ELECTRIC POWER RESEARCH INSTITUTE

Maintenance Work Package Planning Guidance for Fossil Power Plant Personnel

Technical Report

Maintenance Work Package Planning Guidance for Fossil Power Plant Personnel

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REPORT SUMMARY

The work management process is one of the core business processes for the operation and maintenance of fossil power plants. The preparation of work packages is a key element of this overall process. This report provides guidance to power plant personnel regarding work package quality by providing a consistent approach for administrative control, achieving an appropriate level of detail, and ensuring an acceptable level of use, work package format, and application.

Background

Over the past several years in the nuclear power industry, there has been a trend in Areas for Improvement (AFI) written on work package quality during Institute of Nuclear Power Operations/World Association of Nuclear Operations (INPO/WANO), Evaluation and Assistance (E&A)/Peer Review visits. The INPO generic trend notes that “work instruction and procedure shortfalls contribute to maintenance errors.”

In the fall of 2004, the Industry Working Group on Work Package Standards was convened under a charter to be administered by the INPO–Electric Power Research Institute/Nuclear Maintenance Applications Center (EPRI/NMAC) interface subcommittee. The deliverable of the working group was the EPRI report *Maintenance Work Package Planning Guidance* (1011903). As a follow-up to that effort, the NMAC report was revised to produce a Technical Update, *Maintenance Work Package Planning Guidance for Fossil Power Plant Personnel* (1010288). The Technical Update was, in effect, a work in progress sponsored by EPRI Maintenance Management and Technology (MM&T), which was asked to similarly study the work planner function at fossil power stations. The intent was to use that Technical Update as a basis for developing and publishing this technical report for users in the fossil power industry in 2006.

Objectives

- To define the planning function
- To establish work package standard guidance with respect to content, technical subject matter, human performance, inclusion of maintenance experience, error prevention, key attributes, format, and level of detail
- To define fundamentals (skill and knowledge) of work package users with respect to the skill of the craft (regarding work instruction level of detail) and by referencing accredited craft training and qualification
- To establish performance measures to assess work package quality

Approach

In late 2005, EPRI published a preliminary version of the fossil-power oriented guidance as a Technical Update. In 2006, a Technical Advisory Group of key fossil power industry personnel was formed to assist in the development of this technical report.

Results

This report provides an overview of requirements addressing work package content, level of detail, and quality, as well as guidance regarding skills and performance attributes that are essential among work planners and those personnel implementing the work packages. The focus of the report is guidance for developing work packages, which relates different types of work activities and other parameters to various general categories of work packages. It also provides guidance for establishing an appropriate structure, format, and content for work instructions, which is the primary element of a quality work package. The report also provides owners with several methods for measuring the quality of work packages.

EPRI Perspective

The information contained in this technical report represents a significant collection of human performance information—including techniques and good practices—related to the preparation of work packages in support of various work activities that are common at fossil power plants. The assemblage of this information provides a single point of reference for plant work planning personnel, both in the present and in the future. Through the use of this guideline, in close conjunction with the industry guidance, EPRI members should be able to significantly improve and consistently implement the processes associated with developing work packages. This will subsequently help members achieve increased reliability and availability of the components on which the work activities are performed.

Keywords

Work control
Work instructions
Work package
Work planning

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1 INTRODUCTION

1.1 Purpose and Scope

This report provides guidance to fossil power plant personnel regarding work package content. It provides a consistent approach for administrative control, achieving an appropriate level of detail, ensuring an acceptable level of use, work package format, and application.

Each owner is responsible for complying with procedures for work package content and quality and for determining the most effective means of developing work packages that integrate with the related owner-specific processes. The recommendations in this document can be used in their entirety or in part, as appropriate, given the other related processes.

1.2 Background

Over the past several years in the nuclear power industry, there has been a trend in Areas for Improvement (AFI) written on work package quality during Institute of Nuclear Power Operations/World Association of Nuclear Operations (INPO/WANO), Evaluation and Assistance (E&A)/Peer Review visits. The INPO generic trend notes that "work instruction and procedure shortfalls contribute to maintenance errors."

In the fall of 2004, the Industry Working Group on Work Package Standards was convened under a charter to be administered by the INPO–Electric Power Research Institute/Nuclear Maintenance Applications Center (EPRI/NMAC) interface subcommittee. The deliverable of the working group was the EPRI report *Maintenance Work Package Planning Guidance* (1011903). As a follow-up to that effort, the NMAC report was revised to produce a Technical Update, *Maintenance Work Package Planning Guidance for Fossil Power Plant Personnel* (1010288). The Technical Update was, in effect, a work in progress sponsored by EPRI Maintenance Management and Technology (MM&T), which was asked to similarly study the work planner function at fossil power stations. As shown in Figure 1-1, the intent was to use that Technical Update as a basis for developing and publishing a technical report for users in the fossil power industry in 2006.

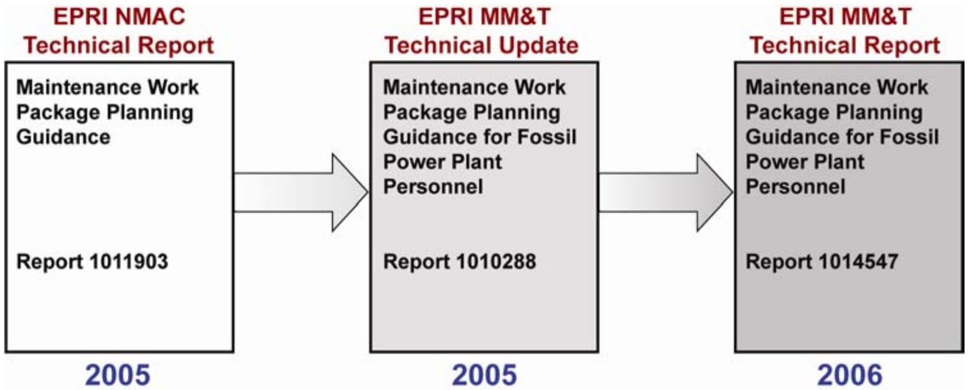

Figure 1-1
Background Regarding the Development of This Report

1.3 Report Structure and Content Overview

Figure 1-2 illustrates the general structure and content of this technical report. The figure identifies key sections in the report that provide guidance to owners to consistently develop and use work packages of high quality.

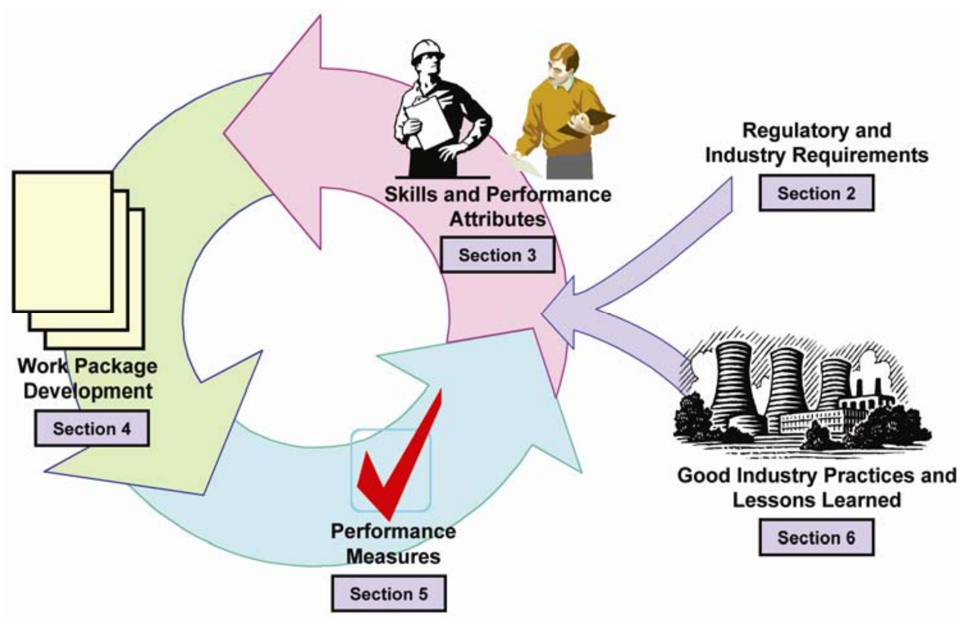

Figure 1-2
Scope and Content of This Report

Section 2 provides an overview of regulatory and industry requirements addressing work package content, level of detail, and quality. Section 3 describes skills and performance attributes that are essential among work planners and the personnel who implement the work packages. The focus of the report is Section 4, which provides guidance for developing work packages. Section 4 relates different types of work activities and other parameters to various general categories of work packages. It also provides guidance for establishing an appropriate structure, format, and content for work instructions, the primary element of a quality work package. Section 5 provides several methods for measuring the quality of work packages. Section 6 presents good industry practices and lessons learned, and Section 7 lists the reference and source materials used during the development of this report.

1.4 Terms and Acronyms

1.4.1 Industry Nomenclature and Definitions

Alternate verification techniques. The use of any additional means to verify an action. These actions include but are not limited to the use of status lights, control room indicators, and functional checks such as flow, temperature, or pressure indications.

Backlog (planning). Work orders not planned by the on-line and outage performance indicators or milestones (as determined by each owner/site).

Corrective maintenance. The classification of any work on power block systems or components in which the equipment has failed or is significantly degraded to the point that failure is imminent (within its operating cycle or preventive maintenance interval) and no longer conforms to or is incapable of performing the equipment's design function.

Critical component. A component that has been evaluated and subsequently categorized as critical, based on owner-specific programs, if applicable.

Critical spare. A spare or replacement item that is identified and controlled in a manner that continually enhances the reliability of the equipment in which it is used, based on either customer demands or the ability to have the item available when needed or both.

Critical step. An irrevocable act whereby improper implementation could result in a plant transient or trip, damage to or improper or unintended function of significant plant equipment, or significant rework or an injury to self or others.

Facilities. Structures, systems, and components not associated with power generation. Structures might include training facilities, warehouses, maintenance shops, and administrative offices. Systems might include fire protection, plumbing, lighting, sewer, and drainage.

First check. The act of an individual establishing verbal communication with the dispatching facility or first line supervisor to ensure that the first component manipulation for a specific task is performed on the proper unit and train.

Flagging. A distinct form of marking that is used to identify components to be worked on or manipulated; it is used to ensure that workers do not work on or manipulate wrong components that are similar in location or appearance.

Generation-sensitive activity. An operational, maintenance, or testing activity that has the potential to cause a unit trip, runback, or derating.

Non-power block equipment. Equipment, buildings, and structures that are not essential for power generation. In most instances, this equipment can also be referred to as facilities maintenance, but it is recognized that this distinction might vary among stations.

Outside of procedures, parameters, or processes (OOPs). A human performance tool that can be used effectively to prevent knowledge-based errors.

Peer check. A series of actions by two individuals working together at the same time and place, before and during a specific action, to prevent an error by the performer. Unlike concurrent verification, peer check can involve audio and visual cues. When required by the supervisor or controlling document, a peer check can be documented.

Periodic maintenance. Time-based preventive maintenance actions taken to maintain a piece of equipment within design operating conditions and to extend its life.

Power block equipment. All equipment required for the safe and reliable operation of the station. It includes all safety-related and balance-of-plant systems and components required for the operation of the station, including radioactive waste processing and storage and switchyard equipment maintained by the station. Equipment required to maintain federal or state regulatory compliance should be included in this grouping. It does not include buildings or structures that support station staff, such as offices or storage structures, or the HVAC and support systems focused only on habitability of those structures. It is recognized that this distinction might vary among stations.

Pre-job brief. An interactive dialogue among those involved in the work to ensure that all personnel understand the scope of what is to be accomplished, procedural steps, roles and responsibilities, and hazards and controls that provide a heightened level of awareness of significant aspects of the task.

Predictive maintenance. Condition-based preventive maintenance actions taken to maintain a piece of equipment within design operating conditions and to extend its life. Predictive maintenance involves troubleshooting, inspection, and testing to assess the condition of an SSC.

Preventive maintenance (PM). Both predictive (condition-based) and periodic or planned (time-based) actions taken to maintain a piece of equipment within design operating conditions and to extend its life.

Qualified individual. For the purposes of concurrent verification and independent verification, a person who has been determined by station management to be qualified to perform verification activities. As a minimum, this individual shall be trained in human performance verification techniques.

Robust operational barriers. Marking or covering of components not being worked on that are within close proximity to similar components being worked or manipulated. This practice ensures that workers are not diverted to and subsequently manipulate the incorrect component.

Self check. An attention-management technique that an individual uses to focus attention on the appropriate component, to think about the intended action and its expected outcome before performance, and to verify component condition after performance.

Stop, think, act, review (STAR). A human performance tool that includes distinct thoughts and actions designed to enhance an individual's attention to detail. STAR is an expected, undocumented standard of performance for personnel at all times during their daily work activities. An individual must be 100 percent sure that the action to be taken is correct before manipulating any equipment. The use of STAR self checks by personnel must be recognizable by any observer at a distance.

Work instruction. Instructions for performance of the work to be accomplished, the level of detail of which depends on the assigned planning level. When applicable, approved procedures can be referenced and can suffice as work instructions.

Work order. A document used to control work and testing activities.

Work package. A compilation of documents including the work order, work instructions, and any other supporting material (that is, drawings, vendor manuals, weld process sheets, operating experience, safety analysis, permits, and so on).

1.4.2 Acronyms and Abbreviations

ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
BOM	bill of material
EDB	equipment database
EUCG	Electric Utility Cost Group
FIN	fix-it-now
FMAC	Fossil Maintenance Applications Center

FME	foreign material exclusion
HUP	human performance
HVAC	heating, ventilating, and air conditioning
M&TE	measurement and test equipment
MCR	main control room
MOV	motor-operated valve
MOVT	motor-operated valve test, motor-operated valve testing
MPPG	Maintenance Planning Peer Group
NIST	National Institute of Standards and Technology
NMAC	Nuclear Maintenance Applications Center
O&M	operations and maintenance
OOPs	outside of procedures, parameters or processes
OSHA	Occupational Safety and Health Administration
P&ID	piping and instrumentation drawing
PM	preventive maintenance
PMT	post-maintenance test, post-maintenance testing
QC	quality control
STAR	stop, think, act, review

1.5 Relationship with EPRI Maintenance Center and to Other EPRI Reports

The development of this report was made possible through the close working relationship among the utility work planning community, the EPRI Nuclear and Fossil Maintenance Application Centers (NMAC and FMAC), and the EPRI Maintenance Management and Technology (MM&T) group. EPRI MM&T continues to serve as a key resource for work planners by providing a wide range of products, including technical reports addressing maintenance processes and system or equipment maintenance guidance with a focus on improving equipment reliability.

