate selected systems. Check the claims of vendors where appropriate. Ask for unabridged users lists and call users. Visit other plants with the software. Call the CMMS support lines for responsiveness. Negotiate and sole source or bid final candidates. Do not expect any one system to be perfect.

One thing that surprises many companies is that the purchase price tends to represent only a fraction of the investment the company will make, perhaps only 20%. The company personnel to install and administrate the system consume an enormous amount of time. There is also the matter of computer equipment upgrades either initially or over time. The leading software vendors continuously upgrade their product. Usually a company pays a yearly license fee to have access to free upgrades and technical support. The CMMS vendor usually makes available an upgrade every other year or so and has a new major release every 3 to 5 years. These changes to the software come about because of the research being done by these vendors and because computer technology is evolving at breakneck speed. Thus, a company has to spend time and effort simply staying current with the latest CMMS software from the vendor already selected and utilized. If a company does not choose to install the latest software, the company risks soon having a system that neither the vendor nor the IS department can well support. This is not all bad. As computer technology evolves, companies may be upgrading their equipment anyway. In addition, the expenses paid to coordinate CMMS upgrades are investments in proper maintenance. Poor maintenance is very expensive as well.

Implementing new software also requires other expenditures and efforts. The data will have to be initialized into the new system. An inventory system already computerized might have to be downloaded into the new system. Who will make the links? Does the IS department have time to write these "scripts" and execute them? Many companies have a consultant who helped them in the CMMS selection or the CMMS vendor themselves help make the transfers. If this is planned, it should be part of the selection process. Computerizing inventory for the first time will require data entry. Does the maintenance organization have the time to do this? Can temporary help be hired? Who will direct their efforts? Can the consultant take care of this? Similarly, does equipment already have unique equipment tag numbers? Is there an existing database to transfer? If not, who will decide how to number equipment? Who will hang the tags and enter them into the CMMS? Will the CMMS have to communicate with other company programs such as payroll or inventory? Who will program these relations? The IS department typically is cautious with new programs interfacing with existing ones. Who will enter all the preventive maintenance tasks? Could the consultant supply clerical help to transfer an existing PM listing into the CMMS? In addition, as the new system is implemented, many specific details will have to be handled as they arise. Questions such as what to do if the new program mandates the use of a different term for waiting-for-scheduling will arise daily.

Also, do not presume that a CMMS must be installed fully all at once. It may never need full installation. If the company bought the CMMS for inventory and work order tracking, it is possible that labor calendars and vendor registries might wait forever to use. The equipment module might be initialized gradually as needed to reference work orders, and the company would be wise to soon initiate automatic generation of PM's. The planners might initialize the planning module gradually as they become familiar with the CMMS. Be cautious that some CMMS systems have used relational databases to such an extent that one cannot implement only a portion of a CMMS package. Appendix L shows a sample milestone schedule of the phased implementation of a CMMS. The decision on how to proceed with package implementation rests on many factors. These factors include mature judgments as to what value each feature of the CMMS holds, personnel and money available for implementation, and management's desire, willingness, or patience. Management may be willing to allow full implementation, but may not have the patience to provide support for a schedule of several years.

Some helpful advice on planning with a CMMS may include the following. Try to incorporate equipment numbers into job plan numbers. This will make it easier to use job plans for similar equipment as a starting point. For instance, different job plans dealing with equipment N02-FC-003 might be numbered N02-FC-003-1, N02-FC-003-2, N02-FC-003-3REBUILD, or N02-FC-003STRAINER. Each plan would have an equipment type code

name at the beginning of the work order description even though there is a separate field for equipment name. For example, the problem description line would state "2A BFP leaking at seal." Reports that list the work orders will then make more sense. Have someone attend and participate in CMMS users' meetings. These meetings allow the CMMS vendor to grow and develop its product to be more helpful. Try to influence the product direction. Also, try to network with other users of the CMMS to exchange ideas and have contacts to call for advice. Buy computer typing games to improve planner keyboard proficiency if needed. A major question always arises regarding old closed work orders. Should they be entered into the system? It might seem relatively simple to have a clerk enter them, it is not at all practical to do so if the work orders reference no equipment numbers. Even if the equipment numbers are present, this effort may be unnecessary. The repetition of maintenance operations on specific equipment soon generates helpful information for maintenance planning purposes. There is not a critical need to enter past work orders and a strategy of work order entry "from this point forward" is frequently satisfactory.

SPECIFIC HELPFUL FEATURES FOR PLANNING AND SCHEDULING

From the standpoint of planning and scheduling as presented in this book, the following represent some helpful features that may not be common on some CMMS systems.

The CMMS would make it easy to enter actual job feedback and have a check-off for different job delays. It would be easy to update actual parts and tools used.

Most entries would be done from a minimal number of screens, preferably a single one that resembles what is printed out as the work order form.

The planner could go to an O&M type module that contains most equipment and job plan information, just like an actual physical O&M notebook. The planner can cut and paste from this manual to form job plans for individual jobs. The manual would in a sense have a master procedure detailing everything that could be done on the pump, complete with general steps, parts, and tools. This plan would actually be developed by the planner as new jobs are planned and feedback is received. With each new job, the planner would check the master to see if the details are present from which to cut and paste. Otherwise, the planner would add new steps to the master to represent this latest job.

The entire CMMS would be backed up daily automatically, probably along with the network automatic routines.

The CMMS inventory function would automatically record the previous use of parts by equipment. This would provide an ongoing development of a parts list for each piece of equipment as maintenance works on jobs. Unfortunately, many CMMS inventory modules do not provide this automatic feature because they presume the plant has a complete set of parts lists for all its equipment. The modules primarily concern themselves with tracking quantities on hand and reservations for specific work order numbers.

The PM function could handle routes on multiple equipment and register the history with the individual equipment.

The company could easily add fields to link or track particular codes or information as needed.

One could easily find work orders and their status.

Supervisors could easily update job progress to help schedulers obtain backlog information.

Supervisors could easily keep on-line calendars to help schedulers obtain crew forecast information.

The scheduling routine would "work persons down" into lower skilled, but higher priority jobs as necessary to create the weekly allocation.

Supervisors could easily assign names into a weekly schedule for a single day.

Schedule compliance would be based on jobs started.

Timesheet information would form the actual cost collection, not feedback on work order forms.

Company would be easily able to implement the CMMS partially or in phases.

Email could be saved by equipment in the CMMS.

SUMMARY

Obviously, planning encompasses more than utilizing a computer. Nevertheless, a modern CMMS can be an important information tool. The planners need an accurate filing system, and the CMMS links a tremendous amount of information to individual pieces of equipment.

Many companies that implement CMMS packages are disappointed in the results. This disappointment appears to stem from only having vague expectations of what the results should be or how specific results were to be achieved. Disappointment does not need to be the case. CMMS packages contribute to the bottom line when purchased for specific information reasons. Although different types of computer systems are available, each can provide this information. Management can control and reduce inventory. Ad hoc and regular reports can provide management with necessary information to control the efforts of maintenance. The maintenance group can better visualize, determine, and manage its backlog with its resources. The maintenance group does have to be wary of becoming distracted with computerizing instead of maintaining the plant, but generally the computer should make a positive impact for its efforts. The CMMS cannot help a planning system that is floundering with the basics of planning such as knowing why to consult feedback from previous jobs. However, the CMMS can help in specific areas with the planning process.

This chapter has but briefly touched the wealth of available information in the literature for guiding companies in selecting a CMMS. If the company's role could be succinctly summed up, it might be with a statement by Nicholas Phillippi (1997). He says that "The best investment protection is a thorough understanding of the existing maintenance processes and application of the maintenance system in concert with these processes." Perhaps it should go without saying that the CMMS vendor should have significant maintenance expertise.

Understand, simplify, and then automate.

plant engineering group, the PdM group becomes involved in newer technology generally ahead of the maintenance group. The PdM group can help update the technology of the maintenance force, especially with the active assistance of the planning group.

Regarding the time accounting by the PdM personnel themselves, PdM personnel function as do plant engineers, separate from work orders in their daily duties. The planning department would issue work orders for PdM routes only in the unusual circumstance where PdM persons were technicians with little specialized training and were working directly for the maintenance supervisors to run relatively simple routes such as for thermography. On the other hand, the plant considers any work orders initiated by the PdM group as predictive maintenance. For example, the PdM work to take vibration readings is predictive maintenance, but not normally conducted under a work order. However, the request by the PdM analyst to have the maintenance group replace a suspected chipped impeller is also predictive maintenance and is done through a work order.

PROJECT WORK AND PLANNING

Similar to PdM work, the objective of the planning group is to plan and schedule work orders to implement projects as regular jobs. The difference is usually in the larger nature of projects coming from the project group and the project group's inclination toward using contractors. The plant normally has the personnel to implement much project work, especially with the productivity of a planning and scheduling system. However, the project group usually favors contractors because of a contractor's ability to commit to a schedule and estimate. Plant management should treat projects as outages and plan them into the plant long-range schedule by working closely with the project group. Planners should be able to estimate and commit to project schedules with plant engineering and scheduler assistance. Planners should not become too distracted from planning day-to-day maintenance, but can assist project work.

Even when not involved in the installation of projects, plant personnel should track and become involved with any new work to be done at the plant. The plant personnel seek to influence the installation of reliable equipment before it is purchased. The plant personnel should be involved with setting plant standards for the project group. The plant personnel should spend time as directed with corporate teams and review project plans seriously. Although many of these duties may be shared among plant groups, planners typically have the edge over plant engineers for valuable field experience. Maintenance supervisors or senior technicians are preferred for these assignments, but frequently management sees planners as somewhat more expendable. If a company has only one or two planners, it may overwhelm the planners' time to become involved in all the standards or projects. On the other hand, if there are 30 planners, it would make sense to have one planner involved in motor standards, one involved in pump standards, one involved in this project, and so on and so forth giving each planner a small additional duty with respect to front end loading.

Planners can best accomplish certain tasks for large projects. Planners must vigorously pursue collecting documentation to establish files and PM's. Planners are also in an overview position where they can cancel certain work orders to patch systems that are due for project replacement or overhaul. This position also affords the planners a good viewpoint for proposing new projects based on records of troublesome equipment.

Other than for major projects, planners can propose new projects by writing work orders or passing ideas to the plant engineering group. Planners can also be as helpful as possible to plant engineers who select equipment without becoming neglectful of their primary planning duties.

CHAPTER 10 CONTROL

This chapter finally arrives at this all important issue: How does one ensure planning works from a management and supervisory standpoint? Surprisingly, it is not on the basis of indicators, although two of the 12 planning and scheduling principles describe indicators. It is on the basis of the selection and training of planners.

ORGANIZATION THEORY 101: THE RESTAURANT STORY

Dr. Stephen Paulson (1988) tells the story of John Smith who retired from the Navy. John was at loose ends for a while and began meeting daily for lunch with several of his friends. John naturally enjoyed cooking and the lunch group usually met at John's house where he made the sandwiches. Everyone would always chip in to pay for the lunch. The company and the sandwiches were good and soon more friends were coming around at noon time. Someone eventually suggested that John should lease a small shop where they could spread out and be more comfortable. There seemed to be enough income from everyone's contributions so John found a small place in Jacksonville Beach where the group could meet. Thus, John's Sandwich Shop was born.

At first, everything continued as before. John made the sandwiches and would join in the company and discussions around several tables. The "organization" of the establishment, so to speak, was simply John Smith. John took care of everything from opening the door in the morning, making the meals, and collecting the money to bussing the tables, sweeping the floor, and closing the door in the late afternoon.

As word got around, some of John's friends started bringing their other friends making the place busier than ever. Soon, John had less time to visit and was spending more time making sandwiches. That was okay with John since he enjoyed cooking. However, he really needed help and so his wife, Mary, began coming in every day to help. The organization of the sandwich empire consisted of two persons on equal footing doing whatever needed doing. John did most of the cooking, but still helped Mary buss tables and collect money. They even bought a cash register to help make change. Communication was no problem. Whenever John needed something, he called over to Mary. Whenever Mary needed something, she called over to John.

The happy atmosphere of John's Sandwich Shop delighted friends and other customers. Business thrived and soon John and Mary needed more help running things. They both decided to hire someone and they brought Joe on board for wages. Joe reported directly to John, who gave direct supervision to his activities. Normally, John had Joe bussing tables and washing dishes. Occasionally, John would direct Joe to perform other

specific tasks. These tasks included activities such as sweeping the floor or running an errand to buy certain supplies that were running low.

With summer approaching and business booming, John and Mary decided to expand and take a lease on the vacant shop next door. Remodeling to remove part of the connecting wall almost tripled the sandwich shop's floor space. They also decided to hire three high school students out of school for the summer. These students had no restaurant shop experience so John organized them behind a counter. John planned for customers to enter the shop and then proceed to a counter to place their orders with his wife. Mary would handle the cash register and pour drinks. For the students, John wrote specific instructions how to make three standard sandwiches customers could order. The first student would set out and slice the type of bread requested applying the required dressing. The second student would add the required meat and tomato or other required ingredients. The last student would place the sandwich in a basket with chips and a cookie and hand it to the customer. John planned to hang around and make any special orders himself. John also continued to direct Joe in his normal assigned duties. This arrangement worked very well and the business was very successful. John did not look forward to the end of the summer when the three students would leave to return to school.

Near summer's end, John and Mary decided to hire three experienced sandwich makers who had mentioned they would not mind working at John's Sandwich Shop. John had discussed their qualifications with them at some length. These persons had quite a bit of restaurant experience which would allow John and Mary to change the organization. The three professionals were able to handle operations behind the counter almost entirely without instructions. They also were able to expand the types of sandwiches being offered. Any of the three could make nearly any specialty sandwich imaginable. They could each handle multiple complicated orders at the same time. For instance, each person could handle making a meatball sandwich (light on the sauce), which required microwaving while simultaneously shredding lettuce to place on a cold ham sandwich. The resulting success behind the counter allowed John to increase the amount of time he could visit with his friends at the tables.

As the years went by, John and Mary opened another, identical shop in neighboring St. Augustine. John and Mary later both stepped back from day-to-day operations, allowing their son to run the original store and their daughter to run the new store. Both stores remained very prosperous. John and Mary still maintained a corporate ownership of the business, but their management style was to have a family business meeting once each year after a special dinner gathering. At this meeting, John would look at his children carefully and ask two questions very seriously. The first question would always be: "What is the net profit after taxes for each store?" The second question would always be: "Does a meatball sandwich in the Jacksonville Beach shop taste exactly the same as a meatball sandwich in the St. Augustine shop?" With these two questions, John and Mary managed the multiple divisions of John's Sandwich Shop.

The restaurant story pointedly illustrates the different basic organization structures that exist, each doing best with a particular type of primary coordination method. An organization is a group of persons with a common objective, such as the maintenance of an industrial plant. Where different persons work together, they must coordinate their work. Coordination methods and practices help direct the efforts of the different persons. Planning itself is a coordination means. Planning coordinates many of the specialized areas of maintenance. Most organizations typically utilize many different coordination methods at the same time, but they usually emphasize a single primary or dominant coordination method. Emphasizing the right primary coordination method with the right type of organization makes an organization stable and effective. Using the wrong kind of primary coordination method with a particular organization structure will cause unnecessary problems and inefficiency.

Dr. Paulson's story pictures the basic organization forms with their preferred coordination methods described by Mintzberg (1983). The account first shows John Smith as an individual doing everything by himself. In the second situation, John and Mary organize and function as an "adhocracy." The *adhocracy* structure of organization consists of different persons brought informally together. The adhocracy coordinates its activities through frequent meetings and exchanges of information much as do Mary and John with their conversations as they go about doing their jobs. The next organization where John supervises Joe represents a *simple structure*. John provides the coordination needed with his direct supervision of Joe. Next, the organization of the summer students represents a *machine bureaucracy*. A machine bureaucracy achieves efficiency by coordinating with explicit rules and procedures. John wrote rules for the students to follow in their assignments. An assembly line typifies this organizational structure. Of course, if the business environment becomes more complex and varied or undergoes rapid change, rules themselves might become too complicated or subject to constant change, making this type of organization unsuitable. As Mary and John transform the store to allow significant independent judgment on the part of the sandwich makers, coordination by a set of rules becomes impractical. The concentration on obtaining skilled employees becomes their preferred coordination method. This organizational structure is known as a *professional bureaucracy*. This structure must be coordinated with attention to staffing, that is, hiring and training. When one thinks of a medical physician, one realizes that there could not be a sufficient set of rules to handle the doctor's behavior throughout each day. The doctor constantly sees different situations calling for independent judgment and skilled action. The expertise of the doctor is much more important than the standard handbook of medical procedures the doctor sometimes consults. Does the doctor have the skill not only to select, but to execute the correct procedure? A professional bureaucracy coordinates itself through the procurement of skills. Finally, Mary and John oversee the company as a *divisionalized form* of organizational structure. Mary and John see two divisions as entities to coordinate although there may be a different form or forms of organizational structure within each shop. From their level, Mary and John best coordinate the effort of either shop with indicators. The use of indicators comprises the preferred method of coordinating this type of structure. Obviously, Mary and John could not manage each shop with direct supervision or constant meetings and communication. Other methods of coordinating are also not appropriate for their level of management in the organization. Variants exist, but these same basic organizational structures are found in organizations throughout the world. The restaurant story shows which particular method of coordination is most appropriate for each of the different basic structures.

SELECTION AND TRAINING OF PLANNERS

With regard to maintenance planning, how do these lessons apply? The identification of preferred coordination methods has direct application to the planning department organization. To begin with, maintenance work orders come in all sizes and shapes, from straightforward to incredibly complex and from ordinary to unusual. Because of the extreme diversity of jobs, planners cannot be given simple instructions for how to plan them. For example, there is not a one-size-fits-all approach to scoping jobs or determining what job details are critical for a job plan. Planners may be directed to scope a job, yet the identification of the correct work scope is entirely a creation of the planner's skill. A planner may be directed to research a minifile, but the planner must recognize what made the difference in the last two filed jobs. Similarly, only the qualified planner can adequately anticipate likely job problems or spare part requirements on equipment that has not yet been disassembled. The planners must function as a professional bureaucracy, being allowed to exercise discretion and personal judgment in

the effective planning organization. Thus, the primary coordination method to manage the planning group must be an emphasis on staffing. The purpose of Planning Principle 4 (skill of the planners) becomes more clear as one realizes that having qualified planners controls the successful planning organization.

Does not every job require having a qualified person? Perhaps, but this concept is not the sense of the professional bureaucracy. A person to operate under direct supervision must be willing to submit to direct supervision. A person willing to work on an assembly line must be willing and able to follow specific instructions. However, the skills required within the professional bureaucracy implies neither of these qualifications.

Without the obtaining of skilled planners as the primary coordination method, none of the other coordination methods matter. First, planners do not need to share information continuously with each other to plan jobs. Neither is there time for each planner to communicate constantly with other experienced personnel regarding job requirements. Second, no planning supervisor could adequately directly supervise the activities of planners planning hundreds of diverse work orders each week. Third, as previously discussed, no set of rules or guidelines could possibly take the place of the skilled planner on the majority of maintenance plans. This explains one of the cautions with the template approach to job planning. When all is said and done, the planner's skills must come into play to use the templates and to provide enough job specific expertise. Finally, indicators may show whether the planning group is making a difference in the work force's productivity, but indicators cannot coordinate the activity of the planners. Indicators only show whether the planners chosen have the skills necessary to make the difference.

After the selection of planners, the emphasis of supervision should be on training and other support. A school system provides an excellent model. The principal does not directly supervise any of the classrooms. The principal is not even present in the classrooms at all times. Instead, the principal performs a primary duty by procuring qualified teachers. Then the principal sustains or enhances those qualifications by making training opportunities available to teachers. For example, these might include seminars about new techniques or concepts of learning. Next, the principal supports the teachers by supplying everyday needs to allow the teachers to execute their teaching skills rather than spend time gathering supplies. For instance, teachers should not have to worry about obtaining copy supplies, having adequate student desks, or providing proper air conditioning of the classrooms. The principal organizes the front office to support the teachers. Rather than have the principal direct the teachers, the teacher should almost direct the principal and the front office group in their support needs. In this type of role, the principal coordinates and controls the smooth functioning of the school organization, a professional bureaucracy. If there are only a few planners, they may adequately report to the maintenance manager or superintendent who is also over the crew supervisors. The manager or superintendent would ensure their proper selection and provide ongoing support. If there are more planners, a planning supervisor or lead planner may be desired. In either case, the ongoing objective would be to provide training and support to the planners. Training should consist of establishing the vision, principles, and techniques of planning and scheduling. Training might also include instruction in the use of computers and a CMMS computer system. Support might include copy machines, paper supplies, computer resources as needed, filing supplies, or other physical necessities that would allow the planners to focus on planning jobs. The supervision over the planners would ensure adequate office support exists. Finally, consider that the objective of support is to keep qualified planners in place adequately performing their planning duties. Planners' wages should be competitive to ensure that qualified persons have the desire to accept and stay in the planner positions.