During the development of this report, a number of these EPRI products were identified that already provide detailed guidance regarding a work activity or work process. In many cases, the work planning function was included in the work process description, but not to the level of detail provided in this report. These existing EPRI reports were primarily used as source material to ensure consistency of applied guidance among owners, and include the following:

- *Facilities Maintenance Guide* (1009670)
- *Guidance for Developing and Implementing an On-Line Maintenance Strategy* (1009708)
- *Guideline for System Monitoring by System Engineers* (TR-107668)
- *Guidelines for Optimizing the Engineering Change Process for Nuclear Power Plants: October 1998 Revision* (TR-103586-R1)
- *Maintenance Work Package Planning Guidance* (1011903)
- *Maintenance Work Package Planning Guidance for Fossil Power Plant Personnel* (1010288)
- *NMAC Post Maintenance Testing Guide, Revision 1* (1009709)
- *System and Equipment Troubleshooting Guideline* (1003093)

1.6 Key Points

Throughout this report, key information is summarized in “Key Points.” Key Points are bold lettered boxes that succinctly restate information covered in detail in the surrounding text, making the key point easier to locate.

The primary intent of a Key Point is to emphasize information that will allow individuals to take action for the benefit of their plant. The information included in these Key Points was selected by MM&T personnel, consultants, and utility personnel who prepared and reviewed this report.

The Key Points are organized according to the three categories: operations and maintenance (O&M) cost points, technical points, and human performance points. Each category has an identifying icon, as shown below, to draw attention to it when quickly reviewing the guide.

Key O&M Cost Point

Emphasizes information that will result in reduced purchase, operating, or maintenance costs.

Key Technical Point

Targets information that will lead to improved equipment reliability.

Key Human Performance Point

Denotes information that requires personnel action or consideration in order to prevent injury or damage or ease completion of the task.

Appendix A contains a listing of all Key Points in each category. The listing restates each Key Point and provides a reference to its location in the body of the report. By reviewing this listing, users of this guide can determine whether they have taken advantage of key information that the writers of this guide believe would benefit their plants.

2
OVERVIEW OF REGULATORY REQUIREMENTS AND SOURCES OF INDUSTRY GUIDANCE

2.1 General Areas Regulated by Federal or State Agencies

In the fossil power industry, there are typically few regulations that directly affect the development, structure, content, or documentation of maintenance work packages. The user of this report should be aware, however, that regulations in the following areas might need to be referenced in some work packages, depending on site procedures:

- **Environmental protection regulations**. Emissions and byproducts from fossil plants are typically controlled and regulated by the state and federal Environmental Protection Agency.
- **Regulations addressing the calibration of measurement and test equipment**. The National Institute of Standards and Technology (NIST) often controls the calibration of measurement and test equipment.
- **Regulations pertaining to personnel safety**. The Occupational Safety and Health Administration (OSHA) provides regulations regarding personnel safety, some of which are applicable to maintenance work performed at fossil power plants.

2.2 Requirements Imposed by Insuring Organizations

In addition to federal or state regulations governing the general areas described in Section 2.1, the fossil power plant work planners should be aware that the owner’s insurance companies might impose requirements regarding maintenance work performed on certain components. Though not regulatory in nature, these requirements might need to be considered when developing work packages and component-specific work instructions and might also impact the rigor associated with a given work package.

2.3 Sources of Industry Guidance

Many fossil power plant maintenance and work planning personnel participate in the Maintenance Planning Peer Group (MPPG). This organization meets annually to discuss a wide array of topics regarding the work planning process and lessons learned in the industry that can be shared among utility personnel. MPPG was started by the Electric Utility Cost Group (EUCG) and was initially focused on planning and scheduling issues at power plants. Although the tie with the EUCG has since been broken, members have provided value throughout the fossil power industry by continuing the MPPG meetings and inviting both plant maintenance and work planning personnel to participate.

2.4 System and Equipment Categorization

To better manage the regulatory and administrative requirements associated with work performed on certain systems and types of equipment at the plant, some fossil plant owners have instituted a process for categorizing systems and equipment based on the following factors:

- Impact on plant generation and reliability
- Impact on environmental protection and compliance
- Potential to cause a plant trip or inadvertent shutdown
- Potential to cause injury to plant maintenance and operations personnel

The system and equipment categorization process is optional and is described in this report only to make owners aware of the process and the benefits that can be achieved when using the graded approach for developing work packages.

3

SKILLS AND PERFORMANCE ATTRIBUTES FOR KEY PERSONNEL

3.1 Basic Premise of the Relationship Between the Planner and Implementers

3.1.1 Reliance on the Skill of the Craft

Key Human Performance Point

The more reliance the planner places on the skill of the craft, the less detail the planner must communicate to the craft in the work package. Similarly, the less reliance the planner places on the skill of the craft, the more detail the planner must provide to the craft in order for the work to be done correctly.

Figure 3-1 shows that, in general, the more reliance the planner places on the skill of the craft, the less detail the planner must communicate to the craft in the work package. Similarly, the less reliance the planner places on the skill of the craft, the more detail the planner must provide to the craft in order for the work to be done correctly. Section 4.2 of this report provides a number of factors that the planner should consider when determining the most appropriate type of work package and the subsequent level of detail communicated to the craft labor.

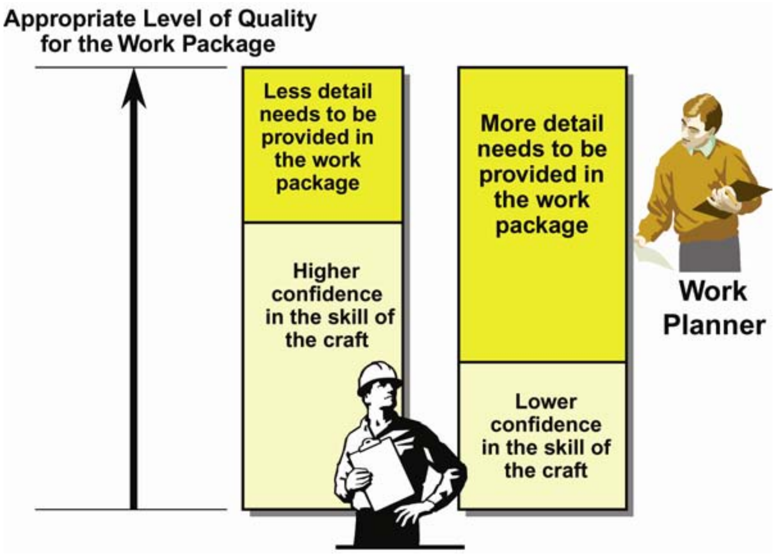

Figure 3-1
Relationship Between the Planner and the Implementers

> **Key Human Performance Point**
>
> Planners should not assume craft skills beyond those fundamental attributes described in this report.

> **Key Human Performance Point**
>
> Planners should not assume that a given work activity will necessarily be performed by one particular individual or team.

A work planner at a fossil power plant should also consider the impact that not having detailed work packages might have on performing work in the future. This consideration is important because the experience level of in-house and contract labor is not as high as it was in the past.

3.1.2 Alignment of Planners with Organizational Structure

Depending on the organizational structure at a given fossil unit, plant site, or corporate-level organization, there are various ways to align planners with the implementing organizations. The following subsections present some options for consideration.

3.1.2.1 Alignment Based on Technical Dispute

In many cases, planners are assigned to work with only a manageable number of crews and those crews with whom the planner shares the same technical knowledge and expertise. For example, a planner with a mechanical background might be responsible for working with three particular crews specializing in maintenance of mechanical rotating equipment.

The primary benefit of this alignment is that it uses more of a traditional concept, so broader application of the planner resource can be used.

The challenges of this alignment can be summarized as follows:

- It becomes difficult to gain an in-depth knowledge of a given component's history because different planners are assigned to the same component over time.
- It becomes difficult to develop consistent, in-depth work instructions, and reliance tends to be placed more heavily on technician knowledge to fill the gaps.
- What one planner learns during package preparation for a specific component might have to be learned again by a different planner in the next evolution, which becomes inefficient and can create errors in planning.
- The planner should check equipment and work order history for additional information.

3.1.2.2 Planner Integrated into the Maintenance Team

This working relationship is often referred to as the "planner-to-the-team" concept. The benefits of this relationship can be summarized as follows:

- The relationship provides a direct benefit to the success of the team by aligning the planner to that team.
- The planner becomes very knowledgeable about the expected package product of the end user, which results in less customization.
- The planner can perform a walkdown and write the package with the technicians who will be performing the work, which means fewer rewrites and edits.
- There is direct alignment with the team's mission and vision. Management should ensure that someone with supervisory authority coordinates planning activities to ensure consistency in this instance.

The challenges associated with maintaining this relationship can be summarized as follows:

- Planners could be redirected by the team supervisor to perform many duties other than planning.
- It becomes difficult to manage global planning issues (quality, error prevention, and standardization) because the planners are scattered among maintenance teams.
- The work package, if handed to another team, might not have the level of detail needed to perform the work.

3.1.2.3 Planners Aligned by Component/Equipment Type

Some plants assign planners based on various types of components or equipment, such as rotating equipment, valves, piping, and switchgear. The two primary benefits of this type of alignment are that 1) it creates expertise in equipment and its history so that more complete and detailed packages can be provided, and 2) if maintenance teams are aligned similarly, it provides a direct relationship with the teams.

The primary challenge of this alignment is that it has a tendency to create specialists and decreases “bench strength” in equipment knowledge. Under the dedicated team concept, a planner can develop extensive specialized skills that would be difficult to replace.

3.1.2.4 Planners Aligned by System Type

Some plants assign planners based on various plant systems, such as the following primary systems that are most commonly addressed at a fossil power station:

- Fuel supply
- Fuel burning
- Boiler
- Boiler air and gas
- General service water
- Feedwater
- Condensate
- Turbine
- Generator
- Station service
- Ash handling

The two primary benefits of this type of alignment are that 1) it creates expertise in system performance, reliability, and history so that more complete and detailed packages can be provided, and 2) if maintenance teams are aligned similarly, it provides a direct relationship with the teams.

The primary challenge of this alignment is that it has a tendency to create system specialists and decreases “bench strength” in knowledge of other operating systems.

3.1.2.5 Summary of Planner Alignment Options

In all these possible alignments, planners should report directly to a planning supervisor in most cases—not the craft supervisors of the disciplines, teams, or component types. An exception might be when the alignment is made in a fix-it-now (FIN) team environment.

> **Key Human Performance Point**
>
> In most cases, planners should report directly to a planning supervisor—not the craft supervisors of the disciplines, teams, or component types.

3.2 Work Package Planners

3.2.1 Typical Functions of Planners

Not all of the functions listed in this section will necessarily be performed by work planners at every site. In a few cases, some of these functions might be performed more effectively by other organizations. However, for the purpose of this report, the list attempts to address as many planning functions as possible, regardless of who performs them in a given organization.

Typical functions of individuals who perform the work package planning and preparation at a fossil power plant include the following:

- Correctly translating engineering design documents into maintenance work documents, while maintaining the design basis of the plant in accordance with the configuration program

> **Key Human Performance Point**
>
> The work planner should ensure that the work package does **not** change the design configuration without required documentation.

- Developing maintenance work documents, administrative controls, specific work instructions, and post-maintenance test requirements to provide instructions to plant personnel to ensure safe and efficient operation of the unit, performance of troubleshooting activities and corrective maintenance, technical specifications, vendor recommendations, engineering documents, and environmental compliance guidelines
- Preparing and updating work packages to resolve condition reports, routine activities, reported deficiencies, or enhancements to ensure completion within the established deadlines and schedules
- Applying vendor recommendations, equipment reliability data, corrective action program data, and industry operating experience to PM bases evaluations to optimize preventive maintenance performed with resources available and adjust maintenance frequencies accordingly, and meet design requirements
- Identifying and specifying correct parts and materials to support work package activities, including identification and coding of contingency material where appropriate

- Ensuring that quality requirements and sufficient quantity are reserved to facilitate repairs or replacements identified in work packages
- Identifying and initiating required material and vendor services and preparing applicable procurement and vendor contract requests to ensure cost efficiency in support of maintenance and design change packages for planned outages and online work activities
- Supplying the procurement organization with technical field information to ensure that correct parts are procured
- Initiating procurement requests for new and obsolete equipment and components, considering lead times of procured items
- Specifying special tools and equipment
- Supporting shop personnel during performance of work packages through the use of work package revisions or addenda, generation of subsequent or support work packages to correct emergent problems, and clarifying work package issues
- Resolving shop feedback forms and electronic files
- Providing input and status updates for coordination requirements to the planning supervisor as requested
- Properly addressing modification and acceptance testing activities for modifications assigned, by attending modification meetings, developing work instructions, and assembling work packages
- Providing or identifying all appropriate documentation and attachments for special requirements such as foreign material exclusion, weld traveler forms, and permits
- Preparing post-maintenance testing in accordance with site-specific PMT procedures
- Reviewing the work package request to determine the required in-process and post-maintenance tests based on the work to be performed
- Determining non-regulatory testing, such as good maintenance practices, and routing through operations for verification
- Assisting planning supervisors or other planners with training new planners using on-the-job techniques, procedure-required reading, station-unique practices, and so on
- Attending training for technician level activities as appropriate to support the front line work groups in the field to obtain outage and non-outage scheduled goals
- Performing additional duties and responsibilities as identified in other site-specific procedures and documents
- Ensuring that quality and attention to detail are part of the work package development process
- Considering human performance attributes during the development of work packages
- Identifying applicable drawings

3.2.2 Typical Work Planner Position Summary, Experience, and Skills

3.2.2.1 Position Summary

The following is an example of a typical work planner position summary:

- Develops, maintains, and completes maintenance work packages, design change work packages, and maintenance, surveillance, fire protection, departmental procedures, preventive maintenance tasks, preventive maintenance basis, and pre-approved work instructions to comply with plant documents, preventive maintenance, and equipment reliability programs
- Provides technical direction and work process support to maintenance technicians
- Interfaces with and assists various departments in the development of permanent and temporary design changes, the identification of material required for these changes, and the resolution of technical and work process problems
- Performs impact reviews of engineering design basis documents and revises maintenance work documents accordingly, to maintain plant configuration
- Participates in plant system teams in developing or modifying PM basis and plant modifications

3.2.2.2 Typical Expertise and Experience Level

Table 3-1 describes typical expertise and experience levels for a work planner and a senior work planner/advisor. Care should be taken not to interpret these as minimum requirements for qualification or certification purposes, but rather as a benchmark for use within each owner's plant-specific program.

Table 3-1
Typical Expertise and Experience Levels

Work Planner	Senior Work Planner/Advisor
Entry level with minimal or no experience as a planner/advisor AND:	Three years of experience as a planner/advisor or equivalent type experience AND:
Completion of an applicable apprenticeship program or five years of applicable trade experience and a high school diploma or equivalent; OR	Ten years of applicable trade discipline fossil power experience and a high school diploma or equivalent; OR
Two years of experience in maintenance, engineering, or fossil plant operations and an Associate's degree in engineering or related physical science; OR	Eight years of experience in maintenance, engineering, or fossil plant operations and an Associate's degree in engineering or related physical science; OR
One year of experience in maintenance, engineering, or fossil plant operations and a Bachelor's degree in engineering or related physical science	Six years of experience in maintenance, engineering, or fossil plant operations and a Bachelor's degree in engineering or related physical science

Key O&M Cost Point

One advantage of having an individual with a degree is the person's computer literacy and ability to process maintenance work orders within the site's information management system.

3.2.2.3 Typical Competencies and Skills of the Work Planner

The following describes skills and competencies common among many individuals performing the work planner functions described in the previous sections. Care should be taken not to interpret these as minimum requirements for qualification or certification purposes, but rather as a benchmark for use within each owner's plant-specific program.

- **Adaptability**. Adjusts quickly to change; remains flexible and productive in times of continuing change
- **Creativity**. Generates creative solutions to work situations; tries different and novel ways to deal with organizational problems and opportunities
- **Communication skills**. Expresses ideas clearly and effectively; adjusts language or terminology to the characteristics of the audience; uses appropriate organization, structure, and grammar in written communication
- **Coaching skills**. Uses appropriate styles to coach, inspire, and guide employees to achieve goals
- **Planning and organization skills**. Establishes a course of action for self and others to accomplish a specific goal; plans proper assignments of personnel and appropriate allocation of resources; establishes procedures to monitor the results of delegations, assignments, or projects

3.3 Basic Skill Sets for Work Package Users/Implementers

3.3.1 Generic Skill Sets

Planners should not assume that individuals possess craft skills beyond those fundamental attributes described in this section. Similarly, planners should not assume that a given work activity will necessarily be performed by one particular individual or team. Figure 3-2 illustrates the generic skill sets that a planner should be able to rely on, however, given the typical minimum requirements that craft labor is expected to meet.

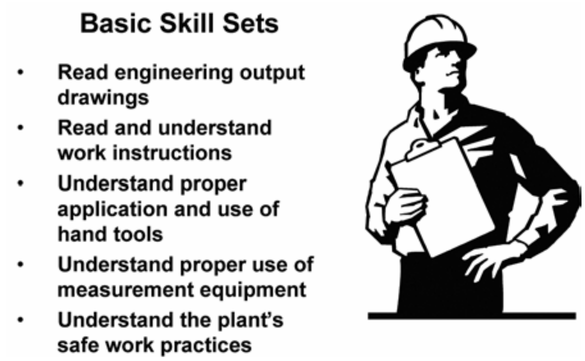

Figure 3-2
Generic Skill Sets Assumed for Craft Labor

The following items describe the basic skill sets that planners should be able to rely on:

- **Read engineering output drawings**. Planners should assume in nearly all cases that the craft labor has been adequately trained to read engineering output drawings such as P&IDs, electrical schematics, electrical line drawings, and flow diagrams. Also included might be information furnished by the supplier or manufacturer, such as component assembly drawings, catalog cuts, component outline drawings, and spare part or replacement item information.
- **Read and understand work instructions**. Planners should assume that the craft labor is able to read and understand the work instructions provided in the work package. Care should be taken to ensure that the instructions are written clearly and contain only the information necessary for the craft labor to perform the work activity.
- **Understand proper application and use of hand tools**. Planners can assume that the craft labor has been adequately trained on the use of hand tools commonly used to perform work activities in their particular technical discipline.
- **Understand proper use of measurement equipment**. Planners should assume that the craft labor has been adequately trained on the use of measurement equipment commonly used to verify the accuracy of work activities in their particular technical discipline.
- **Understand the plant's safe work practices**. In most cases, planners can assume that the craft labor has an appreciation of the plant's safe work practices as a result of their commonality among fossil stations.

Given these basic skill sets, the planner should assess on a case-by-case basis whether additional instructions are needed to ensure that the work activity is performed effectively and safely.

To be conservative, the planner should not assume basic skill sets beyond those listed in this section and should provide the necessary information to the craft labor in the work package. Planners should **not** assume that the craft labor necessarily has all of the following generic skill sets or knowledge:

- Component design and their functions
- Adverse impacts on systems directly affecting generation or environmental control (appreciation of errors that could cause a generator trip and assessing the risk of the maintenance task and managing that risk)
- Risks associated with improperly performing the work activity (fire, personal injury, and so on)
- Special personnel safety requirements
- Application and use of special tools or required measurement and test equipment
- Use of plant-specific computer software (such as EMPAC, SAP, PassPort, or Maximo software), ability to research parts databases or bills of materials (BOMs), or ability to research equipment databases (EDB)

If the craft labor has been properly trained and has the correct level of supervisory oversight, the planner might be able to assume that the laborer possesses some if not all of the skills and knowledge listed here.

3.3.2 Basic Discipline-Specific Skill Sets

The basic discipline-specific skill sets that are commonly assumed among craft labor are often referred to as the “skill of the craft.” These work skills are accumulated knowledge from basic craft experience or those skills resulting from training required to obtain independent qualification or enhanced basic journeyman skills. The essential skills of the craft are typically maintained through involvement in an accredited training program.

Skill-of-the-craft skills are considered to be standard industry practices and might not require step-by-step instructions or an approved procedure in hand for work to proceed or be effectively accomplished. Error tolerance and the possible effects on plant operations should be used as considerations when assessing the need for work instructions or procedures.

Key Human Performance Point

The use of skill of the craft in the performance of a job is not considered a change of work scope if it is confined to the job covered by the work package and all other work done is in agreement with approved procedures.

Table 3-2 illustrates typical skills of the craft that, in most cases, can be established as the minimum skills possessed by any craft laborer in a particular discipline. The skills of most craft laborers exceed those listed in the table; however, for the purposes of establishing a minimum baseline in this report, the following tables should be used as a benchmark.

Table 3-2
Typical Minimum Expected Skills of the Craft

Work Activity	Mechanical	Electrical	I&C	Facilities	HVAC
Air filter, motor: Replace.	X				X
Bolts: Replace with identical item only.	X				
Bolts: Tighten.	X	X	X		X
Cable raceways: Adjust or replace screws.		X			X
Calibration (electrical meters/transducers, pneumatic timing tools).			X		X
Circuits: Check voltage and current measurements.		X	X		X
Computer inks, paper, recorders, and so on: Replace.			X		X
Conduit covers, brackets and screws: Replace, grease, and lubricate.		X			X
Convenience outlets: Rework or replace.		X			X
Corrosion (abrasive or chemical): Remove.	X			X	X
Doors (non-security/fire protection): Replace or repair knobs, locks, hinges, closures, flushbolts, and so on.	X			X	
Drains: Blow out, clear.	X			X	X
Electrical insulation: Check resistance.		X	X		X
Extension cords: Plug in and use.	X	X	X	X	X
Fasteners: Cut to length.	X	X	X		X
Fencing: Rework or replace.	X			X	
Filters: Replace or clean.	X	X	X		X

Table 3-2 (continued)
Typical Minimum Expected Skills of the Craft

Work Activity	Mechanical	Electrical	I&C	Facilities	HVAC
Fuses: Replace with identical item only.		X	X		X
Gaskets: Replace.	X	X	X		X
Grating and grating clips: Rework and replace.	X			X	X
Greasing.	X	X			
Handrail barriers: Rework or replace.	X			X	
Handwheels: Replace or rework.	X				X
Housekeeping, general cleaning, inspection.	X	X	X	X	X
Instrument fittings: Replace.			X		X
Instrument isolation valves: Rework or replace handwheels.	X		X		X
Instrument tubing: Rework or replace support clips, screws, spring washers, or shims.	X		X		X
Instrument tubing: Tighten.	X		X		X
Insulation: Rework and replace screws or bands.				X	X
Junction boxes: Replace gaskets, covers or screws, and latches.		X	X		X
Lenses and caps: Replace.		X	X		X
Light fixtures: Rework or replace.		X		X	X
Lubrication.	X	X			
Masonry: Rework.	X			X	
Nameplates, tags, cover plates, inspection plates: Replace.		X	X		X
Non-skid applications.	X			X	
O-rings: Replace.	X	X	X		X
Pipe flanges: Tighten to stop leakage.	X				X
Plug-in components: Replace.		X	X		X

Table 3-2 (continued)
Typical Minimum Expected Skills of the Craft

Work Activity	Mechanical	Electrical	I&C	Facilities	HVAC
Pumps: Adjust packing.	X				X
Pumps/motors: Add oil or grease.	X	X			X
Refrigerant: Trim charge.		X		X	X
Refrigeration: Remove oil from refrigeration plants.		X		X	X
Roofing (non-fire-barrier asphalt, metal, and so on): Rework.				X	
Seals: Replace.	X				X
Soldering (piping and wiring).	X		X		X
Stairs: Rework (nosings, steps, handrails).	X			X	
Telephone/plant paging system: Rework or replace handles, knobs, switches.		X			
Threads: Clean (mechanical means).	X				X
Tubing: Install (except on seismic restraints), fitting, makeup.	X		X		X
Turbine diaphragms: Seal with RTV/VIP to stop in-leakage.	X				
Valve lapping.	X				X
Valve packing (manual): Adjust.	X				X
Valve stems (manual): Lubricate.	X				X
Walls (non-fire- barrier gypsum, plaster, metal, concrete): Rework.				X	
Welding/brazing.	X				
Wire wrapping (except on printed circuit boards).		X			X

3.4 Fix-It-Now Teams

At some fossil stations, the terms “tool pouch maintenance” and “minor maintenance” are used synonymously, and are often performed by fix-it-now (FIN) teams. These teams perform maintenance activities that are not limited by scope but are usually short-duration, urgent tasks that require some coordination among disciplines and organizations. This process takes maximum advantage of a multi-skilled crew that can perform tasks with minimal planning and scheduling and typically uses either skill of the craft or pre-approved procedures to perform the work.

At some fossil power plants, FIN teams are special cross-functional work teams assembled as a self-sufficient work group capable of independently performing work without outside support. These teams accomplish work outside the normal schedule on a real-time and immediate basis. Stations should establish work limitation guidance for the FIN teams. This ensures that high-risk and complex work activities are still subject to the full planning, preparation, and review process.

The primary purpose of the FIN team is to perform emergent work that has a direct impact on plant operation or is relied on by operations to control the plant during normal, abnormal, and emergency conditions. By accommodating emergent work, the workweek schedule and the shop resources assigned are protected. FIN teams can also be used for routine maintenance.

4
RECOMMENDED WORK PACKAGE DEVELOPMENT GUIDELINES

Experience suggests that there is no one way to categorize and control work-planning activities. The ways in which the work activities were categorized by owners—and subsequently the rigor associated with the work planning and the level of detail in the resulting work package—varied significantly from plant to plant. The reader should keep in mind that many variables are associated with the planning and conduct of maintenance/work activities, some of which are noted in Figure 4-1.

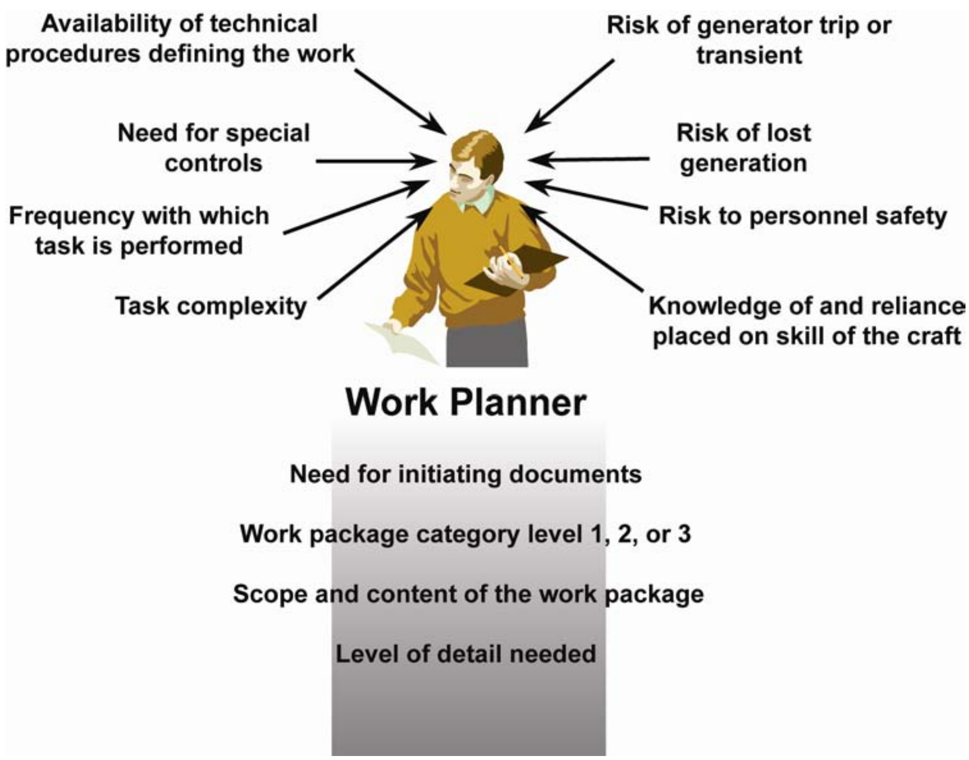

Figure 4-1
Variables Associated with the Planning and Conduct of Work Activities

Figure 4-1 illustrates that after the planner considers these factors, decisions can be made regarding the outputs necessary to plan and execute the work activity. The output decisions are described throughout this section.