One sees that Planning Principle 5 (skill of the crafts) indicates that crew technicians also function within a professional bureaucracy. In addition, Scheduling Principle 5 (crew leader handles current day's work) lends this same structure to crew supervisors. This is because of the diversity of work orders and the increasing technological sophistication needed to maintain modern machinery. This is why one commonly hears admonitions to

train and upgrade one's work force. However, do not job plans provide work rules, which is the preferred coordination method of the unchanging assembly line? Not at all. The work plans provide support both to the crew supervisors and to the craft technicians. The job plans provide information on job scope, crafts, and hours to allow the supervisor to assign and schedule the correct skills. The job plans provide filing support to avoid previous delays and a head start on other job information for the technicians. A heart problem would be assigned to a cardiologist and a foot problem to a podiatrist in a hospital. The office staff and nurses would provide previous medical histories to help each doctor treat each patient. Similarly, planners primarily perform triage and file services for crews. They do not normally dictate mandatory procedures. Their job plans provide support.

There is simply not enough repetition of identical jobs to establish the planners or the technicians into assembly lines coordinated with work rules. There is enough repetition of jobs to allow a planning function to support technicians in learning from past jobs.

Within such a framework, the question of "How do I control planning?" implies a fundamental misunderstanding of the situation. Once the planners have been hired, the majority of the control action has been completed.

INDICATORS

A wider perspective makes indicators or metrics also important. The restaurant story suggests the plant manager might oversee the general operation of the maintenance and operations departments as a "divisionalized form" of organization structure. Without complete attendance to the inner workings of each department, the plant manager might place heavy emphasis on indicators to control these departments. The managers of these departments should be responsible for indicating their efforts through indicators. Even within each group, opportunities exist for indicators to help coordinate efforts, though perhaps not as a primary means of coordination.

Persons can relate to overall plant availability or overall plant capacity fairly well. Figure 10.1 shows a sample overall availability metric. However, these indicators may be so global that they do not provide much assistance in determining what to do to improve their score. What factors have specifically contributed to maintaining a high availability or capacity? What factors have specifically reduced the overall availability or capacity of the plant? Other indicators should support these global indicators. Subindicators to availability or capacity might provide better information for coordinating or managing resources. The following sections present common indicators of maintenance performance.

Planned Coverage

Figure 10.2 illustrates planned coverage, a standard measure for a planning and scheduling system. Management desires that technicians spend more hours on planned jobs than unplanned jobs. This indicator is based on the actual hours technicians spend on jobs. The measure represents the percentage of these hours that are on planned work orders. The actual hours are measured regardless of the originally estimated hours of the planners. The metric utilizes actual labor hours as the unit of measure rather than quantity of work orders because the size of work orders can vary considerably. For instance, typical project work might normally be larger work orders than breakdown work orders. In addition, PM work orders might normally be smaller than breakdown work orders. Management desires for maintenance forces to spend adequate time on the appropriate type of work. Therefore, the metric should utilize a time-based unit. On the other hand, management should cautiously use work order quantities if actual time values are not initially available.

Station Availability

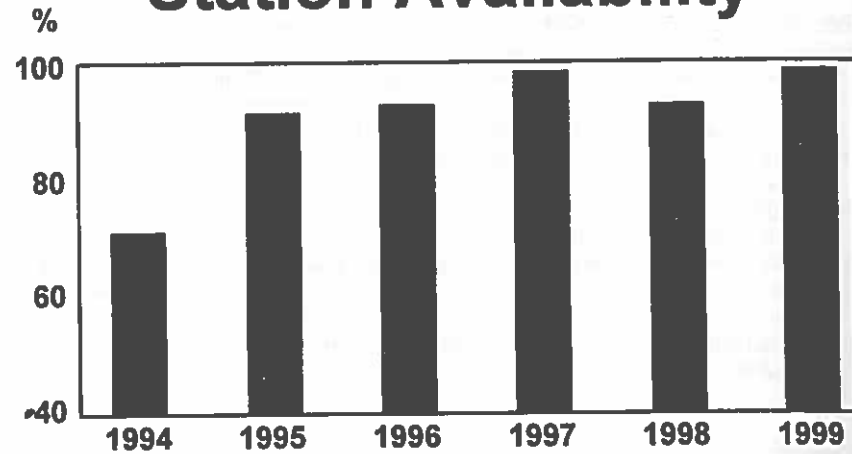


FIGURE 10.1 The simplest measure of overall maintenance effectiveness.

Planned Coverage

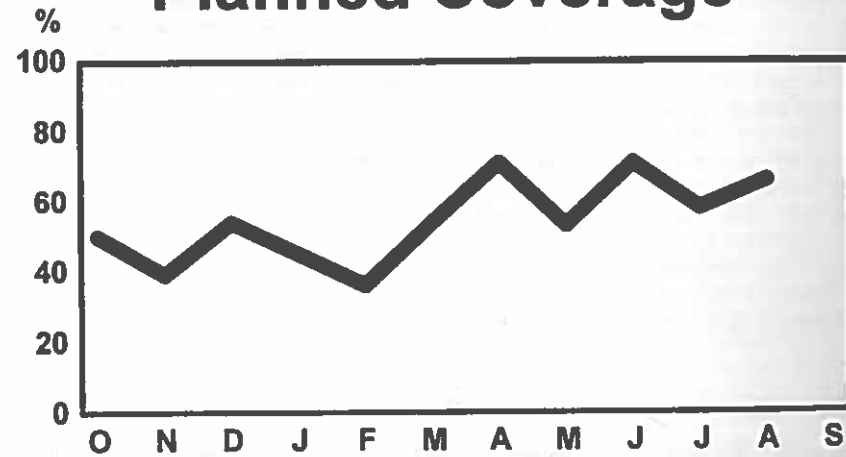


FIGURE 10.2 Management wants more labor hours spent on planned jobs.

Reactive versus Proactive

This metric measures the reactive nature of the plant maintenance work. Management desires reactive work to lessen in proportion to proactive work (Fig. 10.3). This indicator is based on the actual hours technicians spend on jobs. The actual hours are measured regardless of the originally estimated hours of the planners.

Reactive Work Hours

Figure 10.4 shows the absolute amount of reactive maintenance work. Management desires not only to perform more proactive than reactive work, it desires for the absolute amount of reactive work to decrease. The score of this indicator may be very erratic on a monthly basis and might be better measured on a yearly basis. The amount of reactive work may also initially increase as crews increase their productivity and perform more work of all types. This indicator is based on the actual hours technicians spend on jobs. The actual hours are measured regardless of the originally estimated hours of the planners.

Proactive vs Reactive

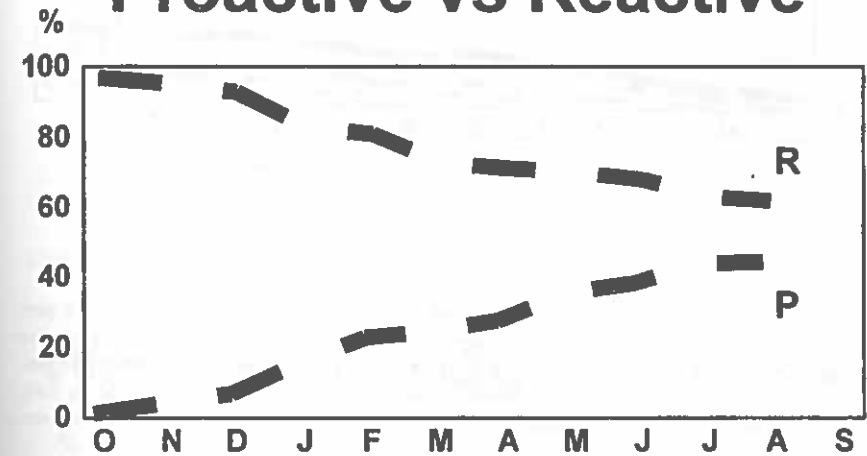


FIGURE 10.3 Management wants to spend more hours on proactive work than reactive work.

Reactive Work Hours

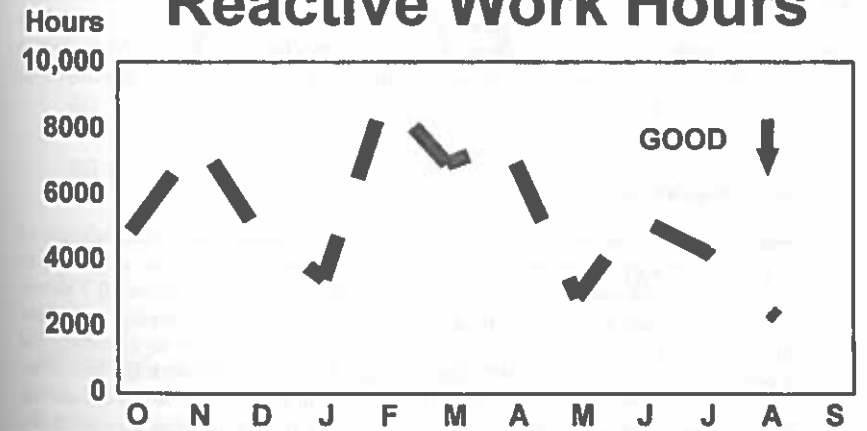


FIGURE 10.4 Management wants the overall amount of reactive work to decrease.

Work Type

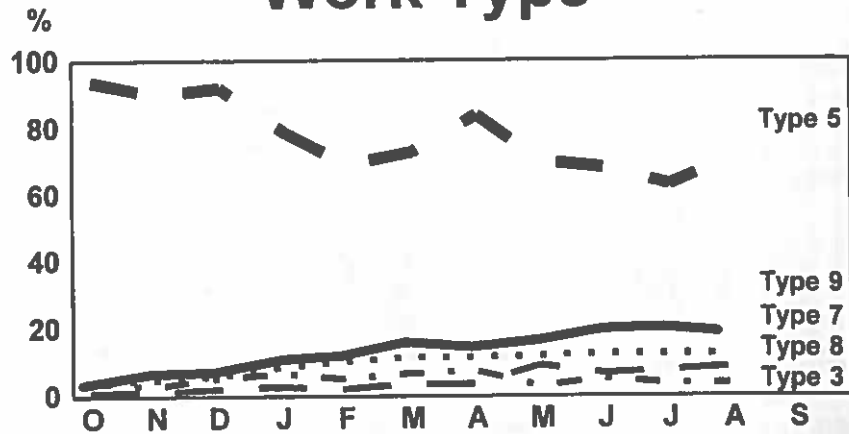


FIGURE 10.5 Another indicator of the proportions of reactive versus proactive work.

Work Type

Management needs information regarding the different types of maintenance work performed. Specific areas of interest are proportions of preventive maintenance, predictive maintenance, project work, and corrective maintenance versus actual failure and breakdown maintenance. This indicator is based on the actual hours technicians spend on jobs. The actual hours are measured regardless of the originally estimated hours of the planners. (See Fig. 10.5.)

Schedule Forecast

Figure 10.6 shows an example of an indicator tracking forecasted hours. Note how the chart indicates carryover hours. A large proportion of these hours could indicate a scheduling problem. This indicator uses hours taken directly off the form for Crew Work Hours Availability Forecast. The sample hours shown are for B Crew's forecast developed in Chap. 6.

Schedule Compliance

As discussed in Chap. 3, weekly schedule compliance provides the ultimate measure of proactivity. Some plants prefer the term *schedule success* to clarify the objective to measure control over the equipment rather than over the supervisors. Figure 10.7 shows a sample chart with data illustrating B Crew's performance. This company measures PM compliance as well. Figure 10.8 illustrates a helpful worksheet to calculate the schedule compliance score. Figure 10.9 illustrates the use of the form with B Crew numbers. The scoring of compliance gives the crew credit for all jobs that will start during the week regardless of whether they will finish. Chapter 6 explains that this gives the crew every possible benefit of any doubt of compliance.

Weekly Schedule Forecast

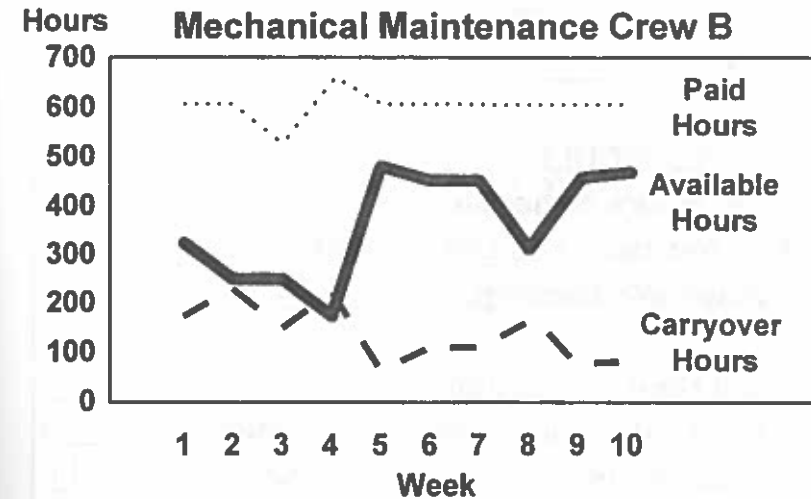


FIGURE 10.6 Maintenance might track forecast hours to help coordinate the scheduling process.

Weekly Schedule Success

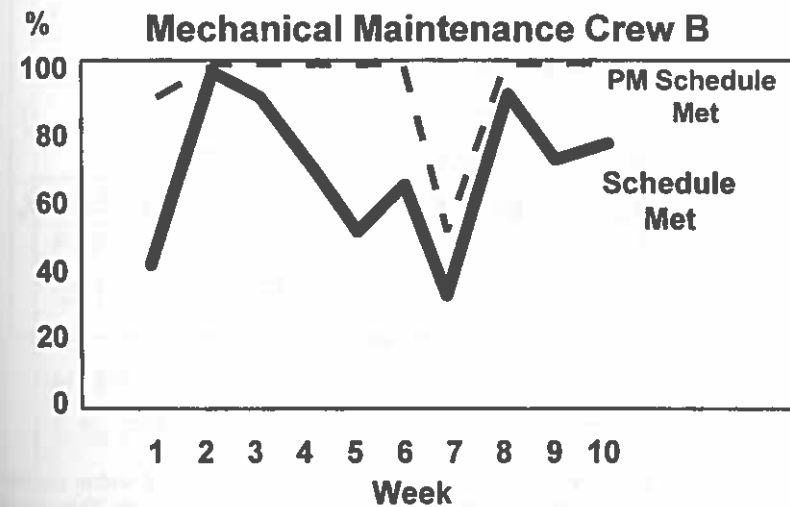


FIGURE 10.7 Schedule compliance to measure schedule success.

| ADVANCE SCHEDULE WORKSHEET #2 | |
|---|---------|
| For week of: _____ to _____ | |
| For crew: _____ By: _____ Date: _____ | |
| TOTAL SCHEDULE | |
| A. Total Hours Scheduled | _____ |
| B. Any Available Hrs Left Unscheduled (_____) | |
| Why? (No backlog, etc.) _____ | |
| _____ | |
| C. Total Hours Returned | _____ |
| Any Hours That Were Unclearable (_____) | |
| D. Sched Hours Worked (D = A - C) | _____ |
| E. % Schedule Met (E = D/A x 100) | _____ % |
| PREVENTIVE MAINTENANCE | |
| F. PM Hours Scheduled | _____ |
| G. PM Hours Returned | _____ |
| PM Hours That Were Unclearable (_____) | |
| H. PM Sched Hours Worked (H = F - G) | _____ |
| I. % PM Schedule Met (I = H/F x 100) | _____ % |

FIGURE 10.8 Sample of a helpful form to calculate schedule compliance.

Wrench Time

Figure 10.10 shows a sample wrench time metric. This indicator utilized within maintenance measures the percentage of time technicians actually spend on the job. This would be time where otherwise available technicians are not involved in delays such as procuring parts, tools, or instructions. Industry commonly refers to this time as *wrench time*. In-house analysts or consultants properly measure wrench time with a work sampling methodology. What is more significant than the time on the job is the analysis of the time and circum-

stances that delay technicians from being on the job. Appendices G and H provide sample work sampling studies.

One limitation of wrench time analysis is that it makes no presumption of how productive a technician is while on the job. On the other hand, one would presume that the on job productivity should stay the same so increasing the amount of time on the job should increase the overall amount of work produced. Planning Principle 6 in Chap. 2 explains that increasing the amount of time technicians are on the job is the purpose of planning. The

| ADVANCE SCHEDULE WORKSHEET #2 | |
|--|----------------|
| For week of: <u>5/11/99</u> to <u>5/14/99</u> | |
| For crew: <u>B Crew</u> By: <u>C. Rodgers</u> Date: <u>5/14/99</u> | |
| TOTAL SCHEDULE | |
| A. Total Hours Scheduled | <u>410</u> |
| B. Any Available Hrs Left Unscheduled (<u>45</u>) | |
| Why? (No backlog, etc.) <u>Backlog</u> | |
| _____ | <u>ran out</u> |
| C. Total Hours Returned | <u>84</u> |
| Any Hours That Were Unclearable (<u>0</u>) | |
| D. Sched Hours Worked (D = A - C) | <u>326</u> |
| E. % Schedule Met (E = D/A x 100) | <u>78%</u> |
| PREVENTIVE MAINTENANCE | |
| F. PM Hours Scheduled | <u>54</u> |
| G. PM Hours Returned | <u>0</u> |
| PM Hours That Were Unclearable (_____) | |
| H. PM Sched Hours Worked (H = F - G) | <u>54</u> |
| I. % PM Schedule Met (I = H/F x 100) | <u>100%</u> |

FIGURE 10.9 Sample of schedule compliance calculations.

Wrench Time

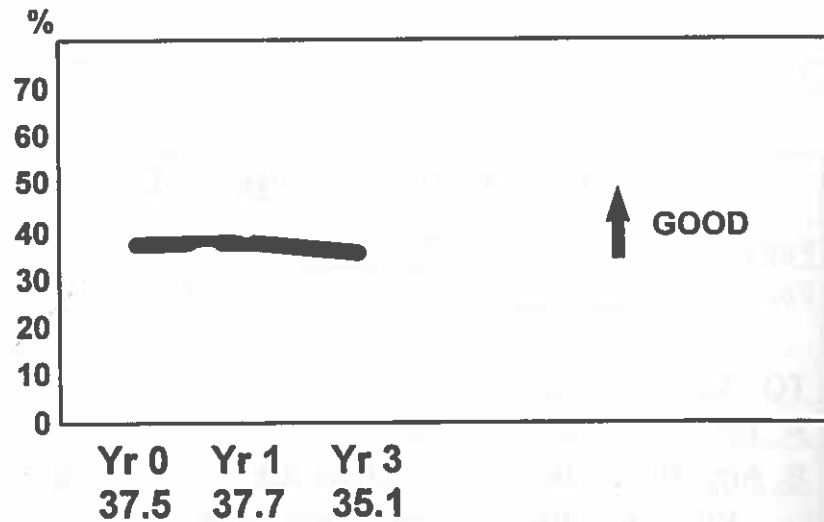


FIGURE 10.10 Sample indicator illustrating wrench time performance.

Total Minifiles

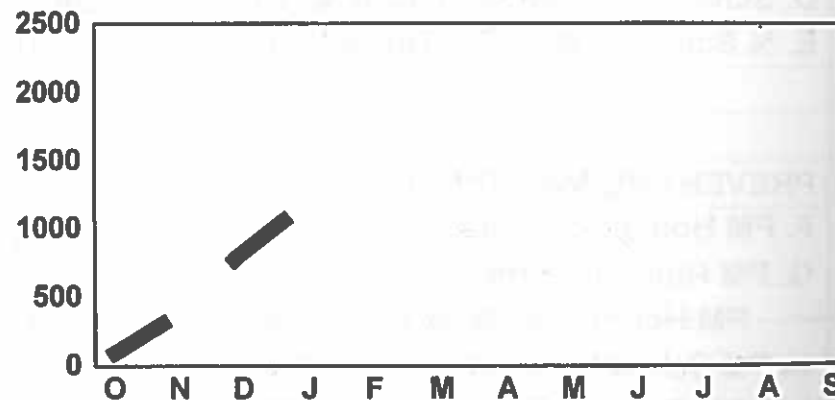


FIGURE 10.11 Ensuring planners understand the importance of the minifiles when starting a planning group.

measure of wrench time indicates the effectiveness of the planning and scheduling process rather than the efforts of the technicians themselves.