This report provides a consensus approach for categorizing and associating these variables to provide each owner with a benchmark from which to adjust their own work procedures, if warranted and desirable.

4.1 General Categories of Maintenance and Work Packages

Table 4-1 provides guidance for determining the most appropriate type of work package (Level 1 or 2), or for identifying those circumstances when a work package might not be required at all (Level 3). The level designation refers to the work planner's level of effort and rigor needed to prepare an appropriate work package, not necessarily the amount of information in the package itself. Using a graded approach to planning has proven to be an effective way to optimize the work planning effort to ensure that maintenance activities are performed correctly and equipment reliability is sustained.

Table 4-1
Factors Affecting the Levels of Work Packages

Determining Factors or Criteria	Level 1 (Detailed Work Package)	Level 2 (Simple Work Package)	Level 3 (Minor Maintenance: Work Instructions Not Required)
Task complexity (see note)	Complex	Simple	Simple
Frequency with which work is performed (see note)	Infrequent (greater than one outage cycle elapses between work)	Frequent (one or fewer outage cycles elapse between work)	Frequent (one or fewer outage cycles elapse between work)
Requirement for and availability of technical procedure defining the work	Necessary; does not exist	Necessary; available and sufficient	Typically not needed
Risk of generator trip or transient	High risk	Low risk	No risk
Risk of lost generation	High risk	Low risk	No risk
Risk to personnel safety	High risk	Low risk	Very low risk
Need for special controls	Yes	Possibly	No
Reliance on skill of the craft	Minimal	Some	High

Note: Both the complexity of the task and the frequency with which it is performed affect the probability of quality work being repeated consistently each time that task is performed. The planner should consider these factors when determining the type of work package and the subsequent level of detail communicated to the craft labor.

4.1.1 Level 1: Detailed Work Package

As shown in Table 4-1, a detailed work package is most appropriate for non-routine tasks that are fairly complex and performed infrequently. Because of the complexity of the work, detailed instructions are needed but are not already available in existing maintenance instructions or procedures. Therefore, the details must be developed and communicated to the craft in the work package.

Work that presents a high risk of loss of generation or trip of the unit or generator typically warrants detailed instructions as a means to preclude these events from occurring. Work that presents a high risk to personnel safety or risk of exposure to contaminants requires a detailed work package.

For cases in which special controls—such as task-specific work permits, confined space permits, and other kinds of permits—are required, a detailed work package might be required. Finally, when detailed work packages are prepared, there is minimal reliance on the skill of the craft, other than ensuring that the individuals have the fundamental skills described in this report.

Key Human Performance Point

A detailed work package is most appropriate for non-routine tasks that are fairly complex and performed infrequently.

4.1.2 Level 2: Simple Work Package

If detailed instructions are already available in existing maintenance instructions or procedures, a simple work package could be appropriate for non-routine tasks that are fairly complex and performed infrequently. The details need not be developed and communicated to the craft in the work package except through a cross-reference to or the inclusion of the existing documents.

Typically, work defined by special programs such as ASME or ANSI B31.1 would not be performed using a simple work package unless the necessary detailed instructions had already been developed and could be cross-referenced or included in the work package. Work that presents a low risk to loss of generation or trip of the unit or generator might not warrant detailed instructions as a means to preclude these events from occurring, and so a simple work package would probably be appropriate. For cases in which the work presents a low risk to personnel safety or contaminant exposure, a simple work package could be used. A simple work package is often appropriate for cases in which no special controls are needed.

In general, when simple work packages are prepared and used, there is more reliance on the skill of the craft to ensure that the work is done correctly.

Key Human Performance Point

A simple work package could be appropriate for non-routine tasks that are fairly complex and performed infrequently if detailed instructions are already available in existing maintenance instructions or procedures.

4.1.3 Level 3: Minor Maintenance (No Work Instructions Required)

As shown in Table 4-1, no work instructions would be required for routine tasks that are fairly simple and performed frequently. Therefore, work instruction details need not be developed and communicated to the craft in either a work package or through cross-reference to an existing work instruction or procedure. Work that presents no risk of loss of generation or trip of the unit/generator would preclude the need for detailed work instructions as a means to prevent these events from occurring; therefore, no work instructions would be required. For cases in which the work presents little or no risk to personnel safety or contaminant exposure, a work instruction would probably not be required.

In general, when no work instructions are prepared and used, there is very high reliance on the skill of the craft to ensure that the work is done correctly. Heavy reliance on the skill of the craft should be deemed appropriate only after careful consideration of the factors considered in Tables 4-1 and 4-2.

Work activities that are performed without work instructions are referred to as minor maintenance and can be defined as follows:

> Minor maintenance is a methodology for implementing work that is minor in scope and does not affect fossil safety functions or increase the risk of plant transients. Normally, work implemented and processed under minor maintenance would not require significant station support for tools and consumables identification, station clearance, and work permits or controls. Little to no package planning would be required because the work would be accomplished under what is characterized as skill of the craft.

Key Human Performance Point

No work instructions would typically be required for routine tasks that are fairly simple and performed frequently.

4.1.4 Tool Pouch Maintenance

Work activities that are performed without work instructions and without an initiating document are sometimes referred to as tool pouch maintenance. *Tool pouch maintenance* can be defined as "a methodology by which work is accomplished that requires no initiating work documents."

In general, common industry practice recognizes the following criteria for a work activity constituting tool pouch maintenance:

- The design function of any system or component will not be affected.
- Correction of the problem requires no documentation or planning to initiate work.
- Work will not interrupt the process flow of fluid, air, or electrical current to operating or standby equipment that is important to plant operation or safety.

- The equipment does not need significant support or operational impact reviews to be deenergized or isolated.
- Work will not interrupt or otherwise affect scheduled activities.

At some fossil stations, the terms *tool pouch maintenance* and *minor maintenance* are used synonymously, and the work is often performed by FIN teams.

4.2 Relationship Between the Category of Maintenance and the Use of Work Packages

As shown in Figure 4-1 and Table 4-1, the determination of the level of detail required for a given work package should consider the following:

- Complexity of the task
- Frequency with which work is performed
- Availability of technical procedures defining the work
- Risk of generator trip or transient
- Risk of lost generation
- Risk to personnel safety
- Need for special controls
- Reliance on skill of the craft

The risks and complexity of the task are often dictated by the type of equipment being affected by the work activity and, in general, by the location of the equipment within the plant or on the plant site. Table 4-2 is a matrix for identifying the most likely type of work package used for a given task. Other factors and criteria that might be considered for determining the most appropriate type of work package are presented in Table 4-1.

Table 4-2
Work Package Usage Based on Type of Work Activity and Location

Work Activity	Power Block Systems and Equipment	Non-Power Block Systems and Equipment or Administrative Facilities or Buildings
Preventive maintenance (condition-based or periodic)	Level 1 or 2	Level 3
Corrective maintenance	Level 1 or 2	Level 3
Design modification	Level 1 or 2	Level 1 or 2
Systematic equipment troubleshooting	Level 1	Level 1 or 2
Post-maintenance testing	Level 1 or 2	Level 2 or 3

For the purposes of this report, the columns of Table 4-2 are described as follows:

- **Work activity**. Typical work activities that might require planner involvement and the development of a work package.
- **Power block systems and equipment**. Power block equipment includes all systems and components required for the safe and reliable operation of the station. Systems, structures, or components required to maintain federal or state regulatory compliance should be included in this grouping. It does not include buildings or structures that support station staff, such as offices or storage structures, or the HVAC and support systems focused only on habitability of those structures. It is recognized that this distinction might vary among stations.
- **Non-power block systems and equipment or administrative facilities and buildings**. Structures, systems and components not associated with power generation. Structures can include training facilities, warehouses, maintenance shops, and administrative offices. Systems can include fire protection, plumbing, lighting, sewer and drainage. Extensive guidance for planning, conducting, and scoping facilities maintenance activities are provided in the EPRI report *Facilities Maintenance Guide* (1009670).

Because of the many variables associated with planning work at a fossil power plant, the user is cautioned that Tables 4-1 and 4-2 are not inclusive of all circumstances that a planner might encounter. Therefore, there might be cases in which plant-specific conditions clearly warrant a higher level than is described in the tables.

The following sections describe the rationale for the categories shown in Table 4-2 and the type of work activity being performed. Categories of the work package (that is, Level 1, Level 2, and Level 3) are described in Section 4.1.

4.2.1 Preventive Maintenance

Preventive maintenance (PM) includes predictive (condition-based) and periodic or planned (time-based) actions taken to maintain a piece of equipment within design operating conditions and to extend its life. It is typically performed before equipment failure or to reduce the likelihood of equipment failure. Any planned maintenance that is initiated based on the identification of a deficiency with that equipment (either through predictive techniques or other preventive maintenance activities) should be characterized as corrective, elective, or other maintenance, and it should not be considered preventive maintenance. This applies even if the station uses a preplanned preventive maintenance task to correct the deficiency. The following sub-categories of preventive maintenance are based on scheduling of the actions:

- **Grace period PM**. Any PM task that is to be performed after its original due date but before the late date for that activity. Normally, this time period (due date to late date) is an additional 25 percent of the original schedule interval for the PM task. No engineering evaluation is required. The grace period is provided as reasonable flexibility to allow for alignment with surveillance activities and functional equipment group bundling and to better manage the use of station resources.

- **Deferred PM**. A PM task that exceeds its original late date with an approved engineering evaluation determining the acceptability for extension to a new due date before the original late date is exceeded.
- **Delinquent (overdue) PM**. A PM task that exceeds its late date (grace period) without an approved extension or deferral.

The distinction between predictive (condition-based) maintenance and periodic (time-based) maintenance is presented in the following subsections.

4.2.1.1 Condition-Based Maintenance

> **Key Technical Point**
>
> This type of maintenance consists of condition-based preventive maintenance actions taken to maintain a piece of equipment within design operating conditions and to extend its life. Condition-based maintenance results from troubleshooting, inspection, or testing that assessed the condition of equipment.

Condition-based maintenance results from a predictive maintenance task that was initiated to take measurements. Examples of predictive maintenance are the following:

- Vibration analysis (includes spectral analysis and bearing temperature monitoring) and lubrication oil and grease analysis are used to monitor rotating equipment
- Check valve testing (non-intrusive)
- Infrared surveys (thermography)
- Oil analysis (tribology)
- Diagnostic motor-operated valve testing (MOVT) or valve operation test and evaluation system (VOTES) testing
- Air-operated valve testing

4.2.1.2 Periodic Maintenance

Key Technical Point

Periodic maintenance consists of time-based preventive maintenance actions taken to maintain a piece of equipment within design operating conditions and to extend its life.

Periodic maintenance can be performed to prevent breakdown and can involve servicing such as lubrication, filter changes, cleaning, testing, adjustments, calibrations, and inspections. Periodic maintenance can also be initiated because of the results of predictive maintenance, vendor recommendations, or experience. Examples of periodic maintenance are the following:

- Scheduled valve repacking because of anticipated leakage based on previous experience
- Replacement of bearings or pump realignment as indicated from vibration analysis or lubrication oil analysis
- Major or minor overhauls based on experience or vendor recommendations
- Instrument calibrations used to meet technical requirements that are not in a surveillance (such as flow or pressure instruments used to meet in-service testing flow criteria)

4.2.2 Corrective Maintenance

From a work planning perspective, *corrective maintenance* is defined as “the classification of any work on power block systems, structures, or components (SSCs) where the SSC has failed or is significantly degraded to the point that failure is imminent (within its operating cycle or PM interval) and no longer conforms to or is incapable of performing the SSC’s design function.”

Therefore, as shown in Table 4-2, when performing corrective maintenance on power block equipment, a Level 1 or Level 2 work package would typically be required. Corrective maintenance performed on non-power block equipment or facilities would be considered minor maintenance with no work instructions required (Level 3).

Key Technical Point

Corrective maintenance is the restoration of equipment or components affecting fossil plant availability, personnel safety, environmental compliance, or plant reliability that have failed, degraded, or do not conform to their original design, configuration, or performance.

As a rule, if the specific component requiring maintenance is substantially degraded (for example, packing or bearing degradation) or failed, the action required to repair it is classified as corrective maintenance.

To be considered corrective maintenance, the component must have failed so that it cannot meet its intended functions or—for degradation identified during a PM—the component will reach this state before the next scheduled PM interval. There might be cases in which corrective maintenance could include standing preventive maintenance orders or procedures that are specifically invoked to correct anticipated component degradation.

A component should be considered failed or significantly degraded if the deficiency is similar to any of the following examples:

- The component is removed from service because of actual or incipient failure.
- Significant component degradation affects system operability. The component might be determined operable by engineering assessment, but the degradation is significant and requires immediate corrective action.
- It creates the potential for rapidly increasing component degradation (that is, steam leaks where cutting degradation is possible).
- It releases fluids that create significant exposure or contamination concerns. Minor leaks that can be controlled and managed by simple drip catch containments would not be included.
- It adversely affects controls or process indications that directly or indirectly impair operator ability to operate the plant or that reduce redundancy of important equipment.
- Significant component degradation is identified from the conduct of predictive, periodic, or preventive maintenance that, if not resolved, could result in equipment failure or significant additional damage before its next scheduled preventive maintenance period.

Key O&M Cost Point

When performing corrective maintenance on power block equipment, a Level 1 or Level 2 work package would typically be required. Corrective maintenance performed on non-power block equipment or facilities would be considered minor maintenance with no work instructions required (Level 3).

4.2.3 Design Modification

For the purposes of this report, the work planner is typically concerned only with a design change that results in a hardware change to a plant component. As shown in Table 4-2, a Level 1 work package is typically warranted when a design modification is performed on power block equipment. This is because the work activity is often unique, and work instruction details are most effectively included in each work package. If detailed instructions are available, a Level 2 work package might be acceptable.

When a design modification is performed on non-power block equipment or facilities and related equipment, a Level 2 package might be appropriate if the extent of the design change is significant. If not, the work should be considered minor maintenance with no work instructions required (Level 3).

Key O&M Cost Point

When a design modification is performed on power block equipment, a Level 1 work package is typically warranted. This is because the work activity is often unique, and work instruction details are most effectively included in each work package. If detailed instructions are available, a Level 2 work package might be acceptable.

4.2.4 Systematic Equipment Troubleshooting

The EPRI report *System and Equipment Troubleshooting Guide* (1003093) defines *troubleshooting* as "a systematic approach to data collection, failure analysis, or a measurement plan that results in high confidence that the complete cause of system/equipment degradation has been determined. There might be potential personnel safety risk."

The report recommends that a detailed plan be developed by the multi-functional team before conducting troubleshooting. Work planning is a key contributor to this plan and, in general, can be responsible for one or more of the following:

- Coordinate troubleshooting activities with other scheduled and unscheduled station activities and perform and comply with risk evaluation of impaired systems. (At some plants, the troubleshooting lead and scheduling organization, working closely with operations, often performs this activity.)
- Identify additional resources as required to support troubleshooting activities. (At some plants, the planning organization might not get involved with this type of activity.)
- Participate in a multi-organizational team, and recommend additional administrative controls for formal troubleshooting activities.
- Review and approval of troubleshooting plan activities and any subsequent changes to the plan before performance of the activities for formal troubleshooting.
- Participate in work control/operations center briefings with the necessary personnel for jobs affecting personnel safety or power generation. (At some plants, this might not be a planner function, unless the planner has been designated as the troubleshooting lead.)

As shown in Table 4-2, when troubleshooting is performed on power block equipment, a Level 1 work package is typically warranted as a means to minimize the risk associated with the troubleshooting and the risk of inadvertently disrupting the operation of the plant. A Level 2 work package is not recommended in these cases because it is unlikely that the detailed work instructions have already been developed in a procedure because of the uniqueness of the equipment failure.

When troubleshooting is performed on non-power block equipment or facilities and related equipment, the work should be considered minor maintenance with no work instructions required (Level 3).

Key O&M Cost Point

When troubleshooting is performed on power block equipment, a Level 1 work package is typically warranted as a means to minimize the risk associated with the troubleshooting and the risk of inadvertently disrupting the operation of the plant.

4.2.5 Post-Maintenance Testing

Post-maintenance testing (PMT) verifies that components and systems are capable of performing their intended functions when returned to service following maintenance and ensures that any original deficiencies have been corrected. Certain inspections and checks that satisfy some PMT requirements follow the activities conducted during the maintenance phase. These inspections, verifications, or checks are usually an integral part of the maintenance procedures. After the maintenance is completed, the additional verifications and tests that are performed ensure that the component or system is ready for operations. The PMT activities should be designed and scoped to ensure that the functionality of the component is verified through a series of progressive testing steps, but to avoid duplicate testing.

When a PMT must be prepared, the planner should select the appropriate test scope from a PMT matrix. If a test is not available, the planner should contact the engineering organization to determine the most appropriate functional test and/or the operations organization for the most appropriate operability test.

The EPRI report *NMAC Post Maintenance Guide, Revision 1* (1009709), provides owners with suggested activities covering the scope of PMT for many different types of equipment. Most owners have adopted these tests and incorporated them into their respective plant procedures. The report defines *post-maintenance testing* as “any appropriate combination of inspections, checks, and testing performed following maintenance to verify that a particular piece of equipment or system performs its intended function based on its design criteria and verification that the original deficiency has been corrected.”

As shown in Table 4-2, when performing PMT on power block equipment, a Level 2 work package would typically be appropriate if the detailed post-maintenance work instructions existed and could be referenced in the work package. Otherwise, a Level 1 package would be necessary. PMT performed on non-power block equipment would most likely be performed with a Level 2 work package, or in some cases as a Level 3, if the instructions already existed. If PMT was required to be performed on facilities and related equipment, it would most likely be considered minor maintenance with no work instructions required (Level 3).

Key O&M Cost Point

When performing PMT on power block equipment, a Level 2 work package would typically be appropriate if the detailed post-maintenance work instructions existed and could be referenced in the work package. Otherwise, a Level 1 package would be necessary.

4.3 Content and Format for Work Packages

4.3.1 General Guidance and Considerations

4.3.1.1 Fundamental Work Package Attributes for Ensuring Quality

Work can be planned to anticipate error-likely situations and to incorporate controls that effectively prevent, catch, or mitigate error during the performance of a specific task by specific individuals. Industry experience also suggests that identifying the opportunities for error and eliminating them is one of the key responsibilities of those developing procedures and planning work packages. The planning stage of work management is an opportunity to identify critical steps of an activity. The structure of the task can be planned in light of single-error vulnerabilities to reduce possible consequences should people err. Additional controls or barriers can be built into the procedure to prevent or catch errors. Feedback from previous occasions and industry operating experience relevant to the task can be factored into the work plan.

Key Human Performance Point

One key attribute to consistently developing a quality work package is to perform a critical task analysis.

A critical task analysis basically consists of the following four steps:

1. Develop a task list.
2. Identify and prioritize critical tasks.
3. Identify critical steps of each particular task, considering the following:
   – Pinpoint error-likely situations at each critical step.
   – Characterize the consequences if errors occurs at the critical step.
   – Identify weaknesses in or missing defenses.
4. Identify and incorporate needed controls or safeguards.

Other key (or critical) attributes when developing a quality work package can include ensuring the following:

- Content is consistent with the knowledge, skills, and experience of the work force, as well as with management expectations.
- Work packages are developed with site instructions/procedures, which can in some cases include the aid of a writer’s guide.
- Work packages are reviewed to check for technical accuracy and consistency with the writer’s guide, if applicable.
- Work packages are validated by qualified users to determine whether the procedure or work instruction can be implemented/used as written.

- Work packages are current and revised appropriately.
- Work packages include relevant operating experience and lessons learned, as appropriate.
- A feedback process is used as a means to continuously improve the quality of the work packages.

4.3.1.2 Inclusion of Maintenance Experience

The work planner should consider the use of applicable maintenance experience and equipment performance history when planning work instructions. Most fossil plant owners recognize industry maintenance experience as a source that provides valuable insight on improving work planning processes based on the learning experiences and/or from other utilities.

Maintenance experience that the planner determines can provide safety, quality, time, or cost benefits to maintenance instructions and/or activities should be added to the owner's information management system. A copy of the maintenance experience can also be provided to maintenance team/discipline leader(s) for future reference.

Key Human Performance Point

When planning a work order (typically required for a Level 1 package but discretionary for a Level 2), the planner should search for relevant maintenance experience. If such information is identified that is relative to the work being performed, it should be placed in the work package.

4.3.1.3 Establishing the Appropriate Level of Detail

As noted in Figure 4-1 and described in the preceding sections, the level of detail contained in a work package and work instructions results from careful consideration of numerous factors, and will vary from job to job. When the work planner proactively considers inputs and appropriately varies the resulting work package category level, scope, content, and level of detail, the planner takes a "graded approach" to the work planning process.

4.3.2 Recommended Work Package Content

The format, structure, and content of work packages varies from plant to plant, and as stated in Section 4.2 of this report, will vary depending on the work level category. Figure 4-2 illustrates the typical components of a Level 1 or Level 2 work package. The primary difference between the two levels is the level of detail of work/special instructions. For Level 2, the level of detail is much less because either a higher reliance is placed on the skill of the craft or because those work instruction details are already described in an existing instruction or procedure that is simply cross-referenced in the work package.

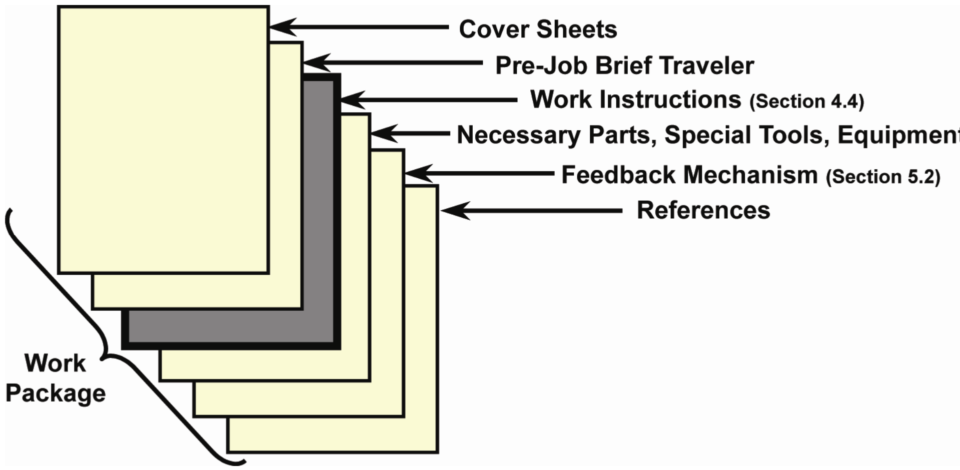

Figure 4-2
Typical Elements of a Level 1 or Level 2 Work Package

4.3.2.1 Cover Sheets

The work planner should ensure that the cover sheet includes the following:

- **Unique work order or task number**. A number that uniquely identifies the work order or task.
- **Equipment description**. The noun name (or tag number) of the component on which the work is being performed, the manufacturer/model information, the ASME Code designation, and the seismic or environmental protection design bases.
- **Problem description**. The initial problem description as defined by the initiator.
- **Scope of work**. The scope of work as defined by the work planner after validation of the initial problem description.

4.3.2.2 Pre-Job Brief Traveler

Key Human Performance Point

The work planner should prepare a pre-job brief traveler for all Level 1 work orders and any Level 2 work orders posing risk to unit operation/generation.

The pre-job brief traveler can be a specific item incorporated within the work instructions or a separate item included in the work package. It should be initiated by maintenance planners during the planning process and expanded as the work order progresses to the implementation phase.

Planners should include the following information in the pre-job brief traveler:

- Critical job steps
- Job safety analysis
- Potential adverse outcomes
- Contingency or compensatory actions
- Error-likely situations and defenses
- Relevant maintenance experience

The traveler should be reviewed during the post-job critique to improve work package and pre-job briefing quality and archived, as appropriate, to support future work package development.

4.3.2.3 Work Instructions

The typical content of work instructions, as well as the level of detail, is described in Section 4.4, Work Instruction Structure and Format.

4.3.2.4 Identification of Necessary Parts, Special Tools, and Equipment

Key Human Performance Point

The work planner should review bills of materials, drawings, component maintenance philosophy, and maintenance history to identify parts that are likely to be needed.

The planner should identify and flag contingency parts and communicate to the supply chain organizations whether the part will be needed on site to support the work. It is typically necessary for the planner to ensure that the correct parts and replacement items are installed in the plant for the work being prescribed and planned. Care should also be taken to ensure that replacement parts are consistent with plant design documentation.

Key Technical Point

Only parts that are physically identical to the original should be installed unless a replacement item equivalency evaluation has been performed by the engineering organization and an alternate item has been approved for use.

The planner should also reserve or initiate procurement of the needed parts or services and identify the date that staging is required. Typically, staging represents material that is picked and segregated into kits by work management personnel for each job and placed in a separate and secure location in the warehouse. Staging facilitates a more level workload in the warehouse, as well as assisting the craft labor with expeditious issuance of the needed parts.

In some cases, it might be beneficial to walk down staged material for certain work activities well in advance of the work to ensure the efficient delivery of material when warehouse facilities are remote from the plant.

The work planner should notify appropriate organizations when engineering evaluations or reviews are required to support the issue and use of required parts and services, as necessary. If the planner has reason to believe that the needed parts will not be available by the preparation milestone, the planner should identify the restraint.

The work planner should also be made aware of potential obsolescence issues that could adversely impact the procurement and availability of necessary parts. *Obsolescence* is a term commonly used in the fossil industry to refer to one of the following conditions: 1) The condition of being out of date as a result of the development of better or more economical products, methods, processes, machinery, or facilities, which results in a loss of value or competitive advantage. Items might be available in the market but are no longer needed in a specific application. 2) The condition of no longer being available in the market as a result of the lack of manufacturer support. Items are needed in a specific application but are no longer available or supported by the original manufacturer and are difficult to otherwise procure.

Although work planners are typically not responsible for resolving part obsolescence issues and procuring alternative items, planners should be aware that obsolescence can result from either of the following scenarios: 1) Obsolete part: The part is no longer made by the supplier or manufacturer. 2) Obsolete equipment: Items in plant service are no longer manufactured or supported by the original manufacturer or are otherwise difficult to procure.

In summary, accurate and timely planning of work should allow the procurement process to optimize the cost of materials and inventory. The work planner should have an appreciation for the criticality of the parts, and planning of work should consider lead times for obtaining parts when stock is not maintained in inventory.

In some cases, the work package can identify and contain guidance regarding the proper application and use of special tools and equipment. Typically, the planner should identify these items and include guidance when there is reason to believe that the craft labor might benefit from additional instructions or that the improper use of the special tools or equipment could have an adverse effect on the maintenance work activities or the equipment being serviced.

4.3.2.5 Feedback Mechanism

> **Key Human Performance Point**
>
> The work package should contain a means for the craft labor to provide feedback to the planning organization regarding the quality and clarity of the work package.

This feedback is typically only one of many elements of the plant's maintenance feedback process. Means for providing feedback to the planning organization regarding the quality of the work package can be accomplished during several stages of work planning and in several ways, some which are described in more detail in Section 5, Performance Measures to Assess Work Package Quality.

4.3.2.6 References

A listing of source documents and references used to compile and assemble the work package should be included. This list may include the following:

- Existing maintenance work instructions and procedures
- Replacement part information (vendor manual, assembly drawing, bills of materials, critical spares database, and so on)
- Component identification (master equipment list, P&ID, electrical drawings, and so on)
- Technical equipment specifications
- Maintenance experience and equipment performance history

4.3.3 Administrative Controls

The administrative controls of work packages vary significantly from plant to plant and can vary depending on the type of package developed using the graded approach described in this report. It is not the intent of this report to prescribe any particular administrative controls, including a particular schedule of activities for a given work activity, or to imply that all plants should conform to the same schedule. Each plant should continue to control its own schedule, using the guidance provided as appropriate.