Minifiles Made

The creation of the minifiles described by Planning Principle 3 is of great importance. A planning supervisor may want to count the number of minifiles each month in the early months of a new planning organization. See Fig. 10.11.

Backlog Work Orders

Backlog of work orders is a very ominous indicator. Experience shows that many management efforts to reduce the size of a backlog result in a reduced amount of new work orders written rather than an increased number of work orders completed. The backlog is thus reduced by no longer identifying the work to which the plant should attend. The generation of new proactive work orders especially suffers. Other games played include writing larger work orders. Instead of writing a separate work order to take care of each fuel oil pump, technicians might write a single work order to take care of all three pumps. The backlog is thus further reduced by hindering the opportunity to keep good equipment records for each pump. If management intends to reduce equipment problems, it should track backlog by specific work type. The plant desires to reduce its reactive backlog, but increase its proactive backlog. The plant might define reactive work orders as failure or breakdown work orders plus other work orders as an urgent priority. The plant might define proactive work orders as project work, PM, PdM, or corrective maintenance except for ones that have become urgent. Through increasing the detection of proactive opportunities the plant can reduce its failures and reactive situations that hurt reliability. Management should vocalize this vision with caution. The simple command to reduce the backlog, but only the reactive backlog, can become confusing and counterproductive.

Work Orders Completed

Simply looking at backlogged work orders can be misleading. On the other hand, measuring the number of work orders completed each month provides an excellent check and balance when used with the backlog number. Management is interested in the maintenance group completing more work orders each month as one indication of productivity improvement. This indicator by itself might encourage the work force to write smaller work orders. For instance, instead of writing one work order to repair a pump, the indicator would tempt personnel to write three separate work orders for disassemble, repair, and reassemble. Because management pressure to reduce work order backlog tempts personnel to write fewer work orders, these two indicators help balance each other when used together.

Backlog Work Hours

Plants making sudden improvement gains in productivity often quickly run out of backlogged work. Plants in highly reactive work environments should then take advantage of the opportunity to create proactive work orders or generate reactive work orders that would have been ignored in the past. The plant's objective with a stable work force should be to maintain at least 2 weeks of craft backlog. Such identification of work promotes the smooth

operation of a productive maintenance department with planning and scheduling. Unfortunately, simple quantities of work orders do not indicate labor requirements. Prompt planning should establish a backlog in terms of hours. Dividing the normal paid hours of each craft into the backlog hours produces a number of backlog weeks. Because the paid hours are normally higher than the available hours for each craft, a goal of at least 2 weeks provides ample work. Management may desire to be aware of how many weeks of backlog are available for each craft. Further analysis by crew or specific skill level is unnecessary.

SUMMARY

The management of the planners themselves is best conducted as a professional bureaucracy. That is, management emphasizes selecting personnel and training them. Management does not emphasize direct supervision, procedures, indicators, or frequent meetings for coordination. A great deal of importance rests on the qualifications of each individual planner. Organizations should select planners with an aptitude for planning. Organizations should train them in the principles and techniques of planning. The organization may obtain qualified planners either through hiring or developing persons with the necessary potential for success. Appendix M, Setting up a Planning Group, discusses how to accomplish the selection and training of maintenance planners.

While selection of planners handles the majority of planning control, management of overall maintenance does make use of several common indicators. The chief of these is overall availability. Other indicators include ones for measuring the proportion of work hours that are planned and the proportions of different types of proactive work versus reactive work. Management should use simple indicators of backlog with caution because the plant must generate a backlog to take care of maintenance. Schedule compliance helps determine if the maintenance force is controlling the equipment or if the equipment is controlling the maintenance force. Management measures crew forecasts and carryover work to help understand the functioning of the schedule process. Management uses these indicators to coordinate the efforts of the divisions or groups together.

Management uses the planning function itself to help control the working of maintenance. Management closely monitors and manages the process of selecting planners to help control the working of planning itself.

CHAPTER 11

CONCLUSION: START PLANNING

What is maintenance planning?

Maintenance planning as envisioned by the *Maintenance Planning and Scheduling Handbook* is not preventive maintenance.

Maintenance planning is not planning how to establish and organize a maintenance department.

Maintenance planning is not using a computer.

Maintenance planning is not providing a detailed procedure describing how to perform a maintenance task.

Maintenance planning is not simply identifying spare parts and special tools before a job starts.

Maintenance planning is providing file information to technicians to allow them to learn from past jobs and avoid delays. Planning also helps ensure the availability of anticipated spare parts and special tools.

Maintenance planning is providing crew supervisors with job scopes plus craft and work hour estimates to allow them better to assign daily work.

Maintenance planning is advance scheduling to allow managers to allocate work for crews based on forecasted labor availability.

Why do companies need maintenance planning? They need maintenance planning because it helps increase the amount of time technicians spend on direct work, actual work without delays. Maintenance planning reduces the time technicians spend in gathering parts, in finding tools, in receiving instructions, or in many other delay situations. In industry today, delays commonly cause maintenance crews to spend only 25% to 35% of their time on job sites making job progress. These delays do not even include time lost to vacation, training, or other type of administrative absences. Maintenance planning helps boost the direct work or wrench time of technicians to 55% or more. A good company at 35% with 30 maintenance technicians would enjoy the effect of having 47 technicians if it had 55% direct work time. The company would add 17 extra technicians without cost to its maintenance efforts. The company with 90 maintenance technicians would see the effort of 141 technicians, a 51-person improvement. And lest one should think maintenance planning helps only the large corporation, the company with 10 maintenance technicians would see the effort of 15 technicians, a 5-person improvement.

5. Persons to stage items are readily available.
6. Equipment downtime is valuable.
7. Equipment downtime is limited.
8. Distance to the storeroom or tool room is excessive.
9. Availability or accessibility of storeroom or tool room is limited.
10. It is relatively difficult later to transport items to the site if they are not staged.
11. Item is easily returnable to storeroom or tool room.
12. The item is disposable if unused or lower in value than would be worth technicians' time to return.
13. There is some experience with planning and scheduling.
14. There is high maturity and sophistication of the planners to anticipate items correctly.
15. There is high confidence that the job will start the week or day scheduled.

Do not stage items that are:

1. For unscheduled jobs unless a nonstock item was exclusively obtained for a job.
2. Difficult or impractical to move repeatedly due to size or storage requirements.
3. Difficult or impractical to move repeatedly due to legal tracking requirements.

GUIDELINES FOR CRAFT TECHNICIANS TO PROVIDE ADEQUATE JOB FEEDBACK

1. Identify quantity of persons and specific craft and grade of each person. Identify the names of the persons.
2. Identify labor hours of each person. Give start and finish times of job. Explain any variance from the plan estimates if greater or less than 20%.
3. Thoroughly describe the problem if not accurately specified by the plan.
4. Thoroughly describe the action taken if the job did not proceed according to the plan. Report any special problems and solutions.
5. Identify actual quantities of parts used and report stock numbers if not given by the plan.
6. Identify actual special tools used or made if not given by the plan.
7. Return the original work order and all attachments provided by planning. Include any field notes and return any datasheets that the technician filled out whether or not planning provided them.
8. Return updated drawings.
9. Note any changes to equipment technical information such as new serial numbers and model numbers and names. Return any manufacturer's information or literature that was received with any new parts being installed. This information is especially vital and often cannot otherwise be determined to help future maintenance.
10. Include any other information such as bearing clearances (radial and thrust), wear ring clearance, shaft runout clearance, bearing to cap clearances, coupling condition and gap clearance.
11. Make any recommendations to help future plans.

APPENDIX B FORMS

This appendix gives a complete set of forms used in this handbook. Readers of this book may use them as they are or modify them for maintenance in their organizations.

| | | | |
|--|------------------------------|--------------------------|---------------------------|
| WORK ORDER # | | | |
| REQUESTER SECTION | | | |
| Equipment _____ | Tag # _____ | Priority _____ | |
| Problem or Work Requested: _____ | | Def Tag # _____ | |
| By: _____ | Outage Req? Y/N _____ | Clearance Req? Y/N _____ | Confined Space? Y/N _____ |
| Date & Time: _____ | APPROVAL: | | |
| PLANNING SECTION | | | |
| Assigned Crew: _____ | | Attachment? Y/N _____ | |
| Description of work to be performed: _____ | | | |
| Labor requirements: _____ | | | |
| Parts requirements: _____ | | | |
| Special tools requirements: _____ | | | |
| By: _____ | Date & Time: _____ | Job Estimate: _____ | Actual: _____ |
| CRAFT FEEDBACK (Modify plan sections above: actual labor, parts, & tools) | | | |
| Work performed including equipment changes & any problems or delays: _____ | | | |
| Date & Time Started: _____ | Date & Time Completed: _____ | | |
| By: _____ | Date: _____ | APPROVAL: | |
| CODING | | | |

FIGURE B.1 Sample work order form.

| | | | | | | |
|--|--------------|--------------|---------|---------|---------|-------------|
| CREW WORK HOURS AVAILABILITY FORECAST | | | | | | |
| For week of: ___ / ___ / ___ to ___ / ___ / ___ | | | | | | |
| For crew: _____ By: _____ Date: ___ / ___ / ___ | | | | | | |
| Craft | # Persons | Paid Hrs | Leave | Train | Misc | Carry-over* |
| Avail Hrs | | | | | | |
| _____ | x 40 = _____ | - _____ | - _____ | - _____ | - _____ | = _____ |
| _____ | x 40 = _____ | - _____ | - _____ | - _____ | - _____ | = _____ |
| _____ | x 40 = _____ | - _____ | - _____ | - _____ | - _____ | = _____ |
| _____ | x 40 = _____ | - _____ | - _____ | - _____ | - _____ | = _____ |
| _____ | x 40 = _____ | - _____ | - _____ | - _____ | - _____ | = _____ |
| _____ | x 40 = _____ | - _____ | - _____ | - _____ | - _____ | = _____ |
| _____ | x 40 = _____ | - _____ | - _____ | - _____ | - _____ | = _____ |
| _____ | x 40 = _____ | - _____ | - _____ | - _____ | - _____ | = _____ |
| _____ | x 40 = _____ | - _____ | - _____ | - _____ | - _____ | = _____ |
| _____ | x 40 = _____ | - _____ | - _____ | - _____ | - _____ | = _____ |
| _____ | x 40 = _____ | - _____ | - _____ | - _____ | - _____ | = _____ |
| Totals | | x 40 = _____ | - _____ | - _____ | - _____ | = _____ |
| <p>*Carryover work is any work which has been physically started in the current period, but will not be finished and will run over into the forecast period.</p> | | | | | | |

FIGURE B.2 Crew work hours availability forecast form.

ADVANCE SCHEDULE WORKSHEET

For week of: _____ to _____
 For crew: _____ By: _____ Date: _____

| Forecast | Available Hours Left |
|--------------|----------------------|
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| | |
| Totals _____ | _____ |

Instructions: Subtract job work hours from available line total until balance reaches zero for each line or backlog runs out.

FIGURE B.3 Advance schedule worksheet.

ADVANCE SCHEDULE WORKSHEET #2

For week of: _____ to _____
 For crew: _____ By: _____ Date: _____

TOTAL SCHEDULE

A. Total Hours Scheduled _____
 B. Any Available Hrs Left Unscheduled (_____)
 Why? (No backlog, etc.) _____

C. Total Hours Returned _____
 Any Hours That Were Unclearable (_____)

D. Sched Hours Worked (D = A - C) _____
 E. % Schedule Met (E = D/A x 100) _____%

PREVENTIVE MAINTENANCE

F. PM Hours Scheduled _____
 G. PM Hours Returned _____
 PM Hours That Were Unclearable (_____)

H. PM Sched Hours Worked (H = F - G) _____
 I. % PM Schedule Met (I = H/F x 100) _____%

FIGURE B.4 Advance schedule worksheet 2 to measure schedule compliance.

| DAILY SCHEDULE | | | | |
|---------------------|--------------|-----|-------------------|----------|
| DAY: _____ | DATE: _____ | | | |
| SUPERVISOR: _____ | | | | |
| WO# | Unit | Pri | Short Description | Comments |
| | | | | |
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| Special Codes: | Special Code | | | |
| V-Vacation S-Sick | & Hours | | | |
| T-Training O-Other | | | | |
| A-Assigned Off Crew | Total | | | |

FIGURE B.5 Daily schedule form.

ALIGNMENT CHECKSHEET

- ___ 1. Break coupling and remove old grease.
- ___ 2. Inspect coupling for damage.
- ___ 3. Secure coupling. Run motor if magnetic center of motor is unknown. Mark motor shaft.
- ___ 4. Shut down motor. Set motor shaft to electrical center. Set coupling gap per coupling instructions.
- ___ 5. Inspect hold down bolts and washers for damage.
- ___ 6. Install jacking bolts on all corners of machines to be shimmed.
- ___ 7. Correct machine to be shimmed for soft foot and defective sole plates.
- ___ 8. Correct stationary machine for soft foot and defective sole plates.
- ___ 9. Remove all shims. Clean or replace as needed.
- ___ 10. Pack proper amount of grease into coupling and reassemble.
- ___ 11. Align machine. Use PdM group instructions for considering thermal growth.
- ___ 12. Tighten all fasteners. Loosen jacking bolts. Turn shaft to ensure free rotation.
- ___ 13. Attach form to work order.

Technician _____ Date _____

FIGURE B.6 Sample alignment readiness form.

UNIT 2 BURNER CHECKSHEET FORM

Burner Number: _____

Date: _____

**TECHNICIAN INITIALS EACH STEP
WHEN COMPLETE**

- ___ 1. Replace orifice, swirl, and spill plates
- ___ 2. Replace both gaskets.
- ___ 3. Verify correct lance setting.
Setting is: _____
- ___ 4. Torque feed tube to 200 ft lb.
- ___ 5. Torque cap nut assembly to 77.5 ft lb.
- ___ 6. Adjust spider to provide 1/8 inch to 3/16 inch
gap between outer tube and washer.

FIGURE B.7 Sample burner checksheet form.

DEFICIENCY TAG
#0084147

EQUIPMENT _____

EQUIP TAG# _____

PROBLEM _____

LOCATION _____

TAGGED BY _____

DATE _____

TIME _____

Carbon & Copy

FIGURE B.8 Sample deficiency tag form.

PARTS INFORMATION SHEET

PAGE ____

EQUIPMENT NAME _____

EQUIPMENT TAG # _____

| | Stock Number | Total Quantity Used for this Equipment | Quantity Needed for this Job* | Description |
|----|--------------|--|-------------------------------|-------------|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |
| 7 | | | | |
| 8 | | | | |
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| 26 | | | | |
| 27 | | | | |
| 28 | | | | |
| 29 | | | | |
| 30 | | | | |

*Use this column after copying this page to issue with a specific job.

FIGURE B.11 Sample minifile form for spare parts.

EQUIPMENT NORMAL PM's AND CHECKS

EQUIPMENT NAME _____

EQUIPMENT TAG # _____

By Maintenance Personnel

| What | Frequency | *Route Designation |
|------|-----------|--------------------|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

By Predictive Maintenance (PdM) Personnel

| What | Frequency | *Route Designation |
|------|-----------|--------------------|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

By Operations, Lab, or Other Personnel

| What | Frequency | *Route Designation |
|------|-----------|--------------------|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

*if any

FIGURE B.12 Sample minifile form for PM's.

INFORMAL CHECKSHEET TO BALANCE OBSERVATIONS

Mark the time started to locate persons within beginning half hour (B) or end half hour (E): Hand write a number beside each half hour to designate the week during which the observation occurred.

Weeks:

| Time Period | Time | Mon | Tues | Wed | Thur | Fri |
|-------------|-------------------|-----|------|-----|------|-----|
| 8 | 7:30-8:30 | B E | B E | B E | B E | B E |
| 9 | 8:30-9:30 | B E | B E | B E | B E | B E |
| 10 | 9:30-10:30 | B E | B E | B E | B E | B E |
| 11 | 10:30-11:30 | B E | B E | B E | B E | B E |
| 12 | 11:30-12:12:30 -1 | B E | B E | B E | B E | B E |
| 13 | 1 - 2 | B E | B E | B E | B E | B E |
| 14 | 2 - 3 | B E | B E | B E | B E | B E |
| 15 | 3 - 4 | B E | B E | B E | B E | B E |
| 16 | 4 - 5 | B E | B E | B E | B E | B E |
| 17 | 5 - 6 | B E | B E | B E | B E | B E |

Special comments:

FIGURE B.13 Sample form to ensure an even balance of work sampling study observations.

PAGE ___ OF ___

WRENCH TIME OBSERVATION DATA SHEET

| (Clock Entry) | Unit Events | Observing Date | Day of Week | Person's Number | Person's Suppr. Number | Work Cat. # | Time Period | OT? | Any Observation Comments (such as purpose of travel) |
|---------------|-------------|----------------|-------------|-----------------|------------------------|-------------|-------------|-----|--|
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FIGURE B.14 Sample form to record work sampling observations.

APPENDIX I

THE ACTUAL DYNAMICS OF SCHEDULING

This appendix discusses two additional elements of productivity and scheduling, namely wrench time in exceptional crafts and plants and blanket work orders in any plant. The *Maintenance Planning and Scheduling Handbook* addresses these topics in this appendix so as not to distract from the main thrust of the book.

First, wrench time may be higher than the industry norm of 25 to 35% in some maintenance organizations without highly developed planning functions. The preceding two appendices showed two such examples. In App. G, the I&C (instrument and controls) group had a 38% wrench time. This I&C group did not have a planning function assisting it. The industry norm more applies to an overall maintenance force than to a specific craft. I&C and electrical crafts without planning typically should be at the top or slightly over industry norm. These groups are typically not at the desired 55% level, but their existing productivity may warrant placing them behind the mechanical group in priority for implementation of planning. In addition, in plants where I&C and electrical groups mostly support the mechanical groups, the improvement of the mechanical group's wrench time through planning improves these other crafts as well. Appendix H shows a mechanical group with a marginal planning effort. With only planning, but no weekly scheduling, the craft is at the top of the industry norm for wrench time. Certain crafts, most notably machinists, achieve 50% wrench time due to the nature of their close-at-hand work assignments.

Another situation, not illustrated by the two included wrench time studies, is that of the plant with extremely high amounts of urgent, reactive work. The craftpersons in these plants have moderate to high wrench times primarily because there is no need to schedule subsequent work assignments. The urgency of the workplace easily directs the resources to the next jobs. There is limited opportunity for idleness or breaks. The plant possesses a productive work force, but has terrible reliability. Then, as management brings more maintenance personnel to the suffering plant, the work force is able to catch its breath. The maintenance force grows to where it can keep up with the reactive work and deliver a somewhat reasonable reliability. At this point, wrench time drops as uncertainty sets in as to where to attack the next job. The discussion and all the reasons set forth in Chap. 6, *Basic Scheduling*, come into play to keep productivity low.

Second, so-called blanket work orders greatly damage both productivity and record keeping. Rather than accept the expense of writing work orders for every little task, many plants have blankets to which personnel charge time for certain tasks. For example, rather than write a work order, the supervisor may direct a mechanic to hang a bulletin board in the front office and "charge the time to Blanket 103" (miscellaneous mechanical work). The productivity problem created is threefold. One, the supervisor and mechanic have stepped outside of the planning and scheduling process. The supervisor could give the mechanic a time estimate, but probably will not. Two, the extraneous job was not scheduled into the week's allocation of work. As the practice of doing work on blankets expands,

App-I.1

the week's allocation becomes meaningless without special attention to schedule compliance. The possibility of doing side jobs on blankets encourages neglect of the weekly schedule. The weekly schedule was based on the work prioritized in the best interest of the plant. These jobs will be delayed by possibly less important blanket work. Finally, the use of blankets invites giving less credibility to the planned time estimates. Instead of assigning a 9-hour job and a 1-hour job from the backlog to a technician on a 10-hour shift, the supervisor may assign only the 9-hour job. The supervisor might direct the technician to do some miscellaneous cleaning up "on the blanket." Likewise, blankets allow the technician to report 5 hours on a planned 5-hour job that took all day. The technician might rather claim the other 5 hours of the day on blanket work rather than having to document all the reasons the planned job took so long. There is a general loss of control, and many plants begin to do an extremely large portion of their work on blankets. One plant could account for less than half of their work hours being spent on specific work orders. The rest was blanket work. Besides productivity, blankets lose vital equipment history. Blanket work leaves no document to store in the paper files or information to record in electronic files. If the plant does some equipment work via work orders and some via blankets, then planners do not have complete history from which to collect delay information or base maintenance decisions going into their plans.