4.4 Work Instruction Structure and Format

4.4.1 Recommended Structure and Format of Work Instructions

Figure 4-3 illustrates the typical composition of work instructions. As noted in Section 4.3, the work package contents will vary depending on many factors related to the work and should be primarily based on plant-specific procedures and guidance. Many work order tasks have detailed procedures that already contain purpose, precautions or limitations, prerequisites, and so on.

When planning a package with a supporting detailed procedure, this level of detail typically should not be duplicated in the work package. Some information might be more appropriate to place in the work package, depending on the extent and detail of the task, the discipline, and the special instructions used.

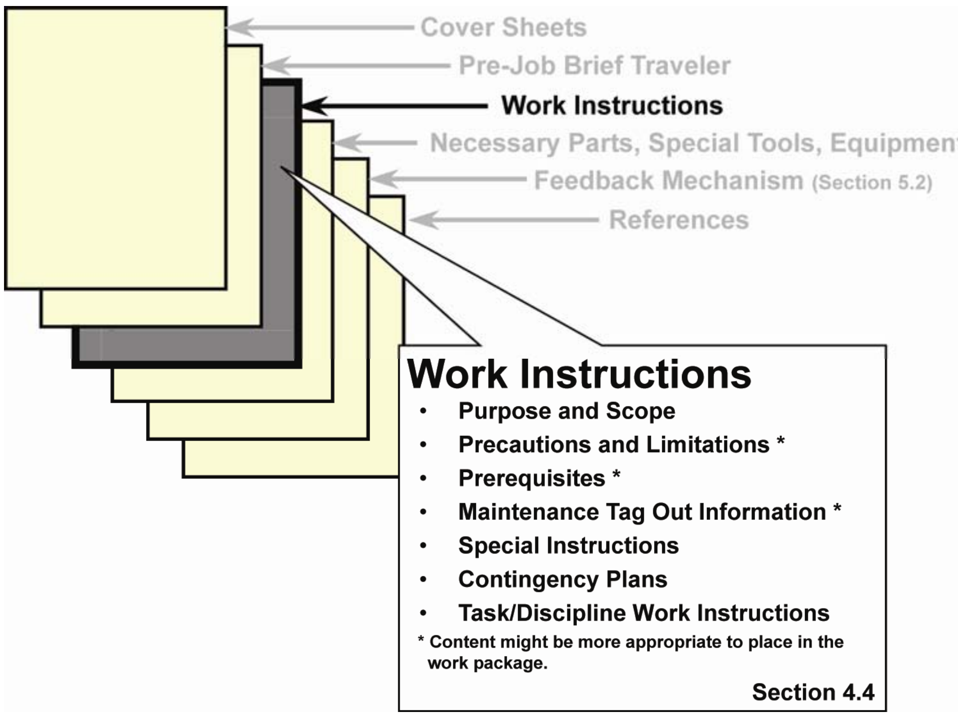

Figure 4-3
Typical Composition of Work Instructions

4.4.1.1 Purpose and Scope

The planner should clearly state the purpose and scope of work to be performed. The purpose should consist of a statement or short paragraph explaining why the work instruction exists. The scope should consist of a statement or short paragraph explaining the applicability of the work instruction's content.

4.4.1.2 Precautions and Limitations

Key Human Performance Point

The planner should enter limitations, precautions, safety concerns, and other information that will enhance field performance for the specific job.

Precautions and limitations should be written to inform the craft labor of hazardous conditions to be avoided and boundaries that must not be exceeded. The planner should also include hazardous conditions that might exist during the task or be encountered at some point during the task. If actions are required by craft labor to respond to precautions or limitations, the planner should provide action steps at the appropriate location in the detailed task instructions. Generic precautions that are part of a job description or inherent to the task need not be included and should be avoided to preclude unnecessary confusion. If warranted by severe consequences or other similar reasons, the planner should include warnings and cautions before the applicable steps.

The planner should consider the following when preparing precautions and limitations as appropriate for the particular work activity:

- The safety of plant personnel and the general public
- The protection of equipment and materials
- Permits required to perform the work
- The reduction of personnel or environmental exposure to any of the following (recognizing that many, if not all, of the following are typically addressed through existing plant administrative programs and procedures):
  - Contamination
  - High-temperature or high-pressure fluids
  - Extreme temperature environments affecting “stay” time for workers
  - Dangerous chemicals, poisons, or asbestos
  - Dangerous metals such as mercury, lead, cadmium, or chromium
  - Dangerous gases such as hydrogen, ammonia, or chlorine
  - Electrical shocks
  - Excessive noise levels
  - Confined space and trenching or engulfing hazards, including emergency response requirements and rescue plans
  - Moving equipment or parts of equipment
  - Fire hazards
  - Fall hazards
  - Physical hazards associated with improper ergonomics
- Inadvertent, incorrect, or omitted actions that might cause plant transients or power reduction
- Inadvertent, incorrect, or omitted actions that might result in limiting conditions for operations
- Limitations identified in approved vendor information
- Limitations identified in applicable design documents
- Unusual alarms affecting plant availability that might occur or are expected to occur as a result of the performance of the task

- Mechanical or electrical bypasses (lifted leads, inhibits, jumpers, and fuse removals) used in the performance of the task
- Electrical and mechanical interlocks involved in the performance of the task and those interlocks that are to be conformed to or overridden by administrative direction provided by other levels of management
- Undesirable consequences of the omission of each precaution or limitation statement, if these consequences are not obvious
- Required foreign material exclusion (FME) controls
- Type and amount of fluids to be caught or disposed
- Scaffold requirements
- Precautions and limitations applicable to extracted procedure steps, such as the following:
  - Plant equipment effects based on alterations such as requested clearances, wire lifts, or component manipulations. Plant equipment that might start or stop during the activity.
  - Expected annunciators and alarms. (If this is described accurately in the body of the work instruction, it should not be reiterated as a special precaution.)
  - Contingency clearance or boundary change information, if applicable.

4.4.1.3 Prerequisites

Prerequisites provide the actions to be completed (or verified) and signed off before proceeding with the performance of the next or main task. The planner should arrange the actions in the proper sequence for the performance and include any required field preparations or notifications such as the following:

- Notifying environmental protection agencies so that appropriate inspections can occur, if required
- Obtaining the necessary permits (burn permits, confined space, and so on)
- Establishing the appropriate system or equipment alignment and power supply
- Confirming operability of systems and components before removal from service
- Installing portable communications equipment
- Preparing special test equipment
- Identifying needed support services (such as scaffolding, insulation, vacuuming, hydro-blasting, or chemical control)
- Inspecting and approving configurations of scaffolding
- Verifying completion of other tasks that must be performed before proceeding with the current task

Another prerequisite that can be included in the work package is an attachment providing information necessary to support the pre-job briefing. The attachment, or traveler, should identify the following:

- Critical job steps
- Potential adverse outcomes
- Contingency or compensatory actions
- Error-likely situations and defenses

4.4.1.4 Maintenance Tag Out Information

The planner should consider including record clearance or tagging information as necessary. Typically, this information is needed for preventive maintenance work orders, but it can be included on any work order for which it is deemed appropriate. In some cases, the planner might be required by station procedures to prepare and submit a detailed clearance request. In other cases, the planner might be required to simply provide a summary of the clearance needs.

If a clearance request is required, it should contain sufficient details to allow the clearance developer to prepare the clearance order. In some cases, the planner might be required to provide the specific scope of work and reference drawings and to enable the clearance order to provide safety to the worker and equipment. Typically, the planner should consider including the following information:

- Clearance boundary scope (electrical, fluid, air, and so on)
- Specific tagging order (if important to the maintenance or work activity)
- Components that should not be tagged (that is, the component must be manipulated or removed)
- Components that will need position verification following the maintenance activity (due to work instructions that manipulate the component)
- Boundary extension needs, if known
- Special precautions or instructions for the clearance developer, such as “hang when requested”

At some plants, the operations organization builds clearances and defines clearance boundaries based on work scope, present plant conditions, and past work experience.

4.4.1.5 Special Instructions

The planner should record useful supporting information in the Special Instructions section, including the following items, as applicable:

- Special tools
- Component location
- Rework statement, if applicable
- Other special instructions such as engineering contacts

4.4.1.6 Contingency Plans

Key Human Performance Point

The planner should include contingency plans when deemed appropriate and should recognize that they might not be required with every package.

When warranted, the planner should include actions to be taken for emergent conditions such as discovery of equipment degradation, additional tools or equipment needed, or increases in the scope of the task. If the potential consequences are significant, job-specific contingency plans should be developed with the work package. Planners should consider the following when determining the requirement for and scope of contingency plans: What is the worst thing that could happen? What defenses or contingencies are in place to address the worst case?

The planner can include actions for coping with potential hazards such as fire, chemical spills, or exposure to harmful contaminants and predictable undesirable events like failures and errors. Contingency plans can be integrated with the appropriate action in the work detail section, if it is more appropriate than keeping them separate. The level of effort and resources used for contingency planning should be commensurate with the significance of the work activity. For example, a Level 1 activity might warrant additional contingency planning measures because of an increase in generation risk of the activity.

Planning for contingency parts should also be considered, and if contingency parts are requested, the appropriate supply chain organizations should be notified. Specifically, the supply chain should be made aware of the priority, whether the parts need to be staged on site, and whether the maintenance organization must know the availability and lead time so that alternative procurement arrangements can be explored. The work planner should recognize that contingent material might not be needed to support the planned work activities. However, the material request should still flag the request as contingent, and the supply chain organization should provide work management with the material availability and lead time in order to allow a cost-effective decision whether to procure and/or expedite the material.

4.4.1.7 Task/Discipline Work Instructions

In developing the task/discipline work instructions, the work planner should consider the factors shown in Figure 4-3. The level of detail of both the work package and the task or discipline work instructions should be an output after considering the factors shown in the figure and properly categorizing the level of the work package.

Number the steps in a procedure, using Arabic numerals. If the owner's information data systems permit it, work instructions should be written with special attention to the use of upper and lower case—that is, the first word of a sentence should be the action verb and should be upper case, and the rest of the letters in the sentence should be lower case. Studies show that fewer human-performance errors occur when this case structure is used.

Key Human Performance Point

When writing work instructions, there should be only one action per step, and steps should be written as imperative statements. Titles and individual words can be capitalized, bolded, or italicized for emphasis.

For example, a work instruction might state the following:

TORQUE six (6) head bolts on the bonnet flange to 25 ft-lb.

The inclusion of critical steps is a key technique for minimizing human error. Critical steps should be uniquely identified and read verbally before their execution. Each step should be peer checked to ensure that it is the proper step and that the intended action is correct. Each step should be signed off when it is completed. If the consequences of incorrect execution are significant, steps are considered critical.

Notes should be used as information to clarify the steps and should specify only administrative actions. Physical actions to be accomplished by the worker should be in a work step. Notes should immediately precede the step that is being clarified. Notes should be written in the same case as procedures (the action verb in upper case and the rest in lower case), in a box, with the heading typically centered and all upper case.

Cautions should be used to describe conditions that can be hazardous to equipment or personnel or can impact unit operations or challenge plant systems. Cautions should immediately precede the action statement for which they are intended. Cautions should also be written in the same case as procedures (the action verb in upper case and the rest in lower case), bold type, in a box, with the caution heading centered, all upper case, and bold.

4.4.2 Human Performance Issues and Error-Prevention Techniques

The guidance in this section is provided because it can ensure the overall quality of the work package as well as its implementation. This report recognizes that the work planner may not be directly responsible for ensuring implementation but typically has an opportunity to incorporate many of these error prevention techniques into the work plan. In addition to the guidance provided in the following sections, more details can be found in the EPRI report *Human Performance: Fossil Operations* (1012786).

4.4.2.1 Human Performance Issues

When developing work instructions, work planners are responsible for specifying the steps that require verification or documented peer checks in work packages. The work planner is also typically responsible for outlining the methodology and sequencing of the work to enable personnel implementing the job to keep track of the process described in the work package.

A human performance trap can arise when multiple actions are imbedded in a single step. A particular challenge occurs when there are bulleted sub-steps and the worker tries to perform them together rather than individually. The preferred method is to have only one action per step of the procedure or work instructions.

4.4.2.2 Place-Keeping Practices

Place-keeping is a technique of clearly marking instructional steps in a document being used to control a work activity to indicate the completion status of a particular step. Steps that are not applicable are typically marked “N/A” (according to the provisions of the specific procedure).

> **Key Human Performance Point**
>
> Place-keeping is particularly important for plant status and configuration control, as well as reassembly of equipment after maintenance, or in any situation in which the consequences of skipping, repeating, or partially completing a step would result in adverse consequences.

When consistently and rigorously applied, place-keeping will reduce the simple human error of missing part or all of a step.

> **Key Human Performance Point**
>
> Place-keeping is used whenever written instructions are referenced to directly perform a task.

Examples of such instructions include procedures, work instructions, technical manual instructions, various checklists, and so on. Place-keeping is typically used by any workers directly referring to written instructions during performance of a task.

Some generic but useful place-keeping guidance includes the following:

- Integrate appropriate place-keeping techniques in the overall structure of the procedure or work instruction. These should be limited to simple, straightforward methods to support completing the procedure or work instruction in the proper sequence.
- Establish the sequence of steps to conform to the normal or expected work sequence.
- When developing procedures or work instructions, consider the human factors aspects of their intended use. For example, ensure that references to components exactly match drawings and label plate identifiers, units are the same as those marked on applicable instrumentation, and charts and graphs can be easily read and interpreted.

Place-keeping tools such as checkboxes and signoff blanks should be provided by the planner when appropriate. Copies of applicable technical manual pages should be included in the work packages.

4.4.2.3 Error Prevention Techniques

The following techniques can be used to help prevent errors.

Remembering and asking four key questions. Asking the following four questions is often a good means to think through the activity with the goal to minimize the risk of human error:

- What are the critical steps or phases of this task? (Identify important parts of the task that must go right.)
- How can we make a mistake at that point? (Identify error precursors.)
- What is the worst thing that can go wrong? (Review potential consequences and contingencies.)
- What barriers or defenses are needed? (Use the human performance [HUP] tools.)

Based on these questions, the planner should consider the use of the following error-prevention tools, as appropriate, for the work instructions being prepared.

Self-check. Self-check (STAR) should be used for component identification and equipment manipulations. STAR is performed as follows:

- **Stop**. The individual will pause before performing a task to enhance the attention to detail in an attempt to eliminate distractions.
- **Think**. Prior to performing any actions, the individual should verify the action to be taken is correct by questioning the intended actions and understanding the expected responses. The individual should also point at or touch the component to identify the correct unit or train and compare it to the controlling document.

- **Act**. The individual will, without losing physical or visual contact, perform the intended action.
- **Review.** The individual will verify that the actual response is the expected response. If an unexpected response is obtained, action should be taken as previously determined. The individual should ensure that the system/component is in a safe condition

Outside of procedures, parameters, or processes (OOPs). If personnel implementing work packages find themselves working outside of procedures, parameters, or processes, they should stop and contact their supervisor. Skill-based errors can be prevented using the STAR method. Rule-based errors can be prevented by properly using written procedures. OOPs is a strong method that should be used effectively to prevent knowledge-based errors.

Peer check. Peer checks should typically be required for work packages associated with main control room (MCR) equipment manipulations for which verification is not required. Peer checks for actions necessary to mitigate a transient are desired but might not be required. Pre-job briefings should determine the need for peer checks warranted by any of the following:

- Departure from routine
- Time pressure
- Something is not right, doubt
- Apparent conflict between indications
- Unfamiliarity, first time performing a procedure
- Tired, fatigued worker

Peer checking can be performed by following these steps:

1. The performer references the controlling document, locates the component, and verbally identifies each unique identifier on the component label to the peer. The performer can point to or touch the equipment to be manipulated during the explanation.
2. The performer references the controlling document and verbalizes the position in which they intend to place (or check) the component.
3. The peer verbalizes the correct component identification and that the intended action is correct and people or systems are ready for the action. Both individuals should be aware of and understand the status of plant equipment that could be affected by the action.
4. The performer places (or checks) the component in the intended position.
5. The peer witnesses the positioning (or check) of the component and physically verifies component position or condition, when applicable.
6. When required, the appropriate individual(s) should document completion of the peer check in the controlling document.

Verification practices. Verification practices should be performed for generation-sensitive activities, activities affecting personnel safety or environmental issues, or as directed by either the governing procedure or a supervisor.

Key Human Performance Point

During the conduct of verifications and positioning, individuals implementing the work package should check all components to ensure that the component identification label is properly attached and in good condition.

Three-way communication. The work planner should ensure that communications are clear, concise, and free of ambiguity. For non-face-to-face verbal communication, the sender and receiver should identify themselves by stating their name or title. Use of the phonetic alphabet is often required to ensure proper component identification. Three-way communications should be used for all information exchanges that will result in decision-making, direction being given, or actions being taken. Words should be avoided during verbal communication that could be mistaken for some other word, such as “increase” and “decrease.” Communication of indicator readings should be provided in the format of parameter, value, trend (for example, reactor pressure is 1000 psig and going down). The use of sign language should be avoided. The appropriate unit designator, system designator, or noun name and appropriate phonetic alphabet component or train designator should be used when communicating equipment nomenclature (that is, 1MS029A should be verbalized as “one Mike Sierra zero two nine Alpha).

First check. Before the performance of the first manipulation of in-field evolutions, as determined by the pre-job brief (typically excluding operator rounds), the proper step intended to be performed, proper unit, proper train, and component should be checked using self-check techniques. Often, the craft labor will also be required to contact the control room or dispatching facility to validate component label information.

The work package should reference or establish a method within the dispatching facility to verify each proper step intended to be performed. These checks and communications should then be repeated for subsequent field actions after any of the following as determined by the pre-job brief:

- Initiation of a new section of the procedure with different effects or major components (for example, proceeding to a second feed pump)
- Significant change of location (for example, moving to a different building)
- Significant elapsed time between steps
- Change of assigned personnel
- When performing any manipulation that changes the status of a main control room alarm or indication

Flagging/robust operational barriers: This process does not substitute for proper self-check using equipment labeling as the indication that the correct component is being manipulated or monitored, nor does it substitute for proper verification requirements determined by plant procedures. It is intended to provide an additional barrier so that when an individual is met with a distraction, they return to the right component prior to continuing work.

Key Human Performance Point

Flagging is best applied for components that will be worked on and manipulated multiple times. Flagging/robust operational barriers are also useful if multiple similar components exist within close proximity or will be manipulated multiple times.

Typically, the method needed for flagging/robust operational barriers should be determined at the pre-job brief. The planner can include the method of flagging/robust operational barriers as part of any job but should also ensure that flags or barriers will not interfere with plant equipment, including indications for operations. Care should be taken not to create an additional hazard by use of a robust operational barrier device.

General guidance: There are a number of techniques, many of which are common in the power industry, that minimize the occurrence of errors. Some common practices to minimize errors are the following:

- Do not use check marks instead of initials or signatures for continuous-use procedures, unless the procedure specifically allows it.
- Do not use ditto marks (").
- Do not sign one set of initials followed by a vertical line through the remaining sign-off blanks.
- Do not sign off a step as complete before it is actually completed.

4.5 Methodology for Developing a Work Package

The general methodology for developing a work package is shown in Figure 4-4.

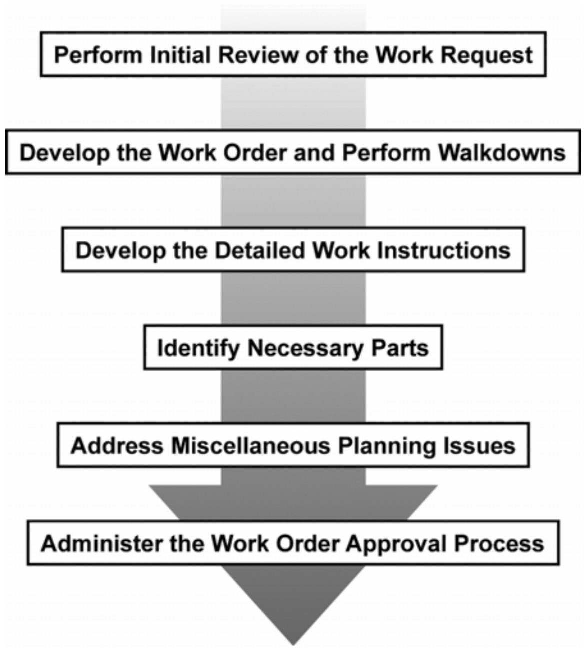

Figure 4-4
Simplified Methodology for Developing a Work Package

4.5.1 Perform Initial Review of the Work Request

The work planner should typically validate a newly created work request. As plant conditions allow, this validation might include a walkdown of the field condition to ensure that the deficiency is confirmed prior to disposition as appropriate. This walkdown should verify the following:

- Equipment tag number
- Nameplate data of the component
- Location
- Problem description
- Condition found and condition left (if already worked as tool-pouch maintenance)
- Identification of needed parts
- Any applicable comments
- Identification of leaks
- Scaffold and insulation requirements

The work planner should review the work management database to determine whether any existing active work orders already address the deficiency noted in the work request. The work planner should then ensure that the work request is initiated against a valid equipment identifier, if this technique is used and if one exists. The work planner typically should then convert the work request to a full-scope work order as necessary to address the condition validated. Special consideration is often given to work orders associated with leaking equipment.

4.5.2 Develop the Work Order and Perform Walkdowns

4.5.2.1 Develop the Work Order

In many systems, the work planner can perform this task by validating and updating the work description or updating an existing work order. The work order description should state the scope of the work being performed. The work planner might also be required to validate and update the task description panel, if needed.

Key Human Performance Point

The task description should clearly state the work to be done, and if required, the work planner should coordinate with the scheduling organization to determine the appropriate task description.

If possible, the task description should include the discipline doing the work, the component tag being worked (or affected), and the task work scope. In some cases, the task description can be the same as the work order title.

4.5.2.2 Perform Walkdowns of the Work Order

Many plants already have standing procedures describing the requirements associated with performing field walkdowns; if this is the case, they should be referenced and followed. The walkdown can be waived if it would result in unnecessary exposure to chemicals or contaminants, requires entry into a confined space, is a priority task, or is not required by the nature of the reported problem as determined by the work planner. Some plant procedures require the craft to perform a walkdown, which often includes drawing out the required parts. This activity is valuable because it affords an opportunity for the craft to provide feedback on the work package before work commences and to get it changed, if necessary, before performing the work activities.

The following general guidance regarding walkdowns should be considered:

- During the walkdown, the work planner should verify equipment problems and collect work methodology information for planning complex jobs.
- During the walkdown, the work planner should identify potential safety hazards.

- During the walkdown, the work planner should verify the installed model number of the component for validation against the approved model.
- If assistance is required to perform a walkdown, the work planner should notify the respective group that support will be needed.
- If the walkdown reveals that an energy release might be necessary, the work planner should make a note in the precautions/prerequisites section, referencing the appropriate plant procedure. (Implementation of the energy release would typically be the responsibility of operations personnel and not the work planner.)
- A work order planning field walkdown checklist (for example, a planning form) should be considered as a means of ensuring consistency, and should be used to assist in planning the work order.
- Photographs or digital images to be included in the work package for clarity and pre-job briefs should be considered.

4.5.2.3 Work Order Task Development

The key to this step is properly structuring the work and resource estimates (including work time, discipline, and skill level requirements). Work order tasks should be based on pre-planning activities and are generally subdivided by crew or by the discipline performing the task. In addition, tasks can be further segregated based on implementation of the task sequence. For example, a task that would normally be divided in the schedule into one or more activities can be broken up into the corresponding number of tasks as determined by the planner based on complexity and scope of the work.

Key Human Performance Point

The work planner should generate separate work order tasks if access to the component to be worked requires removal of interferences such as pipe supports, snubbers, or unrelated piping. Similarly, separate work order tasks should be developed for each major component.

This does not necessarily apply to PMs or work orders that use equipment lists. Development of work instructions associated with complex jobs should be coordinated with other discipline planners to ensure that appropriate work order tasks have been properly identified.

4.5.3 Develop the Detailed Work Instructions

Guidance regarding the recommended scope and content of detailed work instructions is provided in Section 4.4, Work Instruction Structure and Format. In general, the work planner should determine the availability and applicability of existing work instructions before developing new ones. If they exist, the work package can be categorized as a Level 2 package. If they do not exist or they need to be reiterated in the work package, the work package should be treated as a Level 1 package.

4.5.4 Identify Necessary Parts

The planner should retrieve the bill of material information when building a material request for a work order task, and care should be taken to use the most current and approved revision of vendor drawings and catalog information. A walkdown should be used to verify correct model and serial number information. When a bill of material is determined to be inadequate to positively identify the correct part or replacement item, the planner should initiate a request to the owner's engineering or supply management organization for assistance.

4.5.5 Address Miscellaneous Task Planning Issues

Depending on the type of information system used at the plant, a number of miscellaneous issues might need to be addressed before the release of the work package. Examples include the following:

- Including instructions to manually set or change flags and requirements (if not automatically populated)
- Ensuring that accounting codes are correct
- Ensuring that work order crew/craft codes are correct

4.5.6 Administer the Work Order Approval Process

The review and approval process can vary depending on the scope, criticality, and type of work being planned. The technical reviewer is the individual assigned to review the work package content and quality, typically implemented on generation-sensitive activities. A technical review is typically required when approved procedures or pre-approved instructions do not exist for adequately reviewing the following:

- Design change work packages (based on site-specific procedures)
- Work instructions containing complex or unique step-by-step instructions on key equipment
- Work instructions posing a risk of unit or generator trip, plant transient, or lost generation

When the planner has completed entry of the planning details and other appropriate information on the work order task, the planner should then develop the appropriate routing list and submit the work order for approval.

In many cases (such as coatings work, welding, and so on) electronic review and approval might be desirable. The work planner, as necessary for approval or information routing purposes, might add other organizations or individuals such as quality control or engineering.

5
PERFORMANCE MEASURES TO ASSESS WORK PACKAGE QUALITY

5.1 Work Package Quality Performance Measurement

Work package quality performance can be measured in one or more of the following ways:

- Planning process indicators
- Periodic assessment of package quality
- Post-job feedback of package quality (including corrective action program, operating experience, maintenance feedback, post-job critiques, and independent self-assessment)

5.1.1 Planning Process Indicators

Planning process performance indication is primarily depicted by meeting planning milestones. Plants often use performance measurements based on on-line (weekly), outage (monthly), and forced outage readiness milestones. These milestones require work package statuses to be designated “in planning” or issued as “ready to work.” The indicators are typically displayed as a percentage of the total not meeting performance expectations. The status designations are defined as follows:

- **In planning**. Work activities are still being scoped, planned, and scheduled.
- **Ready to work**. Work instructions are complete with scope of work frozen, support request submitted, work scope technical issues resolved, and in routing for review. A package that is ready to work is assembled, walkdowns are complete, holds are removed, and parts are available.

5.1.2 Periodic Assessment of Work Package Quality

Plants assess work packages within the planning process by a technical review of content and quality. Work package quality should be assessed periodically to track and trend the percentage of work packages not meeting quality expectations. (The assessment is typically performed using a representative sample of work packages before their execution.)

5.1.3 Post-Job Feedback of Work Package Quality

Feedback that applies to work package quality should be tracked and trended to ensure that pertinent data are included within future work instructions.

The trend data should be used to improve the planning process such as planner training and performance, work package improvements, and resolution of work impact due to work package error. Plants should trend those work packages having an adverse impact on work execution.

5.2 Measuring the Quality of Work Packages

Key Human Performance Point

The quality of a work package can be checked at many points during its development, issue, and implementation. Feedback provided to the work planning organization can be an effective tool for continuously improving the quality and accuracy of the work packages provided to craft labor.

During the course of work activities, there arise many opportunities for the craft labor to provide feedback regarding the effectiveness of the process. Usually at this point, feedback regarding problems encountered during the work activity can be attributed to either 1) the quality of the work package provided to the craft labor or 2) the quality, acceptability, and correctness of the parts used.