One sees that there are additional issues and situations affecting how planning and scheduling affect productivity. One of these is higher wrench time experienced under certain conditions without significant planning and scheduling. Certain crafts have somewhat higher wrench times than industry averages for overall maintenance. However, even these craft are helped by maintenance planning. Plants experiencing extreme trouble also often do not have poor wrench time. Yet as these plants increase their reliability, they benefit from planning and scheduling to maintain a high productivity. They must maintain higher productivity to allow completion of more proactive work. Another issue is the interference that blanket work orders cause the planning and scheduling effort. Management should eliminate or greatly restrict the use of blankets.

APPENDIX J

WORK ORDER SYSTEM AND CODES

Starting a work order system is the most important improvement one can make to a maintenance program. The work order system is the process by which the maintenance manages all plant maintenance work. The system assists the plant in keeping track of, prioritizing, planning, scheduling, analyzing, and controlling maintenance work. The plant must have a viable work order system as a foundation to planning.

This appendix illustrates a typical manual a company would use to document its work order process. Notes have been inserted to call attention to particular details. Example work orders throughout this book have used the codes from this appendix. The manual should primarily illustrate the work order form, the work order process, and identify the codes used in the system. As a CMMS becomes developed, it is not unreasonable to expect that the CMMS could contain the essentials of the work order manual and replace it.

This example company uses a paper work order system for persons that originate work orders. A clerk enters the work orders into the CMMS system. The plant is currently considering creating a CMMS screen to resemble its work order form and allowing persons to enter their own work orders directly into the system.

It is a good idea to have a document that sets forth the rules of using work orders. It is not necessary that the document be exceedingly thick.

COMPANY WORK ORDER SYSTEM MANUAL

TABLE OF CONTENTS

| |
|--------------------------------------|
| Introduction |
| Work Flow |
| Work Order Form and Required Fields |
| CMMS Instructions for Plant-Wide Use |
| Codes |
| Priority |
| Status |
| Department and Crew |
| Work Type |
| Plan Type |
| Outage |
| Plant and Unit |
| Equipment Group and System |
| Equipment Type |

Action Taken
Reason, Cause, and Failure
Work Order Numbering System
Manual Distribution

INTRODUCTION

The work order system is the process which the Maintenance Department uses to manage all plant maintenance work. The work order system assists the plant in keeping track of, prioritizing, planning, scheduling, analyzing, and controlling maintenance work. (The terms *WO* and *work order* have the same meaning.) A major purpose of using work orders for plant equipment is to be able to track its history. Using blanket work orders or having several pieces of equipment on the same work order destroys the process of keeping history.

The *work flow diagram* shows the steps of the cycle that occur from initiating a work order to work completion.

The plant uses the work order form as the document to record information associated with executing the work request.

After work completion, WO forms which have historical value are filed to assist future work. Codes are used with each work order to allow various sorts and analysis of maintenance work. For example, the outage code allows sorting out all work orders that must be done during a unit outage.

The CMMS (computerized maintenance management system) allows computer tracking and analysis of work orders as well as plant equipment data. The system is on the personal computer (PC) network and may be accessed from any plant.

The WO numbering system provides for assigning each separate work order a unique number to allow keeping the work done under that number separate from other maintenance work.

A *WO System Manual* is distributed to each person on the manual distribution list who is responsible for keeping it up to date with all issued revisions. The Job Planning Coordinator coordinates and distributes all revisions to the *WO System Manual*.

WORK FLOW

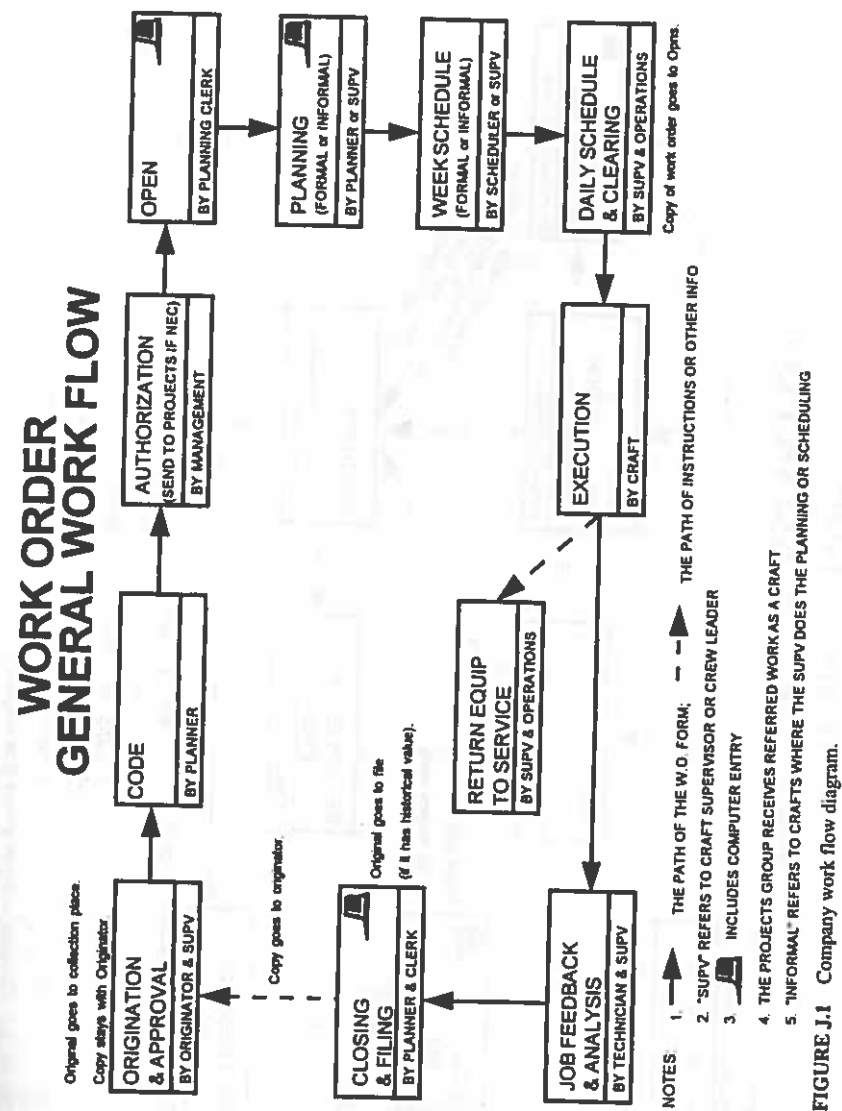
Work flow diagrams show the steps of the cycle that occur from initiating a work order to work completion. Figure J.1 shows the normal steps of the work process. Figure J.2 shows the steps taken during emergencies. In emergencies, action begins with verbal instructions and the paperwork follows later.

WORK ORDER FORM AND REQUIRED FIELDS

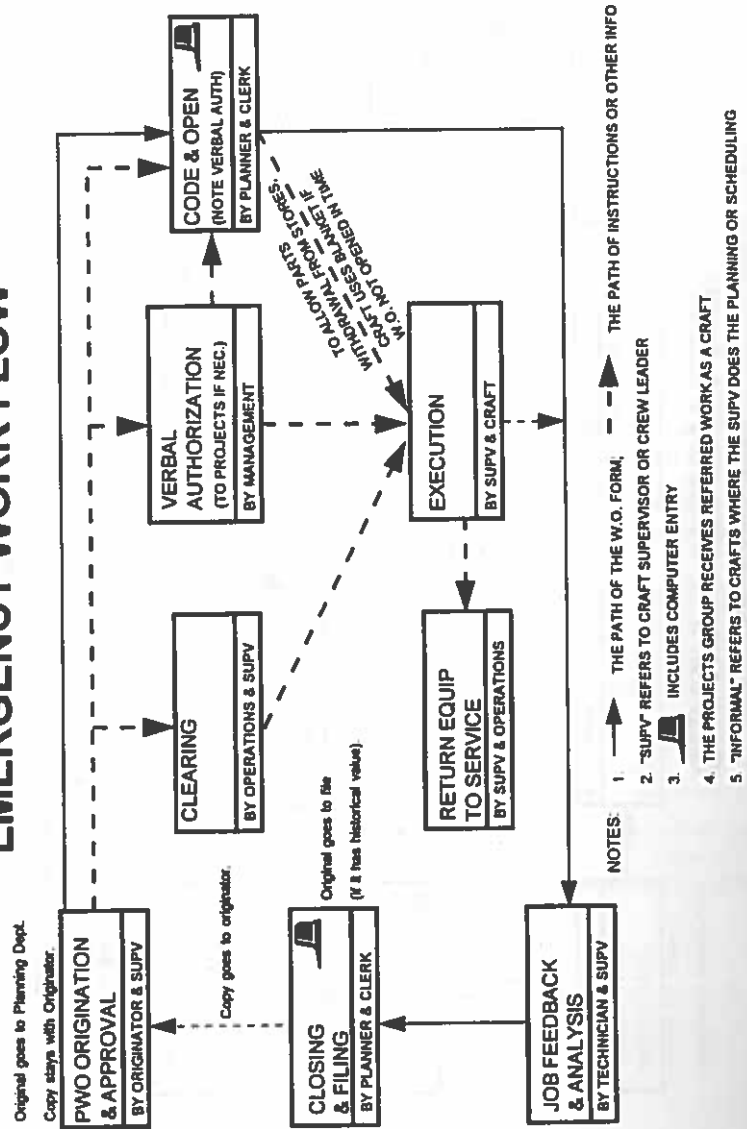
The work order form is the document used to record information associated with:

1. an identified problem, need, or work request
2. the work authorized to be done
3. the plans, details, and schedules necessary to perform the work
4. the results of that work

After work completion, the planning department files work order forms which have historical value to assist future work.



WORK ORDER EMERGENCY WORK FLOW



App-J.4

FIGURE J.2 Company emergency work flow diagram.

Figure J.3 illustrates the work order form this company uses. Figure J.4 identifies who is responsible for completing each section of the form.

The following information is used by the Job Planning Coordinator when ordering new work order forms from the printer. The JPC gives this information to the company graphics department, printer, or forms order company along with a reproducible original.

General Information

- All parts are printed in black.
- Carbonless paper is used.
- Note that the original is reduced in size!
- Copy all four parts; enlarge them to have 1/4-inch left and right margin.
- Numbering should be in red ink at the top of the form.
- No additional numbers should appear anywhere on the form or tab.

Numbering sequence should be as follows:

- | | |
|--------------------------|--------------------------|
| Lot 1: A000 through A999 | Lot 2: B000 through B999 |
| Lot 1: C000 through C999 | Lot 2: D000 through D999 |
| Lot 1: E000 through E999 | Lot 2: F000 through F999 |
| Lot 1: G000 through G999 | Lot 2: H000 through H999 |
| Lot 1: J000 through J999 | Lot 2: K000 through K999 |
| Lot 1: L000 through L999 | Lot 2: M000 through M999 |
| Lot 1: N000 through N999 | Lot 2: P000 through P999 |
| Lot 1: Q000 through Q999 | Lot 2: R000 through R999 |
| Lot 1: T000 through T999 | Lot 2: W000 through W999 |
| Lot 1: X000 through X999 | Lot 2: Y000 through Y999 |

Note: Do not use letters i, o, s, u, v, or z. Package in nearly equal amounts (between 50 and 200); no specific amount is required.

- Part 1 information: White stock, 8 1/2 x 11 inch, print the front and back (see sample).
- Part 2 information: Pink stock, 8 1/2 x 11 inch, print the front only (see sample).
- Part 3 information: Blue stock, 8 1/2 inch x cut at bottom line, print the front only.
- Part 4 information: Goldenrod stock, 8 1/2 inch x cut at bottom line, printing front only (see sample).
- Contacts: Get the Job Planning Coordinator's name and phone number.

CMMS INSTRUCTIONS FOR PLANT-WIDE USE

(Note: This section should cut down the 1-inch-thick computer manual that came with the CMMS to a few pages of key instructions for non-planning group persons such as most plant supervisors, technicians, operators, and managers. The example used for this section has been discussed in Chap. 8 and placed in App. L dealing with a CMMS installation.)

| WORK ORDER # | |
|--|------------------------------|
| REQUESTER SECTION | |
| Equipment _____ | Tag # _____ |
| Problem or Work Requested: _____ | Def Tag # _____ |
| By: _____ | Outage Req? Y/N _____ |
| Date & Time: _____ | Clearance Req? Y/N _____ |
| APPROVAL: | |
| PLANNING SECTION | |
| Assigned Crew: _____ | Attachment? Y/N _____ |
| Description of work to be performed: | |
| Labor requirements: | |
| Parts requirements: | |
| Special tools requirements: | |
| By: _____ | Date & Time: _____ |
| Job Estimate: _____ | Actual: _____ |
| CRAFT FEEDBACK (Modify plan sections above: actual labor, parts, & tools) | |
| Work performed including equipment changes & any problems or delays: | |
| Date & Time Started: _____ | Date & Time Completed: _____ |
| By: _____ | Date: _____ |
| APPROVAL: | |
| CODING | |

FIGURE J.3 Company work order form.

| WORK ORDER # | |
|--|------------------------------|
| REQUESTER SECTION | |
| Equipment _____ | Tag # _____ |
| Problem or Work Requested: _____ | Def Tag # _____ |
| By: _____ | Outage Req? Y/N _____ |
| Date & Time: _____ | Clearance Req? Y/N _____ |
| APPROVAL: | |
| (ORIGINATOR) | |
| (ORIG'S SUPV) | |
| PLANNING SECTION | |
| Assigned Crew: _____ | Attachment? Y/N _____ |
| Description of work to be performed: | |
| Labor requirements: | |
| Parts requirements: | |
| Special tools requirements: | |
| By: _____ | Date & Time: _____ |
| Job Estimate: _____ | Actual: _____ |
| CRAFT FEEDBACK (Modify plan sections above: actual labor, parts, & tools) | |
| Work performed including equipment changes & any problems or delays: | |
| Date & Time Started: _____ | Date & Time Completed: _____ |
| By: _____ | Date: _____ |
| APPROVAL: | |
| (TECHNICIAN) | |
| (TECH'S SUPV) | |
| (PLANNER) | |
| CODING | |

FIGURE J.4 Identification of information responsibility on work order form.

CODES

Codes are used with each work order to allow various sorts and analysis of maintenance work. For example, the outage code allows gathering all work orders that must be done during a unit outage. Here is an example set of codes for an oil and gas fired electric power station that has both steam and gas turbine generating units. These codes illustrate what codes are used for and look like.

Priority

(*Note:* Priority codes allow ranking work orders in order of importance to know which to handle first. See Scheduling Principle 2 for more discussion of their importance and how incorrect usage can hinder productivity. Organizational discipline that comes through education, communication, and management commitment helps ensure correct usage.)

Work Order Priority Codes. First digit—priority type. (*Note:* The first digit does not indicate priority preference; each type has equal weight.)

- S Safety
- H Heat rate
- E Environmental or regulatory
- R Reliability or availability
- G General

Second digit—priority order. (*Note:* The second digit indicates priority preference.)

- 0 Emergency Conditions
 - Loss of unit
 - Immediate or imminent loss of unit capacity
 - In violation of environmental regulations
 - Loss of unit load control
 - Emergency safety hazard
- 1 Urgent Conditions
 - Significant potential for loss of unit or unit capacity
 - Major loss of heat rate
 - Significant potential for violation of environmental regulations
 - Urgent safety hazard
- 2 Serious Conditions
 - Condition that could cause serious damage to critical equipment
 - Serious loss of heat rate
 - Condition that could cause violation of environmental regulations
 - Serious safety hazard
 - PM's
- 3 Noncritical Maintenance on Production Equipment
- 4 Noncritical Maintenance on Nonproduction Equipment

(*Note:* Therefore, work orders with "1" priorities should be handled ahead of work orders with "2" priorities and so on regardless of the letter priority type. Having the letters associated with the priorities helps persons better understand the nature and reasons behind the work orders and their numerical priorities. If one carefully examines the point criteria examples, safety is indeed given more weight in that it is easier for a safety (S) work order to receive a 1 score than it is for heat rate, a unit efficiency measure. In a well functioning plant, 0 and 1 work orders should be infrequently received. It is maintenance's objective to have mostly 2 level PM work orders and 3 and 4 level work orders as the maintenance organization goes about its task of maintaining, not recovering. There is a valid argument that such a short range between 0 and 4 tends to encourage persons to classify work orders as 1 (urgent) and 2 (serious) unnecessarily. For that reason many plants have an extended range, perhaps 0 to 10. They do not get many 10 work orders, but they do get more 3's and 4's and less false 1's and 2's.)

Status

(*Note:* These codes are solely for the CMMS, the simple reason being that the placement of paper work orders determines their status. For example, paper work orders waiting for parts are kept by the purchaser, work orders in progress are kept by the technicians, etc. The CMMS allows the rest of the plant to ascertain where the work orders are in the work order process.)

Work Order Status Codes

- WAPPR—Waiting for approval. This status is the initial status of a WO before plant management has authorized the work request.
- APPR—Approved. Management has authorized the work request and it is ready for planning.
- WSCH—Waiting to be scheduled. The work order has been planned (if planning was necessary) and it is ready to be scheduled for work.
- HOLD-MATL—Waiting for material or tools. Materials or tools are unavailable to either start or continue work.
- HOLD-OTHER—Waiting for other reason than materials or tools. Work is waiting on engineering or management decision to either start or continue work.
- PROJ—Project. This work is being undertaken by the corporate project group. Plant maintenance forces are not involved at this time.
- SCHED—Scheduled. Work has been included on the weekly schedule.
- INPRG—In progress. Work has already begun or it has been included on the next day's schedule.
- COMP—Completed. Work has been completed, but the finished work and documentation have not yet been reviewed or analyzed. WO has not yet been closed..
- COMP-DWGS—Completed, waiting on drawings. Work has been completed, but required drawings have not yet been revised. WO has not yet been closed.
- COMP-OTHER—Completed, waiting on other. Work has been completed, but some specific requirement has not yet been submitted. WO has not yet been closed.
- CLOSE—Closed. All work and documentation have been completed satisfactorily. WO is closed.

CAN—Canceled. This WO is not considered necessary. WO's may be canceled for a variety of reasons such as the WO may be a duplicate of another WO, the need for this work no longer exists, or plant management has decided not to approve the work order for economic, budget, or other reasons.

Department and Crew

(*Note:* These codes when assigned to work orders make it possible to determine and track who originated the work and who is responsible for executing the work. Backlogs and work already performed are easily sorted into crafts such as mechanical and electrical as well as into crews for responsibility.)

Department and Crew Codes

First digit—Department. Second digit—Crew.

DEPARTMENT 1. Mechanical (Cost Center 1004)

CREW 0: Overall craft superintendent

CREW 1

CREW 2

CREW 3

CREW 4

CREW 5

DEPARTMENT 2. Instrumentation & Controls (CC 1006)

CREW 0: Overall craft superintendent

CREW 1

CREW 2

DEPARTMENT 3. Electrical (CC 1005)

CREW 0: Overall craft superintendent

CREW 1

CREW 2

DEPARTMENT 4. Operations (CC 1002)

CREW 1: A shift

CREW 2: B shift

CREW 3: C shift

CREW 4: D shift

CREW 5: Relief crew

CREW 6: X crew

DEPARTMENT 5. Plant Administration (CC 1001)

CREW 1: Plant Manager

CREW 2: Plant Assistant Manager

CREW 3: Plant Engineers

CREW 4: Administrative Support

CREW 5: Training Department

DEPARTMENT 6. Chemistry and Water Support Division (CC 1012)

CREW 1: Administration

CREW 2: Results Laboratory

CREW 3: Central Laboratory

DEPARTMENT 7. Performance Engineering Division (CC 1032)

CREW 1: Administration

CREW 2: Predictive Maintenance

CREW 3: Diagnostic Engineering

CREW 4: Production Analysis

CREW 5: Equip Database, Tagging, and Schematics

DEPARTMENT 8. Support Outside

CREW 1: Outage Management & Contractors (CC 1021)

CREW 2: Project Group & Contractors (use craft CC)

(*Note:* Thus, a work order coded as written by Crew 4-1 and assigned to Crew 1-3 would be a work order originated by the A shift crew in operations and it was for mechanical type work falling into the Crew 3 area of responsibility in the mechanical maintenance department.)

Work Type

(*Note:* The work type coding allows backlogs and work already performed to be sorted to determine how the plant is performing. Is most of the work trouble and breakdown type work or is most of it preventive maintenance? Is there any corrective maintenance to correct situations from turning into trouble and breakdown type problems? The company trying to have a maintenance program and not just a repair service considers this type of information.)