The quality of the work package can be measured or graded in many different ways. Some of the criteria that craft labor can use to grade the quality of the package can include the following:

- Clarity of the work instructions
- Organization of the work package
- Highlighting of precautions and the need for special instructions
- Tools to enhance human performance
- Optimized content and lack of redundancy

Figure 5-1 illustrates various means for measuring the quality of work packages.

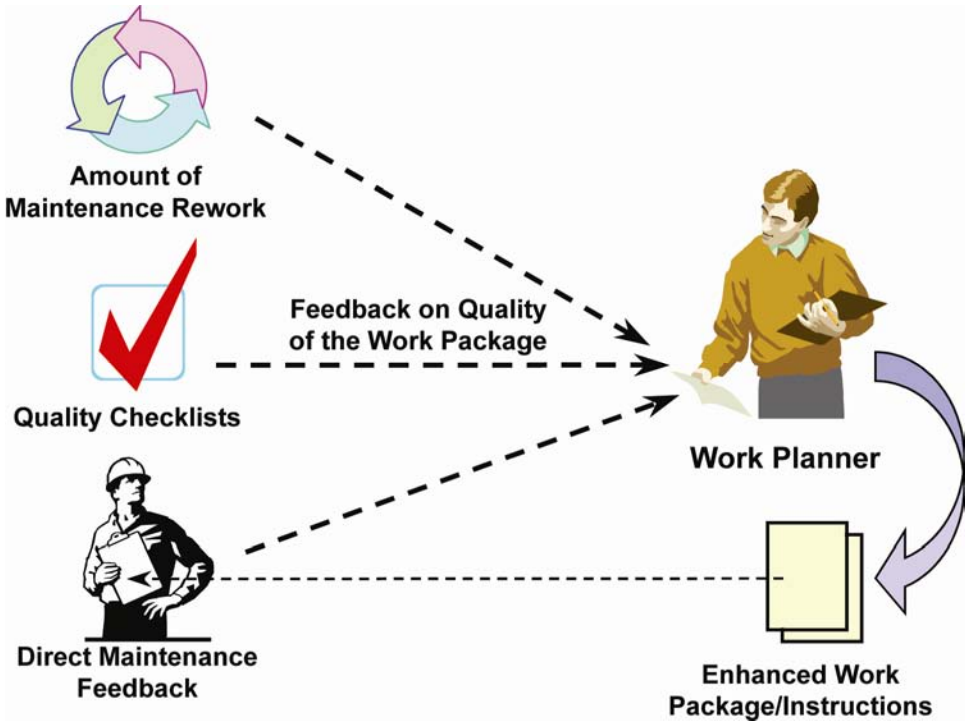

Figure 5-1
Means for Measuring the Quality of Work Packages

5.2.1 Direct Maintenance Feedback

Historically, planning organizations at many plants have used a manual attachment for implementing procedures as a means for obtaining work package feedback, including grading. Experience has demonstrated, however, that input from the craft and supervisors with the manual forms has typically been inconsistent and infrequent. As an alternative, some units have instituted an on-line, electronic work package feedback process using the action-tracking feature provided with many commercially available information management systems. This feedback, when initiated, can be configured to come directly from the craft to the planning supervisor. Some owners include a separate task to ensure that feedback is included and/or to evaluate the feedback that has been provided. When the planning organization finishes the evaluation, an assignment to correct the identified problem with the package or model work order for PM should be routed or issued to the responsible planner. The planning organization should be responsible for closing the feedback loop by communicating with the initiator.

The EPRI PM basis also has checklists that provide feedback related to failure modes and effects and degradation mechanisms.

5.2.2 Quality Checklists

Quality checklists are another means of obtaining feedback on the quality and effectiveness of work packages. The following are various items about which the craft labor and others involved in the work planning process can provide feedback to the planning organization:

- **Content of pre-job briefs**. Was the information relevant, complete, and useful?
- **Error prevention**. Was enclosed maintenance experience applicable and useful?
- **On-line work**. Was it clear when the work was authorized to be performed?
- **Parts availability**. Were the correct parts reserved to perform the task?
- **Permits**. Were the necessary permits prescribed and obtainable?
- **Post-maintenance testing**. Was the prescribed PMT coordinated and adequate?
- **Required support**. Were scaffold, insulation, temporary services, support craft, and so on correctly identified?
- **Supervisory oversight during work**. Was the level of oversight appropriate?
- **Supporting documents**. Were all the proper procedures listed or provided? Were the proper drawings, vendor information, forms, and so on included and adequate?
- **Technical content**. Was the component identification, location, power feed, and so on correct? Were the activity work steps of sufficient detail and ordered properly?
- **Work package quality**. Was the work order acceptable, organized, and accurate as written?
- **Work scheduled in parallel**. Were parallel activities clearly identified and with responsibilities assigned?
- **Work steps for support groups**. Were the instructions clear and appropriate?
- **Workability**. Were special tools or maintenance and test equipment (M&TE) adequately identified? Were the estimated work-hours adequate?

In many cases, there is also an opportunity for the craft laborer to provide general comments about the work package quality on the questionnaire, and in other cases checklists can be used before the work activity is performed.

5.2.3 Amount of Maintenance Rework

Many plants measure the quality of work packages based on the percentage of rework. In this context, rework should clearly be attributed to the information (or lack thereof) communicated in the work package and not as a result of some other cause. Rework should also be considered only in those cases in which a component problem reappears within a year since it was last worked. Most sites establish a rework goal of less than 2%.

6
GOOD INDUSTRY PRACTICES AND LESSONS LEARNED

6.1 Model Work Packages

A model work instruction is a comprehensive set of instructions encompassing all jobs that apply to a component that is removed from service for maintenance (most commonly applied to preventive maintenance). A model applies to multiple components within a particular component type within the power block (for example, SMB-000 motor-operated valve [MOV], GE 480 V breaker, and so on). The advantage of using models is that the model package has to be prepared only once. All operating experience, maintenance feedback, and corrective actions can be updated once, and all subsequent work orders generated will possess the updates. The extent of condition resolution is enhanced because all subsequent PMs will immediately reflect the change, thereby reducing the chance for recurrence. All work performed using the model should also be readily traceable.

Planning factors are specific to a component location within the power block (such as scaffolding, insulation, hangers, ground straps, or lifted leads). Planning factors should be combined with the model within a work order in order to perform maintenance on a specific component.

6.2 Predefined and Auto-Generated Work Packages

During the development of this report, task group members suggested that EPRI develop a repository of predefined model work packages for generic PM tasks associated with commonly installed components. The concept behind the follow-on activity was to enable owners to access these model work packages as a means to create efficiency among utilities and give planners templates from which to develop site- or plant-specific packages.

In parallel with the development of this report, a separate Technical Advisory Group developed a number of generic maintenance work packages for a variety of equipment types, as follows:

- Belt-driven equipment: inspections and alignment
- Boiler feedwater pump: overhaul and inspections
- Heat exchangers: inspections, cleaning and testing
- Low-voltage air operated breaker: overhaul and testing
- Motor control center/load control center: inspection and cleaning

- Limitorque SMB actuator: inspections and testing
- Electrostatic precipitator: cleaning and minor maintenance
- Roll wheel pulverizer: overhaul and inspections
- Dampers: inspections, cleaning, and lubrication
- Gould 3196 process pump: inspection and repair
- Steam traps: testing and minor maintenance
- Gate and globe valves: inspection and minor repair

Guidance regarding these generic maintenance work packages will be provided in the EPRI report *Work Package Templates* (1012288). The purpose of the report is to provide fossil plant maintenance organizations with some generic work package templates that can then be used as guides to develop site-specific work packages. The templates contain information that can be used by maintenance organizations no matter what current level of work planning or work package development might exist. Maintenance organizations that have processes in place can find information that will enhance their current processes. For maintenance organizations that have less structured processes, the templates provide a firm foundation for developing work packages. The templates cover a wide range of equipment types as well as a variety of maintenance activities, including inspections, minor repairs, and overhauls. Work packages can increase the efficient use of resources, improve overall maintenance and equipment reliability, increase overall productivity, and enhance human performance error reduction.

7 REFERENCES

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A
COMPILATION OF KEY POINTS

The following provides the location of the Key Points information in this report.

A.1 Key O&M Cost Points

Key O&M Cost Point

Emphasizes information that will result in reduced purchase, operating, or maintenance costs.

Section	Page	Key O&M Cost Point
3.2.2.2	3-8	One advantage of having an individual with a degree is the person's computer literacy and ability to process maintenance work orders within the site's information management system.
4.2.2	4-9	When performing corrective maintenance on power block equipment, a Level 1 or Level 2 work package would typically be required. Corrective maintenance performed on non-power block equipment or facilities would be considered minor maintenance with no work instructions required (Level 3).
4.2.3	4-9	When a design modification is performed on power block equipment, a Level 1 work package is typically warranted. This is because the work activity is often unique, and work instruction details are most effectively included in each work package. If detailed instructions are available, a Level 2 work package might be acceptable.
4.2.4	4-10	When troubleshooting is performed on power block equipment, a Level 1 work package is typically warranted as a means to minimize the risk associated with the troubleshooting and the risk of inadvertently disrupting the operation of the plant.
4.2.5	4-11	When performing PMT on power block equipment, a Level 2 work package would typically be appropriate if the detailed post-maintenance work instructions existed and could be referenced in the work package. Otherwise, a Level 1 package would be necessary.

A.2 Key Technical Points

Key Technical Point

Targets information that will lead to improved equipment reliability.

Section	Page	Key Technical Point
4.2.1.1	4-7	This type of maintenance consists of condition-based preventive maintenance actions taken to maintain a piece of equipment within design operating conditions and to extend its life. Condition-based maintenance results from troubleshooting, inspection, or testing that assessed the condition of equipment.
4.2.1.2	4-7	Periodic maintenance consists of time-based preventive maintenance actions taken to maintain a piece of equipment within design operating conditions and to extend its life.
4.2.2	4-8	Corrective maintenance is the restoration of equipment or components affecting fossil plant availability, personnel safety, environmental compliance, or plant reliability that have failed, degraded, or do not conform to their original design, configuration, or performance.
4.3.2.4	4-15	Only parts that are physically identical to the original should be installed unless a replacement item equivalency evaluation has been performed by the engineering organization and an alternate item has been approved for use.

A.3 Key Human Performance Points

Key Human Performance Point

Denotes information that requires personnel action or consideration in order to prevent injury or damage or ease completion of the task.

Section	Page	Key Human Performance Point
3.1.1	3-1	The more reliance the planner places on the skill of the craft, the less detail the planner must communicate to the craft in the work package. Similarly, the less reliance the planner places on the skill of the craft, the more detail the planner must provide to the craft in order for the work to be done correctly.
3.1.1	3-2	Planners should not assume craft skills beyond those fundamental attributes described in this report.
3.1.1	3-2	Planners should not assume that a given work activity will necessarily be performed by one particular individual or team.
3.1.2.5	3-5	In most cases, planners should report directly to a planning supervisor—not the craft supervisors of the disciplines, teams, or component types.
3.2.1	3-5	The work planner should ensure that the work package does not change the design configuration without required documentation.

Section	Page	Key Human Performance Point
3.3.2	3-10	The use of skill of the craft in the performance of a job is not considered a change of work scope if it is confined to the job covered by the work package and all other work done is in agreement with approved procedures.
4.1.1	4-3	A detailed work package is most appropriate for non-routine tasks that are fairly complex and performed infrequently.
4.1.2	4-3	A simple work package could be appropriate for non-routine tasks that are fairly complex and performed infrequently if detailed instructions are already available in existing maintenance instructions or procedures.
4.1.3	4-4	No work instructions would typically be required for routine tasks that are fairly simple and performed frequently.
4.3.1.1	4-12	One key attribute to consistently developing a quality work package is to perform a critical task analysis.
4.3.1.2	4-13	When planning a work order (typically required for a Level 1 package but discretionary for a Level 2), the planner should search for relevant maintenance experience. If such information is identified that is relative to the work being performed, it should be placed in the work package.
4.3.2.2	4-14	The work planner should prepare a pre-job brief traveler for all Level 1 work orders and any Level 2 work orders posing risk to unit operation/generation.
4.3.2.4	4-15	The work planner should review bills of materials, drawings, component maintenance philosophy, and maintenance history to identify parts that are likely to be needed.
4.3.2.5	4-16	The work package should contain a means for the craft labor to provide feedback to the planning organization regarding the quality and clarity of the work package.
4.4.1.2	4-18	The planner should enter limitations, precautions, safety concerns, and other information that will enhance field performance for the specific job.
4.4.1.6	4-22	The planner should include contingency plans when deemed appropriate and should recognize that they might not be required with every package.
4.4.1.7	4-23	When writing work instructions, there should be only one action per step, and steps should be written as imperative statements. Titles and individual words can be capitalized, bolded, or italicized for emphasis.
4.4.2.2	4-24	Place-keeping is particularly important for plant status and configuration control, as well as reassembly of equipment after maintenance, or in any situation in which the consequences of skipping, repeating, or partially completing a step would result in adverse consequences.
4.4.2.2	4-24	Place-keeping is used whenever written instructions are referenced to directly perform a task.
4.4.2.3	4-26	During the conduct of verifications and positioning, individuals implementing the work package should check all components to ensure that the component identification label is properly attached and in good condition.

Section	Page	Key Human Performance Point
4.4.2.3	4-28	Flagging is best applied for components that will be worked on and manipulated multiple times. Flagging/robust operational barriers are also useful if multiple similar components exist within close proximity or will be manipulated multiple times.
4.5.2.1	4-30	The task description should clearly state the work to be done, and if required, the work planner should coordinate with the scheduling organization to determine the appropriate task description.
4.5.2.3	4-31	The work planner should generate separate work order tasks if access to the component to be worked requires removal of interferences such as pipe supports, snubbers, or unrelated piping. Similarly, separate work order tasks should be developed for each major component.
5.2	5-2	The quality of a work package can be checked at many points during its development, issue, and implementation. Feedback provided to the work planning organization can be an effective tool for continuously improving the quality and accuracy of the work packages provided to craft labor.

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