Work Type Codes

1. *Spare equipment (noninstalled).* Maintenance activity performed on noninstalled (spare) plant equipment. Rebuilding rotating spares is included.

2. *Structural.* Maintenance activity performed to maintain general plant structural integrity. This includes associated support work such as surface preparation, painting, structural weld repair, and insulation renewal. Insulation and lagging removal and replacement necessary to perform an inspection or repair of a covered or protected component would not be considered as structural.

3. *Project.* Maintenance activity performed on equipment or plant involving a modification, upgrading, or improvement and performed on a one-time basis, whether or not a unit outage is involved.

4. *Buildings and grounds.* Maintenance activity to maintain general plant appearance such as trash hauling, janitorial work, gardening, material handling, safety inspections, and general housekeeping efforts. *Exceptions:* Additional effort required due to extensive plant structural repairs is structural work.

5. *Trouble and breakdown.* Maintenance activity required to return a unit or plant equipment to normal operating conditions due to an equipment breakdown or failure to operate properly. Failed or improperly operating equipment discovered or worked during a

planned outage is this work type only if the particular item is preventing the return to service of the unit at the time of discovery.

6. Overhaul. Maintenance activity performed for general overhaul inspection or rebuild of one or more major equipment groups during a scheduled outage shown on the 1-Year Outage Plan. An overhaul is intended to keep equipment in proper operating condition or restore capability that has gradually diminished over time. All work performed in preparation of, during, in cleanup from, or otherwise due to the overhaul is considered to be this work type. The work is not project work because an improvement over the original design capability is not intended. An overhaul is beyond the scope of normal preventive maintenance. The overhaul occurs before specific trouble or breakdown has happened and before predictive maintenance is recommended.

7. Preventive maintenance. Maintenance activity performed which is repeated at a predetermined frequency and is scheduled from a preventive maintenance listing or program. The frequency established need not be related to calendar time but can be required based on predetermined service time or events such as the number of service hours or starts. Work which is performed during an overhaul outage, but would be performed anyway if the outage was postponed, is included in this work type.

8. Predictive maintenance. Maintenance activity performed based on a prediction that future equipment breakdown or failure to operate properly will occur. The prediction is based on trend analysis of diagnostic data collected by techniques such as vibration or lube oil analysis. The need for maintenance would not normally have been apparent without analysis of the diagnostic data.

9. Corrective maintenance. Proactive maintenance activity performed based on a prediction that future equipment breakdown or failure to operate properly will occur. The intent of corrective maintenance is to maintain equipment optimum performance. The need for maintenance is normally established by inspection. The prediction is *not* based on a predictive maintenance type technology or trend analysis, nor is it based on a preventive maintenance type predetermined frequency.

Plan Type

(*Note:* The proactive and reactive part of the plan type code is similar to work type but is a broader category. In general, all the work types except number 5, trouble and breakdown, are proactive. The maintenance department wants to be working on proactive work to avoid later trouble that would inconvenience the plant operation and require excessive maintenance effort. By definition, proactive work is not urgent, so the planning department wants to spend more time planning these jobs to be most effective and efficient when executed. The planning department also wants to recognize the reactive work orders so they can be quickly passed on to the maintenance department for timely resolution. Minimum versus extensive maintenance coding also helps the planning department recognize how much effort to expend on planning the work. Small jobs are frequently not worth much time spent on planning, though some time is still necessary.)

Plan type codes. First digit—Reactive or Proactive

R Reactive

Equipment has actually broken down or failed to operate properly.
Priority-1 jobs are defined as urgent and so they are reactive.

P Proactive. Proactive work heads off more serious work later. If the damage is already done, the work is reactive.

Work done to prevent equipment from failing.

Any PM job.

Generally Predictive Maintenance initiated work that if done in time will prevent equipment problems.

Project work.

Second Digit—Minimum Maintenance or Extensive Maintenance

M Minimum maintenance. Minimum maintenance work must meet *all* of the following conditions:

Work has no historical value.

Work estimate is not more than 4 total work hours (e.g., two persons for 2 hours each or one person for 4 hours).

While parts may be required, no ordering or even reserving of parts is necessary.

E Extensive maintenance. All other work is considered "extensive."

(*Note:* "RE" would be an example plan type code for a reactive job that is also extensive.)

Outage

(*Note:* These codes are not the same as work order status codes. If the maintenance group can only perform a certain work order during a unit outage, it is critical that this limitation be recognized as soon as possible. This is regardless of whether the work order has yet been approved or planned. The planning group must be able to recognize these work orders in order to plan them more expeditiously than other work. There may or may not be a sudden window of opportunity to execute the work. If there is an unexpected outage for some other reason, it is wise to have planned these work orders in time. *Outage* refers to the condition of the entire plant unit, not the individual piece of equipment.)

Outage Codes

1. Forced short outage. A component failure or other condition which requires the unit to be removed from service immediately or at any time prior to the end of the upcoming weekend.

2. Scheduled short outage. A component failure or other condition which requires the unit to be removed from service, but not necessarily before the end of the upcoming weekend. The work does not have to be done during a major outage.

3. Major outage. Work which can only be done during a major outage such as a major rebuild or overhaul inspection or work on one or more major equipment groups. The outage is normally shown as a planned outage on the 1-Year Outage Plan. Testing after a major outage at limited loads is included.

4. Not Used.

5. Forced derating. A component failure or other condition which requires the maximum capability of the unit to be reduced immediately or at any time prior to the end of the upcoming weekend.

6. Scheduled derating. A component failure or other condition which requires the maximum capability of the unit to be reduced, but not necessarily before the end of the upcoming weekend. The work does not have to be done during a major outage.

7. *Potential outage, redundant installed equipment.* A trouble condition which requires a piece of redundant equipment to be taken out of service without affecting the unit capability; but if the backup equipment failed an outage or derating would result.

8. Not used.

9. *Potential outage, noninstalled spare equipment.* Work performed on noninstalled spare equipment (such as rebuilding rotating spares) where if the unit suddenly needed the spare, the spare would not be available and a more serious than normal unit outage or derating would occur.

U. *Starting up.* Work which requires the unit to be in a start-up mode where the unit is being brought on-line. Equipment tests or adjustments that can only be done during a start-up condition are included.

D. *Shutting down.* Work that can or should only be done when the unit is on line, but Dispatch no longer needs the unit and the unit is about to be shut down. Typically, equipment tests or adjustments that may trip the unit are included.

(*Note:* Thus, a work order coded as a 2 could only be done when the unit is down on outage for some reason. If a SNOW (short notice outage work) outage occurs and the outage will take 48 hours, this SNOW work order might be a candidate for including in the outage work scope. This work order could only be included if it is already planned and ready for scheduling. One might not know if the work order could be done if the job was not furnished with an expected duration via planning, say 24 or 78 hours of duration.)

Plant and Unit

(*Note:* The plant and unit coding begins the equipment coding system. The company has an "intelligent" numbering system. The equipment number identifies the plant, unit, and system of the equipment being discussed.)

Plant and Unit Codes. First digit—Plant. Second and third digits—Unit.

PLANT N—North Generating Station

UNIT 00—Steam Plant Common

UNIT 01—Steam Unit One

UNIT 02—Steam Unit Two

UNIT 03—Steam Unit Three

UNIT 04—Steam Unit Four

UNIT 30—Gas Turbine Plant Common

UNIT 31—GT Unit 1

UNIT 32—GT Unit 2

UNIT 33—GT Unit 3

UNIT 34—GT Unit 4

PLANT S—South Generating Station

UNIT 00—Steam Plant Common

UNIT 01—Steam Unit One

UNIT 02—Steam Unit Two

UNIT 03—Steam Unit Three

UNIT 04—Steam Unit Five

(*Note:* Thus, a code of N02 would indicate North Station Unit 2.)

Equipment Group and System

(*Note:* Each equipment group is shown with its composing systems. For example, Group A, Air, is followed by the systems within the Air Group, System I, Instrument Air, and System S, Service Air. Following this listing is a comprehensive definition of each system.)

Group and System Codes. First digit—Group. Second digit—System.

- A Air
 - I Instrument
 - S Service
- B Boiler
 - A Air Flow for Combustion
 - B Boiler Tubes and Steam Generating Section
 - C Controls
 - E Air Preheater Heat Exchanger
 - F Burner Front
 - G Gas Flow from Combustion
 - I Aspirating Air
 - J Casing and Structure
 - P Convection Pass
 - S Sootblowers
 - T Seal Air
 - V Vents and Drains
 - W Wash Drains
- C Condensate
 - D Feedwater Heater Drains
 - F Flow
 - P Polishers
 - R Recovery
 - S Supply
 - V Vacuum Supply
- D Feedwater
 - A Auxiliary Feedwater
 - D BFP Fluid Drive
 - F Flow
 - O BFP Lube Oil
 - P Boiler Feedwater Pump
 - T BFP Steam Turbine
- E Electrical
 - C Communication
 - D 120-250 Vdc
 - I Control Room Instrumentation

- L Plant Lighting and Distribution.
- M Miscellaneous
- S Switchgear, Load Center, and MCC
- Y Switchyard
- F Fuel
 - B Fuel Oil Burner Supply and Return
 - C Fuel Oil Service Pump
 - D Diesel Storage and Transfer
 - H Fuel Oil Heaters
 - I Ignitor Fuel Supply
 - N Natural Gas
 - O Fuel Oil Storage and Transfer
 - P Propane Gas
 - V Vehicle Fuel Storage
 - W Wharf Facility for Ship Unloading
- G Generator
 - D Diesel Generator
 - E Exciter
 - H Hydrogen
 - I Isolated Phase
 - O Seal Oil
 - P Protection Circuit
 - R Rotating Field
 - S Stator
 - V Voltage Regulator
 - W Stator Oil and Cooling Water
- H Water
 - A Treatment Plant Acid
 - C Treatment Plant Caustic
 - D Demineralizer
 - P Potable Water Supply
 - R Raw Water Supply
- I Intake
 - C Canal
 - F Fish Protection Traveling Screens
 - R Intake Chemical Treatment
- J Cooling Water
 - C Condenser Cleaning
 - I Circulating Water
 - L Closed Cooling

- R River Water
- T Cooling Tower
- X Condenser
- K Fire Protection
 - D Dry Chemical
 - P Portable
 - U Gas Turbine
 - W Water and Foam
- N Environmental
 - A Air Quality
 - W Water Quality
- R Reagent and Chemical
 - A Acid Cleaning for Boiler
 - C CO₂ and H₂ Supply
 - D Condenser Discharge Chemical Injection
 - M Miscellaneous
 - N Nitrogen Supply
 - O Fuel Oil Treatment
 - P Condensate pH Chemical Injection
 - W Boiler Wash
- S Steam
 - A Auxiliary Piping
 - E Extraction Piping
 - M Main Steam Piping
 - P Primary Superheating Section
 - Q Secondary Superheating Section
 - R Reheat Piping
 - S Reheat Superheating Section
 - X Auxiliary Boiler
- T Steam Turbine
 - A HP and IP Section
 - B IP Section
 - C LP Section
 - F Front Standard
 - H HP and IP Turbine Control
 - I Monitor Supervisory Instrumentation
 - J Turbine Controls
 - L Steam Seals
 - O Lubricating Oil
 - P Pedestal

- S Structure
- V Vents and Drains
- X Crossover Pipe
- U Gas Turbine
 - A Accessory Station
 - B Bearing and Coupling
 - C Compressor Section
 - D DEH Control
 - E Exhaust
 - G Generator
 - H Housing
 - I Combustor Section
 - J Cooling Water
 - O Lubricating Oil
 - P Protection and Control
 - R Starting
 - S Supports
 - T Turbine Section
 - U Turning Gear
 - W Water Wash
 - Z Atomizing Air
- V Ventilation
 - A Air Conditioning
 - D Equipment Dry Layup
 - M Miscellaneous Vents and Exhausts
 - S Steam Heating
- W Waste
 - F Waste Fuel Collection
 - H Water and Boiler Wash Collection
 - I Water Instrumentation
 - L Liquid Waste
 - S Solid Waste Disposal
 - W Sewage Treatment
- Y Blanket Accounts
 - A Operations
 - B Maintenance
 - C Administration
 - D Engineering
 - E Structural

- F Production Equipment
- G Facilities
- H Computer
- Z Miscellaneous
 - B Buildings and Grounds
 - C Turbine Deck Bridge Crane
 - E Electric Tools and Equipment
 - F Freeze Protection
 - H Hydraulic Tools and Equipment
 - L Laboratory
 - M Machine Shop Equipment
 - O Other Tools and Equipment
 - P Pneumatic Tools and Equipment
 - S Security
 - V Plant Vehicles

Group and System Definitions. Except as noted in the individual system definitions, several general definitions apply. Each system includes its related gauge work, instrumentation and controls, power and control wiring, and breakers. *Piping* means the complete piping system, including the pipe itself, insulation, lagging, hangers and supports, steam tracing lines, valves, safety relief valves, orifices, strainers, drains, and traps associated with that pipe. All electrical, instrumentation, and mechanical devices which exclusively serve a major component are accounted for in the same system as that component.

A AIR

AI Air Instrument

Provides compressed air to pneumatic controls and instrumentation. Includes compressors, dryers, coolers, separators, air tanks, and piping. Instrument Air can also be described as piping coming from the service air compressors when the compressors serve both systems.

AS Air Service

Provides compressed air for general plant service (house air) such as air motors and air hose connections. Includes compressors, dryers, coolers, separators, air tanks, and piping.

B BOILER

BA Boiler-Air Flow for Combustion

All combustion air ducting from the air intake ports to the windbox. Includes all related hangers and supports, dampers, damper controls, expansion joints, orifices and the windbox. Includes FD fans, fan casings, inlet vanes, motors and foundation. Includes the overfire air system. Does not include preheaters (BE) or seal air system (BT).

BB Boiler-Boiler Tubes and Steam Generating Section

Steam drum and its internals, mud drum, furnace tubes (all passes), downcomers, risers, tube headers, boiler circulation pump, and drum safety valves. The blowdown lines, drain lines, and flash tank are part of system BV. The convective pass tubes are found in system BP. The economizer is part of the feedwater flow in system DF.

BC Boiler—Controls

Controls for the fuel and air supply to the burners. Includes boiler master controls and associated signal transmitters and analyzers. Includes electronic control systems, transmitters, and terminals.

BE Boiler—Air Preheater Heat Exchanger

Regenerative or tube type air preheater. Bearings, baskets, casing, seals, lube oil system, drive motors (air and electric), and gears. Includes wash lances. Also includes the steam coil air preheater. Includes coils, inlet and outlet valves, piping from the steam source, condensate hotwell, and any condensate drain piping to condensate recovery. Does not include sootblowers which are in BS.

BF Boiler—Burner Front

Oil and gas burners, ignitors, air register, and flame controls. Steam used to purge and clean the burners and fuel oil headers at the burner decks. Includes piping downstream of the auxiliary steam header.

BG Boiler—Gas Flow for Combustion

All combustion gas ducting from the economizer plenum to and including the exhaust stack and the gas recirculation ducting. Related hangers and supports, dampers, damper controls, expansion joints, and the exhaust stack. Includes ID and GR fans, fan casings, ID fluid drives, motors, fluid drive oil coolers, the lube oil piping system, and foundation. Includes any turning gear drive systems associated with the fans. Stack gas monitoring equipment are in NA. Does not include the air preheaters (BE) or the seal air system (BT).

BI Boiler—Aspirating Air

Blowers and piping that provide aspirating air to the burner front flame scanners. The same system may also provide combustion air to the propane ignitors. Does not include seal air (BT).

BJ Boiler—Casing and Structure

Outer casing, insulation, inner casing, structural steel, access doors, gas seals, expansion joints, deck plates and grating, hand rails, stairs and ladders, access doors, and furnace buckstays. Includes any penthouse and header enclosure structures. Includes ash hoppers. Includes any penthouse blowers. Includes any boiler seal skirt which wraps around the bottom hopper of the boiler furnace. Does not include steam piping or headers (Group S).

BP Boiler—Convection Pass. Includes convective pass wall tubes and inlet and outlet headers.

BS Boiler—Sootblowers

Sootblowers, drive motors, steam supply, and air supply piping. Includes control panel interlocks and wiring. Does not include the boiler caustic wash piping (BW).

BT Boiler—Seal Air

Piping that provides seal air from the combustion air system to the induced draft and gas recirculation fan seals. Piping that provides cooling air to the gas recirculation fan. For positive pressure boilers such as South Unit 3, this system also provides seal air to sootblower and view port openings.

BV Boiler—Vents and Drains

Waterside drain lines and all vent lines necessary for boiler filling and draining. All boiler blowdown and drain piping and valving. Blowdown (flash) tank, blowdown tank drain pump. Does not include the headers being serviced by the vents and drains. Does not include the nitrogen supply which is in system RN.

BW Boiler—Wash Drains

Wash drain piping and collection troughs which serve the furnace, air preheater, and economizer sections of the boiler and includes piping prior to the sumps and trenches in system WH.

C CONDENSATE**CD Condensate—Feedwater Heater Drains**

Drain piping from all feedwater heaters. Includes heater drain pumps, high- and low-pressure flash tanks, and piping up to the condensate flow system (CF). Includes turbine water induction protection system. Also includes manual vent and drain piping.

CF Condensate—Flow

Condensate piping beginning at the condensate pump outlet through to the deaerator, condensate booster pumps, low- and intermediate-pressure feedwater heaters (high-pressure feedwater heaters are in system DF), the deaerator, and the deaerator storage tank. Does not include the condensate (hotwell) pump which is part of the condenser system (JX).

CP Condensate—Polishers

Serving vessels, regenerator tanks, resin, backwash pump, sluice pump, and piping.

CR Condensate—Recovery

Collects high temperature condensate from various parts of the system. May collect boiler water for transfer to storage tank. Includes condensate recovery flash tank, cooling condenser, condensate recovery transfer pump, hotwell drain pump, and piping.

CS Condensate—Supply

Includes condensate storage tanks whether the water is polished and treated water tanks or only demineralized. Includes pumps and piping to and from the demineralizer system. Also includes the boiler fill pump.

CV Condensate—Vacuum Supply

Vacuum pumps, exhaust silencers, hogging jet, primary and secondary steam air ejectors, moisture collection tanks, oil drain tanks, vacuum breaker, and piping.

D FEEDWATER**DA Feedwater—Auxiliary Feedwater**

Auxiliary feedwater pump, feedwater heaters, and piping which supply the reboilers (SA). Does not include the auxiliary boiler feedwater system which is included with the auxiliary boiler (SX).

DD Feedwater—BFP Fluid Drive

Fluid drive unit to the boiler feedwater pump and fluid cooling system. Includes oil supply and return piping to BFP bearings.

DF Feedwater—Flow

Feedwater booster pumps, high-pressure feedwater heaters, economizer. Piping, including piping after the economizer up to the steam drum and piping after the deaerator storage tank. Does not include the feedwater pumps which are in system DP. For North Unit 1, this includes the piping from the economizer outlet header up to but not including the furnace first pass inlet headers, which is in system BB.

DO Feedwater-Lube Oil for BFP and BFP Steam Turbine
Lube oil storage tank, lube oil pumps, oil coolers, and piping.

DP Feedwater-Boiler Feedwater Pump

Boiler feedwater pump, motor, feedwater piping up to and including suction and discharge valves. Includes seal water piping. Does not include the fluid drive (DD) and lube oil piping (DO). Does not include a drive turbine (DT), if present.

DT Feedwater-BFP Steam Turbine

Turbine, inlet and outlet steam piping, including the steam governing valves, condensate drains. Lube oil is covered under system DO. Steam seals are included in system TL.

E ELECTRICAL

EC Electrical-Communication

All in-house and outside telephone systems. Public address system.

ED Electrical-120-250 Vdc

DC inverters and motor-generator sets used for charging the relay batteries and any other dc applications. Includes the batteries.

EI Electrical-Control Room Instrumentation

Controls and instrumentation for specific devices are part of the system in which the device resides. For example, the boiler feed pump controls belong in the boiler feed pump system. Otherwise, this system contains all other panel controls, recorders, gauges, displays, etc., located in the boiler or turbine-generator control rooms. Nonelectric controls are usually specific enough to place them in their respective systems.

EL Electrical-Plant Lighting and Distribution

All general illumination fixtures, including their wiring and switches. Includes aviation lighting and portable lighting.

EM Electrical-Miscellaneous

Reserved for any equipment that would not be in any of the other designated systems. Examples are cable trays, portable power centers, and grounding grid. Also includes electrical freeze protection circuitry if not specific to a system.

ES Electrical-Switchgear, Load Center and Motor Control Center

Includes main buses and housing. Tie breakers, feeder breakers, and related transformers. Does not include individual breakers which belong to the motors of another system.

EY Electrical-Switchyard

Switchyard breakers, power lines, and gantry work. Main transformer, startup transformer, auxiliary transformer, etc.

F FUEL

FB Fuel-Fuel Oil Burner Supply and Return

Oil supply piping downstream of fuel oil heaters, high-pressure strainers, constant differential pumps, piping serving individual burners, burners in and out controls, and oil piping upstream of the return line to the valve farm. Includes oil purge system. Does not include oil burners which are in system BF.

FC Fuel-Fuel Oil Service Pump

Fuel oil service pumps, strainers, piping up to but not including the fuel oil heaters.

FD Fuel-Diesel Storage and Transfer

No. 2 oil storage tanks, retaining dikes, transfer pumps, and piping to and from the gas turbines. Does not include the unloading dock (FW).

FH Fuel-Fuel Oil Heaters

Fuel oil heaters and related piping. Steam supply piping from auxiliary steam (SA). Not included are the condensate drains, which are part of the heater drain system (HK).

FI Fuel-Ignitor Supply

Equipment and piping leading from the natural gas (FN) and propane (FP) systems which uniquely supply the ignitors of the main burners of the boiler. Includes the natural gas trip valves, burner ignition valves, and vent piping.

FN Fuel-Natural Gas

Metering station, scrubbers, vaporizers, and piping (including vents and drains) to the burners. Does not include gas burners which are in system BF. Does not include ignitor supply as defined in system FI.

FO Fuel-Fuel Oil Storage and Transfer

Fuel oil tanks, steam coil heaters and transfer pumps including their reduction gearing and piping, including the valve farm, retaining dikes, and oil sumps. This would also include any fixed oil and water separating equipment. Also includes the supply piping between the valve farm and unit fuel oil strainers (FC) and the return piping (FB). Includes steam supply and condensate return for steam tracing.

FP Fuel-Propane Gas

Propane storage tank, vaporizer, common piping up to but not including the gas ignitor fuel supply FI. Does not include propane to the auxiliary boiler, which is part of system SX.

FV Vehicle Fuel Storage

Separate diesel or gasoline storage tank for vehicle supply. Propane for the forklifts is tapped off the main storage tank in system FP.

FW Fuel-Wharf Facility for Ship Unloading

Marine arms, unloading pumps, stripping pumps, piping, and dock structure, including the tanker-man house. The oil piping is included up to the fuel storage tanks.

G GENERATOR

GD Diesel-Engine and Generator

Includes any reserve generator driven by a piston engine (diesel or gasoline). The rest of the systems in G group are for turbine-driven generators.

GE Generator-Exciter

Generator exciter. Includes the casing, rotating and static elements, and field breaker. Includes any exciter cooler and closed cooling piping exclusive to the exciter.

GH Generator-Hydrogen

Hydrogen coolers, hydrogen control panel, hydrogen and carbon dioxide manifolds, liquid detector, purity meter, gas dryer, and hydrogen and carbon dioxide piping. Does not include the hydrogen or carbon dioxide bulk storage which are in system RC.

GI Generator-Isolated Phase

Bus assembly from the generator lead box to the main transformer, ducting, heater and cooler, and generator disconnect switch. Main generator breaker in the switchyard is in system EY.

GO Generator-Seal Oil

Main seal oil pump, emergency seal oil pump, recirculation pump, vacuum pump, vacuum tank, detrainning tank, shaft seals, seal drain header, and piping. For a unit that shares a common system for generator seal oil and turbine lube oil, use system TO.

GP Generator-Protection Circuit

Various relays, transmitters, recorders, panel gauges, switches, and interlocks used to protect the generator from damage.

GR Generator-Rotating Field

Generator rotor and coils, collector ring and brushes, rotor couplings, any rotating blades, and field rheostat.

GS Generator-Stator

Main stator assembly, generator casing, support assemblies, end bells, generator bearing assemblies, fan shrouds, hydrogen diffuser baffle, bus bar enclosure, and main lead connection box and bushings.

GV Generator-Voltage Regulator

Voltage regulator assembly, excitation transformer, control panel.

GW Generator-Stator Oil and Cooling Water

Stator cooling oil tank, stator cooling pumps, coolers, vacuum pumps, and piping. Includes any stator cooling water deionizer, heat exchanger, pumps and piping.

H WATER**HA General Water-Treatment Plant Acid**

Acid tank, feed pump, and related piping.

HC General Water-Treatment Plant Caustic

Caustic transfer pump, caustic mixing tank, and related piping.

HD General Water-Demineralizer

Cation, anion, and mixed bed tanks, resins, carbon purifier, degasifier or aerator, silica analyzer, transfer pump, and related piping.

HP General Water-Potable Water Supply

Plant water piping downstream of the chlorination source. This could be a city water tie-in or an on-site chlorinator. Includes the chlorinator. Includes general use fixtures such as domestic water heaters, sinks, commodes, etc. Includes any storage tanks and service pumps. Does not include piping exclusively dedicated to fire protection or fire hydrants (system KW).

HR General Water-Raw Water Supply

Well pumps, raw water booster pumps, aerator tank, and related piping which is used strictly for raw water. Does not include plant chlorination equipment, which is the beginning of system HP.

I INTAKE**IC Intake-Canal**

Intake canal, log screens, bubble buster, trash rakes, cathodic protection, tide gate, and intake well. Includes stationary cranes. Mobile cranes would be in ZV. Does not include the circulating pumps, which are in system JI.

IF Intake-Fish Protection Traveling Screens

Used for filtering of debris, fish, etc., from the intake canal water before it enters the circulating pumps. Includes the traveling screen assemblies, fish return troughs, and screen wash pumps. South Stations has a screen wash pump with each screen assembly. North has a screen wash pump that supplies all screen assemblies.

IR Intake-Intake Chemical Treatment

Sodium hypochlorite or chlorine tank and piping, including the injector pump and piping to each intake well.

J COOLING WATER**JC Cooling Water-Condenser Cleaning**

Condenser cleaning system.

JI Cooling Water-Circulating Water

Circulating water pumps and intake piping leading to the condenser water boxes and condenser discharge piping.

JL Cooling Water-Closed Cooling

Closed cooling provides a heat sink for various bearings, lube oil systems, and other processes throughout the plant. The system is isolated from other water systems in the plant, hence its name. The closed cooling heat exchanger discharges this heat into the river water system. Includes closed cooling heat exchangers (river water heat exchangers), closed cooling pumps and booster pumps. Includes supply and return piping. Does not include the supplied heat exchangers, each of which belongs to its respective system.

JR Cooling Water-River Water

River water is taken from the condenser inlet headers and sent to the closed cooling heat exchanger to provide a cool source for the accumulated heat of the closed cooling water system. The warmed river water is then sent to the condenser outlet header to be sent to the discharge flume or cooling towers via the circulating water piping. River water booster pumps, strainers, and piping used for providing river water between the condenser (JX) and closed cooling heat exchangers (JL).

JT Cooling Water-Cooling Tower

Cooling tower structures and components receive water from and return water to the circulating system (JI). Does not include air conditioning cooling towers.

JX Cooling Water-Condenser

Condenser shell, tubing, water boxes, condensate drain nozzles into condenser, and condensate pumps. Includes exhaust shroud between LP turbine and condenser. Includes the water box vacuum pumps used to assist the filling of the circulating water system. Does not include the vacuum pumps in system CV.

K FIRE PROTECTION**KD Fire Protection-Dry Chemical**

Fixed dry chemical systems exclusively dedicated to fire protection. Includes associated alarms and controls.

KP Fire Protection-Portable

All types of portable extinguishers. Water, CO₂, Halon, potassium nitrate (Purple K), etc.

KU Fire Protection-Gas Turbine

Fixed systems self-contained in the gas turbine unit. Includes carbon dioxide and Halon systems.

KW Fire Protection—Water and Foam

Fixed dry and wet water piping systems exclusively dedicated to fire protection. Includes fire hydrants feeding from potable water supply. Includes protected areas such as burner fronts, transformers, lube oil reservoirs, and offices. Includes associated alarms and controls. Includes any exclusively dedicated fire pumps. Potable water itself is listed as system HP.

N ENVIRONMENTAL**NA Environmental—Air Quality**

Atmospheric discharge monitoring equipment. Weather monitoring equipment. Opacity monitor, NO_x monitor, SO₂ monitor, CO monitor, ambient temperature and humidity probe, transmitters, analyzers, and other computer equipment.

NW Environmental—Water Quality

Groundwater monitoring wells and instrumentation. Cooling water and liquid waste discharge monitoring are included in JI and WI, respectively.

R REAGENT AND CHEMICAL**RA Chemical—Acid Cleaning for Boiler**

Piping (temporary or permanent) and piping connections for acid cleaning of the boiler waterside surfaces. See system RW for caustic washing of the fireside surfaces. For the boiler wash drains, see system BW.

RC Chemical—CO₂ and H₂ Supply

This system provides bulk gas storage for the generator. Hydrogen is used in the generator as a heat removal medium. Carbon dioxide is used to purge the generator of hydrogen for fire prevention purposes. This is not considered a fixed system to be included in KD. Includes tanks, manifolds, regulators, and piping. Does not include the hydrogen panel in system GH. Does not include CO₂ supply for gas turbines or chemical waste treatment systems.

RD Condenser Discharge Chemical Injection

Chemicals such as sodium bisulfate which are used to dechlorinate the condenser discharge water.

RM Chemical—Miscellaneous

Chemical storage not specified in other systems.

RN Chemical—Nitrogen Supply

Nitrogen is used primarily for blanketing the waterside of the boiler and sometimes feedwater heaters during reserve shutdown. It is usually tied into the equipment vents. Includes tanks, manifolds, regulators, and piping.

RO Chemical—Fuel Oil Treatment

Chemicals which are added to fuel oil in order to induce an effect. Includes magnesium oxide day tanks, feed pumps, and piping into fuel oil supply.

RP Chemical—Condensate pH Chemical Injection

Chemicals which are used to neutralize the pH condition of condensate and feedwater. Includes tanks, pumps, and piping for ammonia and hydrazine injection into the condensate flow system. Also includes phosphate injection system into the steam drum. Does not include sodium hypochlorite or chlorine which are in system IR.

RW Chemical—Boiler Wash

Caustic solution used to clean the firesides of the boiler and other equipment subjected to flue gases. Includes soda ash storage tank, mixing and service tanks,

related pumps, piping up to the sootblower piping (BS), and boiler wash hose connections. Includes any piping that is subjected to the boiler wash caustic solution, even if it can also be used to supply raw water. See system RA for waterside acid cleaning. The air preheater wash lances are included in system BE.

S STEAM**SA Steam—Auxiliary Piping**

All auxiliary steam piping not specified in other systems. Includes desuperheater supply.

SE Steam—Extraction Piping

Steam extracted from various stages of the superheated steam flow used primarily as a heat source for feedwater heating. Extraction steam piping begins at the first field weld at the extraction nozzle (either in the turbine or steam piping) up to the final field weld at the feedwater heaters. Includes extraction drain lines up to the condenser. Does not include feedwater heaters (CF and DF) or condenser (JE).

SM Steam—Main Steam Piping

Main steam piping from the first field weld of the secondary superheater outlet header to the final field weld before the main steam stop valve at the high pressure turbine. Includes drain piping.

SP Steam—Primary Superheating Section

Primary superheater, including inlet and outlet headers, and piping to the secondary superheater section (SQ). Includes any flow control valves, hangers and tube supports. Includes attemperator and attemperator supply piping.

SQ Steam—Secondary Superheating Section

Secondary superheater, including inlet and outlet headers. Includes flow control valves, hangers, and tube supports.

SR Steam—Reheat Piping

Hot and cold reheat piping between turbine and reheat superheater. Includes attemperator and attemperator supply piping.

SH Steam—Reheat Superheating Section

Reheat superheater, including inlet and outlet headers, hangers, and tube supports.

SX Steam—Auxiliary Boiler

Auxiliary boiler(s), fuel supply, water supply, air supply, exhaust ducting, and common steam headers.

T STEAM TURBINE**TA Steam Turbine—HP and IP Section**

Outer and inner casings, all internal components including HP and IP rotor, blade rings (diaphragms), stationary impulse diaphragm, balance piston, reheat seal, and nozzle block and chest. Does not include steam seals (TL). For units with separate HP and IP sections, use system TA for HP section and system TB for IP section.

TB Steam Turbine—Intermediate Pressure (IP) Section

Outer and inner casings, all internal components including IP rotor, blade rings (diaphragms), stationary impulse diaphragm, balance piston, reheat seal, and nozzle block and chest. Does not include steam seals (TL). For units with combined HP and IP sections, use system TA.

TC Steam Turbine—LP Section

Inner and outer casings and all internal components including LP rotor and blade rings (diaphragms). Includes multiple LP sections on same unit. Includes any low-pressure exhaust hood sprays and supply piping. Does not include steam seals (TL). Does not include the crossover pipe(s) which is listed in system TX.

TF Steam Turbine—Front Standard

Casing, pedestal, thrust bearing and adjuster, main speed governor and overspeed governor, and instrumentation board assembly. The shaft driven lube oil pump is part of system TO.

TH Steam Turbine—HP and IP Turbine Control

The steam side of the turbine controls. Main steam stop valves and actuators, governor valves, main steam bypass valves, warm-up valves, steam chest, piping to nozzle block, and intercept and reheat valves. Includes any drain lines from these devices.

TI Steam Turbine—Supervisory Instrumentation

Vibration monitors and controls, bearing temperature monitors and controls, cylinder expansion monitors, rotor position monitor, eccentricity monitor, speed monitor, various control valve position indicators, steam pressure and temperature indicators and transmitters, and no-load trip devices.

TJ Steam Turbine—Turbine Controls

Includes electric-hydraulic, digital-electric-hydraulic, and mechanical-hydraulic controls. Any related hydraulic pumps, piping, coolers, etc.

TL Steam Turbine—Steam Seals

Steam packing exhauster, shaft seals and casings, supply and drain piping up to the turbine casing, associated desuperheaters, regulator, and controls. Includes steam seals to any BFP turbines.

TO Steam Turbine—Lubricating Oil

Main and auxiliary pumps, lube oil reservoir, filter tank (bowser), storage tanks, coolers, and piping. For a unit that shares a common system for generator seal oil and turbine lube oil, the system is in TO.

TP Steam Turbine—Pedestal

Concrete pedestal, sole plates or pedestal cover, bearings, oil wipers and baffles, and the couplings. For all HP, IP, and LP sections. Includes the turning gear assembly which includes the bull, pinion, and reduction gears, turning gear motor, clutch, lube oil supply, and return piping.

TS Steam Turbine—Structure

Decking, stairs, handrails, enclosures, foundation, and pedestals not otherwise listed. The turbine building itself would be accounted for in buildings and grounds (ZB).

TV Steam Turbine—Vents and Drains Drain piping and valves from the various stages of primary steam turbines to their drain destinations.

TX Steam Turbine—Crossover Pipe

Includes crossover piping leading into the LP turbine. Includes bolting and thrust protection.

U GAS TURBINE**UA Gas Turbine—Accessory Station**

Motor control center, fuel oil pump. Does not include starting motor, which is in system UR.

UB Gas Turbine—Bearing and Coupling

Thrust bearing loader and unloader, labyrinth seals, bearings and casings, oil wiper seal ring, and coupling.

UC Gas Turbine—Compressor Section

Provides compressed air for fuel atomization and combustion as well as combustion gas cooling. Includes compressor rotor, blade rings, and casings.

UD Gas Turbine—Digital-Electric-Hydraulic Control

Hydraulic pumps, tubing, and DEH controls.

UE Gas Turbine—Exhaust

Exhaust hood, air cone, bearing heat shield, and expansion joint.

UG Gas Turbine—Generator

Generator section of gas turbine.

UH Gas Turbine—Housing

Air inlet and exhaust housing, control, accessory, excitation, and gas turbine compartment housings.

UI Gas Turbine—Combustor Section

Combines no. 2 oil with combustion air and ignites the mixture. Includes combustion chamber assemblies, transition ducting, cross-fire tube, fuel manifold and fuel nozzles, chamber casing, and diffuser case.

UO Gas Turbine—Lubricating Oil

Provides lubricating oil to all bearings, gears, and control system. Includes oil reservoir, lube oil pumps, pressure regulators, oil coolers, oil filters, and piping.

UP Gas Turbine—Protection and Control

Temperature control circuit, fuel control and monitoring, governor and speed control, sequencer, vibration monitors and trips, overspeed trips, combustible gas detector, flame detector, relays, relay batteries, etc. Includes "false start" drain sumps, used for protection to allow fuel drainage in case of an aborted start. Does not include the DEH controls which are in system JD.

UR Gas Turbine—Starting

Starting motor, accessory gearbox, and torque converter.

US Gas Turbine—Supports

Alignment devices and pedestal foundation.

UT Gas Turbine—Turbine Section

Combustion gases expand through the turbine to provide shaft power to turn the generator and compressor sections. Includes the turbine rotor, nozzle guide vanes (blade rings), and casings.

UU Gas Turbine—Turning Gear

Prevents warping of the turbine rotor by turning it at slow speed while the unit is cooling down from operation. Includes drive assembly, jaw-type clutch, and turning gear motor.

UZ Gas Turbine-Atomizing

Air Starting air compressor, cooler, separator, tank, and piping required to provide atomizing air to the gas turbine fuel nozzles.

V VENTILATION**VA Ventilation-Air Conditioning**

Includes central systems and window units.

VD Ventilation-Equipment Dry Layup

Includes dehumidification equipment and piping for short- and long-term "cold" storage.

VM Ventilation-Miscellaneous Vents and Exhausts

Includes any exhaust fans, hoods, etc., not associated with other systems.

VS Ventilation-Steam Heating

Steam or hot water heating systems used for personnel space heating needs.

W WASTE**WF Waste-Waste Fuel Collection**

Waste oil tank and piping to the fuel oil service pump strainers. Piping from the various burner front collection funnels.

WH Waste-Water and Boiler Wash Collection

Sumps, sump pumps, drain trenches, including storm drains, and drain piping to chemical waste treatment system or percolation ponds (WL).

WI Waste-Water Instrumentation

Water quality monitoring equipment at the chemical waste treatment system (WL).

WL Waste-Liquid Waste

Chemical waste treatment system or percolation ponds. Includes the grit bed pumping station as it receives influent from system WH, surge tanks, sludge settling ponds, and percolation ponds. Includes any associated clarifiers. Includes the lime storage bin, rotary lime feeder and slaker, work tank, slurry pump, rapid and slow mix tanks, piping, and controls. Includes the CO₂ storage tank, refrigeration and vaporization equipment, piping, and controls. The monitoring wells surrounding a basin are included in system NW.

WS Waste-Solid Waste Disposal

Fixed systems such as a landfill.

WW Waste-Sewage Treatment

For on-site treatment, includes the sewage collection piping, lift stations, discharge piping, barscreen, aeration tank, blower, settling tank, digester, clarifier tank, and chlorine and aluminate feed systems. For discharge to the city sewage system, includes the sewage collection piping and any pumping stations.

Y BLANKET ACCOUNTS

Used for plant expense accounting for work that is not equipment specific or otherwise accounted for in another of the equipment systems. These systems are to be used sparingly and are not to be used as an easy substitute for more detailed work order coding.

YA Blanket Accounts-Operations

Operations-related expenses.

YB Blanket Accounts-Maintenance

Maintenance-related expenses.

YC Blanket Accounts-Administration

Miscellaneous administrative expenses as clerical, guarding, and grounds keeping.

YD Blanket Accounts-Engineering

Engineering expenses.

YE Blanket Accounts-Structural

Maintenance of steam structures expenses.

YF Blanket Accounts-Production Equipment

Maintenance of power production equipment.

YG Blanket Accounts-Facilities

Miscellaneous buildings expenses.

YH Blanket Accounts-Computer

This would include maintenance of mainframe and PC computer networks. Use this code for time and monies expended on a CMMS.

Z MISCELLANEOUS**ZB Miscellaneous-Buildings and Grounds**

Building structures not otherwise listed in other systems. Also includes items as roads, parking lots, elevators, lawns, and picnic areas.

ZC Miscellaneous-Turbine Deck Bridge Crane

Entire crane assembly, including the brakes and gears, power wires, track, controls, and supports. Does not include portable hoists (ME), shop hoists (ZE), or mobile cranes (MV).

ZE Miscellaneous-Electric Tools and Equipment

Various fixed and portable electric driven tools and equipment. Arc welders, metallizing machines, bolt heaters, portable fans and space heaters, hand drills, electric chainfall hoists, etc.

ZF Miscellaneous-Freeze Protection

Various systems, not otherwise specified, used to protect plant equipment from freeze damage.

ZH Miscellaneous-Hydraulic Tools and Equipment

Various fixed and portable hydraulic tools. Includes presses, bending brakes, lifts, porta-power devices, and wrenches.

ZL Miscellaneous-Laboratory

Laboratory analysis equipment for fuel oil, water, and steam sampling analysis. Sample points would be listed in the involved system.

ZM Miscellaneous-Machine Shop Equipment

Drill presses, lathes, milling machines, grinders, etc.

ZO Miscellaneous-Other Tools and Equipment

Other tools, usually unpowered, not covered by the other tool systems. Includes specialized tools for turbines, oil spillage control, and safety. Includes nonproduction equipment such as ice makers. Measurement tools such as micrometers are also included.

ZP Miscellaneous—Pneumatic Tools and Equipment

Various fixed and portable pneumatic driven tools. Includes sandblasters, spray paint equipment, impact wrenches, and portable air compressors.

ZS Miscellaneous—Security

Perimeter fences and gates, guard houses, surveillance cameras, intruder alarm systems, etc.

ZV Miscellaneous—Plant Vehicles

Forklifts, mobile cranes, bulldozers and other heavy equipment, plant assigned cars, trucks and boats, etc.

(Note: An example of using the plant, unit, group, and system codes would be N02-CP to indicate North Station Unit 2's condensate polishing system.)

Equipment Type

(Note: These codes are useful for analyzing problem areas in the plant. For example, the plant could segregate work orders and determine how much plant work was being expended on pumps, equipment type code 01. Planners place these codes on the work orders during the coding process, but the codes are not part of the equipment component tag number. Equipment type codes could be included in the equipment number itself, but the numbering system would be stretched to the limit. Adding the equipment type codes to the equipment number itself may be beyond the point of diminishing returns. It can become confusing and frustrating to require a tremendous string of numbers to be manipulated. Certainly, additional intelligent equipment coding beyond these numbers would be difficult.)

These codes are to be used consistently throughout the various equipment systems. For any system described, these code numbers will be unique to the equipment described. For example, 01 means pump regardless of in what system the equipment lies. A pump in the condensate polishing system would be coded as 01 and a pump in the intake basin would be coded as 01 for the equipment type code. Certain major pieces of equipment such as the boiler feed pumps and the steam turbine generators are complex enough to merit their own Group and System designations. In these cases, major pieces may be given their own major code numbers, e.g., high-pressure steam turbine inner casing.

Equipment Type Codes

00. **General:** Intended to represent the system in general. When a specific piece of equipment is involved, this code is not to be used.
01. **Pump:** Device intended for the movement of liquids. Does not include vacuum pumps.
02. **Compressor and Vacuum Pump:** Device intended to change the pressure of the gas involved. Device should provide a pressure differential greater than 35 psi.
03. **Fan and Blower:** Device intended to increase the flow volume of the gas involved. Device should provide a pressure differential less than or equal to 35 psi.
04. **Hydraulic Coupling:** Fluid drive unit located between a driven object and its driver. (Simple couplings are considered a part of the driven object.)
05. **Gear Set:** Separately cased gear set, reduction gear, or turning gear located between a driven object and its driver. (Gear sets integral to an object are considered a part of

that object. Simple couplings are considered a part of the driven object.)

06. **Pressure Vessel:** A container designed to continuously hold a pressurized fluid.
07. **Vented Vessel:** A container which is vented so that it does not hold more than static pressure head of the substance contained. The vent need not necessarily go to the atmosphere.
08. **Heat Exchanger:** Includes open and closed types such as tube-and-shell and plate-type heat exchangers, condensers, and deaerators.
09. **Piping or Ducts:** Piping which is used for transferring fluid from one point to another. Includes flexible piping and hose. Insulation, simple hangers, supports, flange work, expansion joints, etc., are considered part of the piping or duct to which it is attached. No distinction is made on operating pressure. Does not include open troughs (see item 50).
10. **Hanger Assembly:** Includes large hanger mechanisms as found on the major steam piping. (Simple hangers are considered a part of the piping under item 09—Piping.)
12. **Control Valve and Actuator:** Includes all valves with remote actuation (except solenoid valves). The valve and its actuator are considered as one item, regardless of how attached they are to each other.
13. **Solenoid Valve:** Any valve which is solenoid actuated. Includes the solenoid.
14. **Manual Valve:** A valve which must be manually operated. Includes check valves. Includes backflow preventer assemblies. Does not include safety valves.
15. **Safety Valve and Others:** Includes safety valves, relief valves, rupture disks, vacuum breakers. Can also include trip valves.
16. **Flow and Restriction Orifices:** Includes the orifice plate (Venturi or other), and upstream and downstream pressure taps.
17. **Steam Trap Assembly, Moisture Trap Assembly, Float Trap Assembly:** Includes trap, strainer, isolation valves, bypass valve, drain valve and any test valve. Continuous drains are listed here.
18. **Filter and Strainer.**
19. **Regulator.**
21. **Switchgear:** Circuit breakers, including the primary disconnects and operator with auxiliary equipment such as the switch, trip device, solenoid and arc chute assembly. For voltages of 460 and higher. Smaller voltages are typically considered a part of the equipment being served, or are listed as part of a distribution panel in systems such as EB. Breakers such as metal-clad, oil-filled, air blast and air magnetic types are included.
22. **Electric Motor, Single-Phase.**
23. **Electric Motor, Three-Phase, under 500 V.**
24. **Electric Motor, Three-Phase, 500 V+.**
25. **Electric Motor, dc.**
26. **Power and Control:** Cables, control devices, etc., between the switchgear and electrically driven device, typically a motor.
28. **Motor Starter and Contactor:** Includes the toggle switch, solenoids, relays and timers.
29. **Transformer.**
30. **Structure:** Girderwork, stairs, floors, walls, ceilings, containment walls, etc.

31. *Air Dryer:* Includes both refrigerant and desiccant type dryers. Includes the dehumidifiers.
33. *Motor Control Center:* A grouping or combination of motor starters in a single cabinet or enclosure. Consists of lead-in cables, molded case circuit breaker, starter contactor, control transformer, and fuses.
34. *Instrumentation:* All types of instruments including devices used to record information automatically on paper and flow meters. Does not include flow orifices, which are listed as major code 16. Includes rotometers and level indicator vessels.
35. *Auxiliary Driver:* Diesel engine and its accessories such as air starter, fuel pump, heat exchanger, etc., that drives the emergency fire pump. Also included is the steam engine that drives the fuel oil transfer pump.
41. *Sootblower Assembly:* Device used to remove accumulated soot and debris from a heat transfer surface. Typically found in boilers and air preheaters. Can include permanent wash lances.
43. *Attemperator:* Includes the spray head, thermal liner, inlet nozzle, and casing. Does not include the control valve, which would be coded as 12.
44. *Lubricating Assembly.*
45. *Burner Assembly:* Includes oil and natural gas burners—the nozzle, gun, diffuser, canes, etc. Does not include the air register, which would be coded as 47.
46. *Generator:* Small generators, ac or dc, such as motor-generator sets. Does not include prime mover generators, which are covered in Group G.
47. *Damper or Register Assembly:* Device for regulating gas flow, including its driver and actuator (if applicable).
48. *Exhaust Stack, Exhaust Silencers.*
49. *Traveling Screen Assembly:* Does not include the screen wash pump or troughs.
50. *Trough, Trench, Ditch, Sump Pit.*
51. *Air Motor:* A rotating pneumatic device used to provide power to a driven device such as a pump or generator.
52. *Gas Ignitor:* Natural gas and propane ignitors.

(*Note:* Notice that code 12 includes both actuators and their valves and that there is no code 11. It became impractical to classify valves as 11 separate from actuators. It was frequently difficult to tell which was the problem area, the valve or its actuator. Early planning strategy at this plant was to have the planner be alert to change the code after the job was completed to have the exact equipment identified. In actual practice, however, it became apparent that the first equipment number placed on the work order would stick and not be changed. It made life much easier to combine these devices. Later as the planning system matured and computer "help" was brought in, the computer required that everything be separate to list the manufacturer with the equipment on a one-to-one basis. Now it was easy with a paper file to list two manufacturers and scores of suppliers for any particular valve and actuator combination. At this plant, the computer was modified to allow continuation of the existing practice.)

Action Taken

(*Note:* This section of the work order manual would normally be utilized for codes to identify specific maintenance operations performed. This example plant had a list of 36 basic

maintenance operations and expected either the planner or technician to select a single code representing the type of work completed. The practice ran into two problems. First, most maintenance tasks involved more than a single code. This made it difficult to judge which code was most appropriate. Second, no one ever used the codes for any type of analysis so feedback to the persons doing the coding was nonexistent. The plant abandoned using these type codes.)

Reason, Cause, and Failure

(*Note:* This section of the work order manual would normally be utilized for codes to identify specific reasons or causes of different types of failures. This example plant had a list of 200 basic maintenance operations and expected either the planner or technician to select a single code for each job. Similar to the above section for Action Taken codes, the practice ran into problems. The primary problem was that the list was so extensive that each technician generally selected about ten codes to utilize on all jobs. Each technician would have a different set of ten codes that the technician favored. In addition, no one ever used the codes for any type of analysis so feedback to the persons doing the coding was nonexistent. The plant also abandoned using these type codes. These type codes may be more useful when segregated by equipment type. Caution as expressed in Chap. 8 should be utilized when these codes are used as templates to define solutions.)

WORK ORDER NUMBERING SYSTEM

(*Note:* The WO numbering system provides for assigning each separate work order a unique number to allow keeping the work done under that number separate from other maintenance work. The work order number arrangement at many plants evolves in form such as its length and inclusion of alphabet characters. Having a record of how the numbering system works and has worked is very useful. Keeping this record pays dividends in the future if there is commitment to keeping it current.)

Current Numbering System

Each WO is numbered with a separate, unique seven-digit code.

The first digit is the plant code (as defined in the Plant and Unit Codes). The second and third digits are the last two digits in the calendar year when the WO is originated (e.g., "93"). The originator writes in the first three digits (plant and year) when initiating a WO. The last four digits are made up of one letter followed by three numbers. Each separate WO is given a unique combination of last four digits, which may be from A001 to Z999. The last four digits (unique) of the WO are already preprinted on the blank WO forms.

For example, WO number N93G457 is a unique WO number for a work order at North Station written in 1993.

The WO number is also used for the CMMS system as well as the mainframe system.

Blanket work orders are kept in the mainframe system exclusively. A WO form is not required for a blanket work order. The Maintenance Department Mainframe System Administrator assigns blanket work order numbers using the same seven-digit numbering sequence as for regular WOs except that the second and third digits are the unit codes (as defined in the Plant and Unit Codes) and the last four digits are all numbers from 8000 to 9999. The Mainframe System Administrator keeps a log to maintain consistent

blanket numbers among plants and to avoid assigning duplicate blanket numbers for different activities.

For example, blanket WO numbers N009132, S009132, and K009132 are for maintenance planning activities for each plant.

The use of blanket work orders is not encouraged for equipment maintenance. The creation of a new blanket WO must be authorized by the Assistant Plant Manager.

Previous Numbering Systems

Prior to mid-December, 1993, the first digit (plant) was preprinted on the form and the second and third digits were the unit codes (as defined in the Plant and Unit Codes). The originator wrote in the Unit Code when initiating a WO. (This system was changed to the current system to allow using the same form at all plants and because there were still too few available WO numbers.)

Example: WO number N01G257 would be a unique WO number for a work order on North Unit 1.

Prior to 1991, the last four digits of regular WOs were 0001 to 7999 and blanket WOs were 8000 to 9999. (This system was eventually changed because there were too few available WO numbers.)

Prior to about 1990, each plant had separate WO numbering systems and conventions such as using NS at the beginning to designate North Station.

Notes

These are general notes for numbering work orders. Using years instead of unit for the second two digits will cause a potential conflict with old WOs and blankets in the year 2000 that will need to be addressed eventually. The conflict arises because the year 2000 and unit common both would use 00.

MANUAL DISTRIBUTION

(Note: The plant should keep a list of who has the manuals so that it can update their documents. It is also valuable to list actual names along with titles so that all crew supervisors, managers, engineers, planners, and even computer support persons can be included in having the work order system documentation. Normally this listing is published along with the manual in this back section. A plant with general access to an internal intranet Web site should consider discontinuing the maintenance of a hard copy work order system manual in favor of the more plant-wide access to a Web document. Alternately, a plant with a CMMS with plant-wide access may have the computer system contain the bulk of the documentation of the work order system and codes. In either case, this paper document would be discontinued because of its more limited access and the trouble of keeping it current.)

APPENDIX K

EQUIPMENT SCHEMATICS AND TAGGING

This appendix sets forth guidelines for equipment identification and tagging which are essential for setting up the filing system used by planning. Planning uses the equipment tag numbers in its filing system. Nearly every piece of equipment should be tagged with a number if maintenance work is ever performed on it. The repetitious nature of maintenance work demands that records be kept identifying the circumstances of past work. The past work cannot be improved upon if records are not kept. Records cannot be kept if there is no numbering system to allow arrangement of the files or computer records. It is also not enough to have an equipment number for each item. That number must be clearly visible on the piece of equipment. With this arrangement, it is possible to utilize equipment numbers practically to assist finding equipment and keeping records. A plant might set guidelines if not all equipment is to have an equipment number or tag. All lines and devices critical to processes should have numbers and tags. It may be permissible to exclude certain drain lines smaller than 2 inches. Appendix J equipment type codes recommended giving control valves and their actuators a single number. Similarly, a plant should seriously consider giving a single number to an entire drive-train such as a pump, its fluid drive, and its motor. Components internal to other equipment such as boiler tube section inside a furnace may be impractical to tag, but numbers can be established for files to track different sections of tubes. Valves contained within the protective structure of a steam turbine might be numbered, but not tagged directly. A placard may be set near the turbine identifying such concealed valves and their designated numbers. The numbers might be placed on labels in the control room near appropriate controls or switches.

The following sections establish practical guidelines that may be used to establish equipment numbers and place appropriate tags on the equipment.

EQUIPMENT TAG NUMBERS

There are several issues necessary to mention when discussing equipment numbers. Included among these issues are the uniqueness of the numbers, the use of intelligent numbers, and the use of equipment schematics.

First, equipment numbers must be unique. A number used by one piece of equipment cannot be used for any other equipment. Because the planners will keep individual records for each piece of equipment, each number must indicate a single repository for information. If the plant utilizes existing numbering systems supplied by vendors, it must avoid accidental duplication.

APPENDIX L

COMPUTERIZED MAINTENANCE MANAGEMENT SYSTEMS

This appendix gives additional information on implementing and utilizing a CMMS to assist planning, as referenced in Chap. 8. This information was not included in the main text to avoid detracting from the book's overall thrust of how to do planning.

SAMPLE STREAMLINED CMMS USERS' GUIDE

This section actually gives an example of how to cut down an inch-thick computer manual to a few pages of key instructions for non-planning group persons such as plant supervisors, technicians, operators, and managers. (Persons at this plant request work on a paper work order form which they deliver to the planning department for computer entry and processing. This company uses another system for inventory management.)

Basic Steps and Guidelines for Using CMMS

System Notes

1. The following text contains step-by-step instructions for basic use of the computer to find information. (Instructions for data input and modification are contained in the "CMMS Instructions for Planners" section created for the planning group. Complete instructions for CMMS use are contained in the *CMMS User's Guide and Tutorial* supplied by the vendor.)
2. Minimum PC requirements to access CMMS from the network: at least 486/33 with 8 megabytes is recommended.
3. The CMMS System Administrator at North Plant (Joe Brown, 222-2222) is responsible for setting system security and personnel rights to each CMMS screen and field.
4. CMMS is unavailable each week for a short period for system backup and adjustment. Any changes to the normal schedule for this period are published by e-mail.
5. Advisements between updates of these guidelines are published normally on e-mail.

To Enter CMMS

1. Log in to the plant network. You are now in Windows. (If you are not set up for Windows and the CMMS, contact the CMMS System Administrator for a personal setup for your computer.)
2. If you do not have mainframe rights, skip to step 3. If you have mainframe rights, double-click the mouse on the RABBIT icon for simultaneous loading of the mainframe emulation for inventory transactions. Hold down the ALT key and press the TAB key to leave the emulation. (After step 4 below you may access and leave the mainframe emulation anytime from the main menu by holding down the ALT key and pressing the TAB key.)
3. Double-click the mouse on the CMMS icon.
4. You should now have a window titled CMMS Login. Using the mouse or tab key move among the fields and type your name (or GUEST) for user and your password (or GUEST) for password. Click the mouse on the "OK" button to bring up the CMMS main menu.

(Note: To experiment with the CMMS, there is a test database you can access. This setup does not affect the real databases or records. Contact the CMMS System Administrator for details.)

To Exit CMMS

1. Close the window with the following: Click on the minus (-) sign on the top left corner of the window. Then click on "Close." Repeat these two steps for every window that comes up including the main menu.
2. You are now out of the CMMS itself. If you want to get out of Windows altogether, click on the minus (-) sign. Then click on "Close." Click on "Okay" for ending the windows session.

CMMS Notes

1. Each of the following step-by-step guidelines presumes you are already at the main menu.
2. The CMMS is designed for Windows and primarily relies on your using a mouse. Use the mouse (point and click) when moving around and selecting an icon from the main menu (and later when selecting a field or command from a screen).
3. Click on the window right-hand side down arrow to see the lower half of any screen.
4. Lock your caps on your keyboard.

To Query the Status of Work Orders

This section allows you to find where a work order is in the work order flow process.

By Work Order Number

1. Click on the work order icon.
2. You should now have the work order screen. Press the esc key to reset the screen.
3. Type the work order number in the work order number field; then press the ENTER key.
4. You should now have all the fields including the Status field filled in for that work order.
5. Repeat steps 2 to 4 for other work orders.

By Equipment Number

1. Click on the work order icon.
2. You should now have the work order screen. Press the esc key to reset the screen.
3. Type the equipment component tag number complete with all hyphens (-) (e.g., N02-FC-003).
4. Press the ENTER key, which fills in the work order screen for the first work order with that equipment number.
5. Continue to press the ENTER key to bring up each work order with that equipment number one at a time. Or Click on the "Listing" icon to list all the work orders for that piece of equipment.
6. Repeat steps 2 to 4 for other equipment.

By System. Repeat the above steps for "By Equipment Number," but instead of entering an entire equipment number, enter only the station, unit, group, and system codes followed by a % (e.g., N02-FC% for the North 2 fuel oil service pump system). This entry will select all work orders for that entire system.

By Deficiency Tag Number or Other Associated Document Number. Steps 1, 2, 4, 5, and 6 are the same as for By Equipment Number. Step 3: Enter the deficiency tag number (or other document number) surrounded by asterisk signs in the Def/Other Number field (e.g., *D-56935*).

By Originator or Originating Crew. Steps 1, 2, 4, 5, and 6 are the same as for By Equipment Number. Step 3: Enter the originator or crew number surrounded by asterisk signs in the Originator field (e.g., *SMITH* or *4-1*).

By Certain Type of Work Order or by Key Words

1. Click on the work order icon.
2. You should now have the work order screen. Press the esc key to reset the screen.
3. Type all of the information in all of the various fields that you would like the work order(s) in question to match. For example, if you wanted to consider only PM work orders that dealt with control valves you would type 7 in the work type field and 12 in the equipment type code field. (7 is the work type code for preventive maintenance and 12 is the equipment type code for control valves.)
4. You may also use arithmetic operators when entering data in the field as follows such as greater than or less than. For example, >06/01/93 in the Origination Date field would mean to consider work orders originated after June 1, 1993, only.
5. You may also use wild cards _ (underscore) for a single character and * (asterisk sign) for a string of characters. For example, if you wanted to consider only work orders that had the word "leak" anywhere in the work order description, you would type *leak* in the work order description field (the long field next to Work Order #). Another example: To consider only work orders assigned to any Operations crew you would type 4* in the Craft field. (4 is the craft code for Operations.)
6. Click on "Count" to see how many work orders exist matching the field information you specified.
7. Press the ENTER key to scroll through the individual matching work orders. Or You may also click on the "Listing" icon to list all the selected work orders.
8. Repeat steps 2 through 7 for other queries.

To Query for Equipment Data. *Note:* Only equipment given a equipment tag number is included in the database.

Find Equipment Nameplate Data

1. Click on the main menu equipment icon.
2. You should now have the equipment screen. Press the **esc** key to reset the screen.
3. Type the equipment number (e.g., N02-FC-003) in the equipment number field (adjacent to the word "Equipment"), then press the **ENTER** key.
4. You should now have all the fields including the Other Equip Data field filled in for that equipment.
5. Repeat steps 2 through 4 for other equipment.

Find Groups, Systems, or Equipment by Scrolling

1. Click on the main menu equipment icon.
2. You should now have the equipment screen. Press the **esc** key to reset the screen.
3. Type the unit number (e.g., N02) in the equipment number field (adjacent to the word "Equipment"); then press the **ENTER** key. You should now have the unit name filled in on the screen.
4. Click on the Level Down icon. After a brief pause, you should have a list of all the equipment groups for that unit. Scroll through the list to find pertinent groups.
5. Select a group by clicking, then click on the Level Down icon to get a list of systems for that group.
6. Select a system by clicking, then click on the Level Down icon to get a list of equipment for that group.
7. Click on the Level Up icon to move up in level from equipment to systems, systems to groups, or groups to units.
8. Repeat steps 2 through 7 for other units.

To Print a Copy of Any Screen, Listing, or Work Order

Click on "File," then "Print," then "Screen," "Listing," or "Work Order Form."

Reports. Clicking on the "Reports" icon gives a listing of reports that may be selected and run. Some of these reports are available now and certain others are being developed for use by the CMMS System Administrator.

SAMPLE STREAMLINED CMMS PLANNERS' GUIDE

Here is an example of trimming a thick computer manual from the CMMS vendor to just a few pages of key instructions for the planning group.

CMMS Instructions for Planners

System Notes

1. The following text contains step-by-step instructions for basic use of the CMMS to input and modify information. (Instructions to find information are contained in the "Basic Steps and Guidelines for Using CMMS" section of the *Work Order System Manual*. Complete instructions for CMMS use are contained in the vendor-supplied *User's Guide and Tutorial*.)
2. Minimum PC requirements to access CMMS from the network: at least 486/33 with 8 megabytes is recommended.
3. The CMMS System Administrator at North Plant (Joe Brown, 222-2222) is responsible for setting system security and personnel rights to each CMMS screen and field.
4. CMMS is unavailable each week for a short period for system backup and adjustment. Any changes to the normal schedule for this period are published by e-mail.
5. Advisements between updates of these guidelines are published normally on e-mail.

To Enter CMMS

1. Log in to the plant network. You are now in Windows. (If you are not set up for Windows and the CMMS, contact the CMMS System Administrator for a personal setup for your computer.)
2. If you do not have mainframe rights, skip to step 3. If you have mainframe rights, double-click the mouse on the RABBIT icon for simultaneous loading of the mainframe emulation for inventory transactions. Hold down the **ALT** key and press the **TAB** key to leave the emulation. (After step 4 below you may access and leave the mainframe emulation anytime from the main menu by holding down the **ALT** key and pressing the **TAB** key.)
3. Double-click the mouse on the CMMS icon.
4. You should now have a window titled CMMS Login. Using the mouse or tab key move among the fields and type your name for user and your password. Click the mouse on the "OK" button to bring up the CMMS main menu.

(Note: To experiment with the CMMS, there is a test database you can access. This setup does not affect the real databases or records. Contact the CMMS System Administrator for details.)

To Exit CMMS

1. Close the window with the following: Click on the minus (-) sign on the top left corner of the window. Then click on "Close." Repeat these two steps for every window that comes up including the main menu.
2. You are now out of the CMMS itself. If you want to get out of Windows altogether, click on the minus (-) sign. Then click on "Close." Click on "Okay" for ending the windows session.

CMMS Notes

1. Each of the following step-by-step guidelines presumes you are already at the main menu.
2. The CMMS is designed for windows and primarily relies on your using a mouse. Use the mouse (point and "click") when moving around and selecting an icon from the main menu (and later when selecting a field or command from a screen).

3. Click on the window right-hand side down arrow to see the lower half of any screen.
4. Lock your Caps on your keyboard.

To Open Work Orders (by Planning Clerk)

1. Click on the "Work Order" icon.
2. You should now have the work order screen. Click on the "New Record" icon to reset the screen.
3. You are now in the Entering mode for entering data. Use the TAB key (or mouse) to move among the fields.
4. Enter the work order number and description (in the adjacent long blank). Include the equipment name at the beginning of the work order description; for example, 34002 4A SUMP PUMP PUMP IS CAVITATING.
5. Enter the equipment number complete with all hyphens (-); for example, N02-FC-003. If the equipment number is blank, N/A, or not on the work order, use the first six characters of the equipment coding and the word -ITEM. For example, N02-FC-ITEM designates that the equipment is an item in the system which the planner will later clarify.
6. If the database does *not* accept the record and the screen subtitle says "equipment number not found," first check for typographical errors in the entering of the equipment number such as the capital letter "O" for the number zero "0" or missing hyphens (-). If the CMMS still does not accept the equipment go to step 7.
7. To enter new equipment in the database, tab to the main menu and click on the equipment icon. You should now have the equipment screen. Click on the "New Record" icon to reset the screen and begin the entering mode. Type in the equipment number and equipment description. Type in the first six characters of the equipment coding for the level up field (e.g., N02-FC). Enter the two major equipment coding characters in the equipment type code field (e.g., 18). Enter any location or other information in the respective fields. Press the "Save record" icon to put this equipment into the database. Then close the equipment window pressing the SHIFT and F4 keys together and return to the work order screen and enter the equipment number.
8. Enter the originator (last name plus department and crew, include initial for a common last name, e.g., Smith, J. 4-1), origination date (delete system-added date if incorrect), and deficiency tag number.
9. Enter status (APPR) (put WSCH if the work type is 7). Enter work type, priority, and outage code. Enter craft, insulation?, cost center, FERC/account, and SubFERC account.
10. Enter PM week and frequency, if any.
11. To put the newly entered work order into the database, click on the "Save Record" icon.
12. Repeat steps 2 through 11 for each work order to be entered.

To Close Work Orders (by Planning Clerk)

1. Click on the work order icon.
2. You should now have the work order screen. Press the ESC key to reset the screen.
3. Enter the work order number and press the ENTER key. You should now have all the information for that work order filled into the screen fields.
4. Change the status to CLOSE (or CAN for canceled or voided work order). *Note:* If the status says HOLD, do not change the status. Stop and inform the Planning Supervisor.

5. Enter the technicians' last names and crafts. Enter the actual hours for each technician and actual job duration. Enter actual material and quantities. Enter actual tools and quantities. Enter actual end date (use the date in the technician sign off blank from the WO form). In the action taken field, enter all other job feedback.
6. To put the newly entered information into the database, click on the "Save Record" icon.
7. Repeat steps 2 through 6 for each work order to be closed.

To Plan Work Orders (by Planner)

1. Click on the "Work Order" icon.
2. You should now have the work order screen. Press the ESC key to reset the screen.
3. Enter the work order number and press the ENTER key. You should now have all the information for that work order filled into the screen fields.
4. Tab to the main menu and click on the "Plans" icon. You should now have the master plans screen. Find the desired plan and cut and paste necessary information to the current plan into the plans space of the work order screen. Create a new master plan if one has not been previously recorded for the equipment. The work plans should begin with the equipment number and then have suffix letters as appropriate, e.g., N02-FC-003STRAINERREPLACE.
5. Enter your last name in the planner field. Enter the estimated duration, labor hours, material cost, labor cost, and tool cost. Change and correct all work order information discovered during planning including equipment number.
6. Change the status to HOLD-MATL if the work order is waiting on parts (or some special tool).
7. Enter Y in the Insulation? field if the job requires insulation work.
8. Change the status to WSCH when the planning and obtaining of parts is complete. The job is now waiting to be scheduled. *Note:* If the status says CLOSED or CAN, do not change the status. Stop and inform the Planning Supervisor.
9. Commit all changes to the database by clicking on the "Save Record" icon.
10. Repeat beginning with Step 2 to plan other work orders.
11. The planner continually improves the job plans in the master plans module by entering appropriate feedback from completed jobs before completed work order forms are given to the planning clerk for closing.

To Update Parts Ordering Information (by Purchaser or Planner)

1. Click on the work order icon.
2. You should now have the work order screen. Press the ESC key to reset the screen.
3. Enter the work order number and press the ENTER key. (Or enter pertinent materials tracking number using * on each side; e.g., *15789*.)
4. You should now have all the information for that work order filled into the screen fields.
5. Enter the appropriate changes to the materials tracking number field and the matl ordered/received field. Always put the date ordered next to the tracking number.
6. Change the status to HOLD-MATL or WSCH as appropriate. *Note:* If the status says CLOSE or CAN, do not change the status. Stop and inform the Planning Supervisor.

7. Commit all changes to the database by clicking on the "Save Record" icon.
8. Repeat steps 2 through 7 to update other work orders.

SAMPLE PLANT-WIDE TRAINING OUTLINE FOR CMMS

- I. Purpose and goals of CMMS and course
- II. Plant work order manual
 - A. Work order form
 - B. Codes and conventions
 - C. CMMS documentation
- III. CMMS screens
 - A. Locating and selecting fields
 - B. Data entry practice for queries
 - C. (Any special commands not yet in CMMS documentation)
- IV. Computer work
 - A. Login to CMMS
 - B. Queries practice exercises—find and print
 - C. Free practice time
- V. Test
- VI. Course evaluation

SAMPLE MILESTONE SCHEDULE FOR IMPLEMENTING A CMMS IN PHASES

This sample schedule shows how a CMMS might be gradually implemented for a maintenance group.

1. Year 1, quarter 1: Complete purchase of system
2. Year 1, quarter 2: Upgrade and add minimum hardware
3. Year 1, quarter 2: Schedule future users and computer upgrades
4. Year 1, quarter 2: Set initial signature authorities
5. Year 1, quarter 2: Begin system backup and security copies
6. Year 1, quarter 3: Implement inventory module
7. Year 1, quarter 3: Ability to check part breakdowns for equipment
8. Year 1, quarter 3: Provide vendor contact information
9. Year 1, quarter 4: Ability to search WO status
10. Year 1, quarter 4: Ability to track estimated cost and hours on planned WOs
11. Year 1, quarter 4: Ability to print search results
12. Year 2, quarter 1: Automatic generation of PMs
13. Year 2, quarter 1: Ability to check equipment nameplate data
14. Year 2, quarter 2: Ability to check equipment technical data

15. Year 2, quarter 3: Use planning module
16. Year 2, quarter 4: Provide assistance with hold tags
17. Year 2, quarter 4: Originate WOs via terminals
18. Year 2, quarter 4: Provide service contract warrantee information
19. Year 3, quarter 1: Ability to track actual cost and hours as reported on WOs
20. Year 3, quarter 2: Automatically schedule work
21. Year 3, quarter 3: Coordination of labor module with timesheet system
22. Year 3, quarter 3: Ability to track actual cost and hours with timesheet information
23. Future: Integrate tool module
24. Future?: Coordinate with PdM
25. Future?: Use condition monitoring
26. Future: Use purchasing module
27. Future: Have technicians give feedback via terminals
28. Future?: Add past history of previous years before CMMS into database

Do we insist on job feedback? Can planners easily show examples of some technician feedback that was put into the files? Would a technician in the middle of the night be able to find equipment information? Do we assure technicians that planning is not intending to use their feedback to develop plans so that contractors can replace the technicians?)

7. Do the pieces of equipment in the field have labels in place showing their equipment numbers? (Do the files use the same number? Does the equipment numbering system make sense? Is the equipment tagging group supporting the planners needs? Are equipment tags being placed in order of higher maintenance systems first? Do equipment tags look neat? Is the tagging group responsive to the planning group's suggestions?)

8. Are the planners planning all the work? (Are we trying to avoid detailed job procedures? Do we realize that a scope from an accomplished technician that gives craft skill and hour estimates is an advantage over the original work request? Do we know we do not need O&M manuals on every job? Do the planners ultimately trust their instincts for determining time estimates? Do planners avoid estimating most jobs by the shift arrangement such as estimating 4 or 8 hours just because the work shift is 8 hours? Do we know that planning should not slow down the start of work on reactive jobs?)

9. Do we schedule for an entire week for each crew? (Are we willing to have the crews follow an advance allocation of work for a week? Does the 1-week schedule account for every available crew hour? Do we insist on proper use of the priority system? Do we support weekly and daily scheduling by not holding special meetings or events with less than a week's notice? Do supervisors assign work orders using the hours estimated by the planners? Is the percentage of labor hours spent on reactive work becoming less? Are we completing more proactive work orders than previously?)

10. Are we doing any staging of parts or tools? (Should we consider staging parts? Are there no parts currently staged for jobs that have already been completed? Does the right person stage the parts?)

11. How do we utilize the computer system? (Do we know that a computer system is not necessarily planning? Do we understand the proper role of a CMMS and how much it should help? Do we know a computer will not compensate for a poor maintenance process? Does the computer system do a daily backup of its records?)

12. Are we avoiding trying to obtain more out of planning than is there by itself? (Do we have a good work order system? Are technicians doing all work through work orders? Are we avoiding blanket work orders? Do we have clear guidelines on how to write work orders? Is there a standard work order form at each location? Does the work order form collect cost? Do the supervisors spend more time in the field coaching than in the office doing desk work? Are shops and tools useful for completing work? Is the storeroom service satisfactory for both having parts and allowing quick retrieval? Are unused items easily returned to the storeroom? Is the percentage of our work on PM measured? Is a majority of all work orders initiated during PMs? Are PMs oriented toward inspections? Do technicians write up work orders to correct other deficiencies when performing preventive maintenance? Are more work orders written by maintenance personnel than operations personnel? Are preventive maintenance jobs planned and scheduled? Is the feedback from preventive maintenance jobs reviewed? Does the computer cancel PMs if the crew does not complete them before the next ones are issued? Does PdM use the same equipment numbers as the planners? Is any PdM information going into the planning files? Is the percentage of our work on project work to improve equipment measured? Do we look for root causes after any failures? Has the maintenance group set up any equipment standards for the corporate project group to follow?)

13. Is planning "working"?

GLOSSARY

aging Automatically increasing the priority or attention given to an incomplete work order the older it becomes. The concept of aging is that an older work order should get higher attention than a similar work order only recently written. This practice may help a crew with low productivity, but hinder a crew with already high productivity. The former crew might increase its productivity to include the aged work order. The latter crew might have to drop a more serious work order to accommodate the aged, though less important, work order.

backlog Amount of identified work on work orders either by number of work orders or work hours.

blankets or blanket work orders Standing work orders not specifying specific work but allowing the collection of work hours for time accounting.

book hours Standard hours by which maintenance personnel might be paid regardless of actual hours spent.

clearing equipment or systems Tagging or locking out the necessary valves or devices surrounding equipment to be worked on so that the equipment is safe. Also may involve draining or otherwise making equipment ready to be maintained.

CMMS Computerized maintenance management system.

component level file A file made for a specific piece of equipment rather than for a system or group of equipment. Also called a *minifile* to emphasize its size relative to a system file.

confined space An area with limited access and potential respiratory hazard requiring a special permit to enter.

corrective maintenance Work to restore an equipment to proper operating condition before failure or breakdown occurs.

CPM (Critical Path Method) A schedule technique allowing determination of the overall time of a large maintenance by arranging and sequencing tasks with preceding and succeeding events.

deficiency tag An information tag hung by the requester of maintenance work to identify the equipment.

equivalent availability Equivalent availability factor (EAF). EAF is a common utility performance measure of how much generating capacity is actually available over a given period for producing power. When a unit is only available (whether it is running or not) for less than full load, the equivalent amount of its full load availability is counted. For example, a unit having boiler feedwater pump problems and only available for half-load for the entire month would have an equivalent availability of 50%.

Likewise, a unit available for full load the entire month of 30 days except for a full outage lasting three of those days would have an equivalent availability of 90%. The equivalent availability of an entire plant site or utility would be calculated by weighting the units by megawatt capacity. Equivalent availability is normally expressed as a percent such as 90%, although technically the factor itself would be shown as 0.90.

extensive maintenance Maintenance that takes more than a few hours and may have historically significant data.

equipment file, equipment history file See *component level file*.

front end loading Spending time and resources ensuring that equipment will be suitable for maintenance before the equipment is purchased or installed.

GPM Gallons per minute.

I&C Instrument and controls craft.

infant mortality The failure of a component or equipment soon after initial installation or after a maintenance operation. There is a higher percentage chance that equipment will need repair at these times than during the remainder of its time in service.

insource Using in-house resources to obtain a service or material. Making equipment or components with in-house labor.

job tool card A record kept by a tool room to keep track of tools issued to jobs rather than individual technicians.

metrics Indicators or measures of maintenance performance.

minifile See *component level file*.

minimum maintenance Maintenance work requiring less than a few hours and not historically significant.

MSDS Material Safety Data Sheet describing dangers and safety procedures for a specific hazardous substance.

MTBF (mean time between failure) A calculation showing the trend of average time periods between failures of the same equipment over time or showing the time periods between failure of different equipment. For example, "The MTBF of the circuit has improved from three weeks to over two months."

O&M manuals Operation and maintenance manuals provided by the equipment manufacturers or suppliers giving basic details on operation and maintenance of the equipment. They usually included suggested preventive maintenance tasks, troubleshooting guides, and identification of parts and special tools.

OEM Original Equipment Manufacturer.

OJT (on-the-job training) Many times either the best or the only training an employee receives is while actually doing the job either alone or under the eye of an experienced co-worker.

operations, production The plant personnel responsible for operating the plant equipment and systems.

operations coordinator A specific person in the operations group specifically tasked to help maintenance planners.

originator A person that writes a work order or other request for maintenance work.

outage A condition of being out of service and unavailable for operation. Refers to the condition of the entire plant unit, not the individual piece of equipment.

overhaul Normally a major outage requiring a significant amount of time and planning.

piece workers, piece work An arrangement where technicians receive pay based on how many units are produced.

pigeon-holing Estimating a job's time requirements by referring to a table or index of similar jobs and making adjustments for particular job differences.

planner, maintenance planner The person responsible for preparing work orders for execution through applying the principles of maintenance planning.

planning, maintenance planning The preparatory work to make work orders ready to execute. This term may involve scheduling depending on how it is used.

planned job, planned work, job plan The product of the planner including all the preparatory work done.

planner active file A planner may keep the original work order in an active file and take a copy into the field for scoping purposes.

PM optimization A similar process to RCM to develop preventive maintenance tasks and frequencies to reduce likely failure modes. Makes significant use of existing PMs as a starting point.

point of diminishing returns The point where an additional action or task provides a benefit, but the benefit would not outweigh the cost of the additional action or task.

predictive maintenance The use of technologically sophisticated devices as vibration trend analysis to predict future impending equipment problems.

preventive maintenance Time- or interval-based maintenance designed to head off or detect equipment problems.

proactive maintenance Maintenance performed to head off failure and breakdown.

product life cycle The economic curves showing profitability of any given product for sale. Initially profit is low as the product is developed. Next, profit increases as sales increase. Then profit begins to drop as market substitute products and other competition become common. The company may attempt to modify the product and willingly take some drop in profit before the effect of market forces. This modified product eventually achieves greater profitability than possible from the initial product. An analogy can be made to playing tennis. One can become a fairly good player without using correct techniques. But when the player decides to adopt correct grips, stances, and other techniques, the player's ability will first drop as the new skills are learned. However, the player should be able eventually to rise above the old level of ability.

project work, project maintenance Modifying or improving a piece of equipment or system.

RCM (reliability centered maintenance) A process or system to evaluate equipment and develop preventive maintenance tasks and frequencies to reduce likely failure modes.

reactive maintenance Maintenance work performed as a response to a failure, breakdown, or other urgent equipment situation.

scoping, scope Determining the job scope, studying and defining what work a job requires, deciding the magnitude of the work involved. For an individual job, this requires determining the objective of the job. For an outage, this involves determining all the jobs involved in the outage.

shakedown Returning units or plant processes back to service after maintenance activities. The shakedown process identifies discrepancies with the maintenance work that require attention.

SNOW An acronym for short notice outage work.

stretch goals Goals that are hard to reach, but not seen as impossible.

stockout A measure of how many times the storeroom is out of stock for an item when that item is requested. Stockouts do not necessarily measure that a storeroom is either out of a material or has a less than desirable quantity on hand.

vicious cycle A situation where the solution to a circumstance creates another problem in a chain that makes the original problem worse. An example is when a plant attempts to save labor by reducing preventive maintenance. The incidence of equipment failure rises requiring more labor and leaving no time for ever doing preventive maintenance. The plant finally saves no labor and has worse equipment reliability.

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