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Construction of New Nuclear Power (NNP) Plants
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Advanced Light Water Reactors

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Preface

Legal Notice

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Introduction

Two decades of difficulty

If ever there was a time the electric utilities needed skillful construction management and sophisticated project control methods, the 1970s and 80s were that time. However, it is well documented that utilities had difficulties getting their hands around the many nuclear plants under construction in those two decades. Increased regulations, to a large extent related to the accident at Three Mile Island, created an increasing number of design changes. Quite frankly, the industry management was unprepared to cope with the scope and ramifications of these changes.

What's important

This volume details the issues that a number of management personnel involved in nuclear construction during these turbulent years think are important to consider for improving construction performance when nuclear construction in the United States resumes.

The program's objective

In its early phases, the Design for Constructability Program established an objective to influence two key areas:

- Inputs to plant design that can enhance constructability
- Improvements in the construction process

The investigations, workshops, meetings, and studies have focused the topics on these areas. The result is this volume, *Improving Construction Performance*, and Volume IV, *Enhancing Constructability Through Design*. Volume III's development came primarily from Construction Management and Project Control workshops, with input added from Industry Review and Construction Technology workshops.

How the volume is arranged

The sections are arranged by major issue for each subject. At the end of each section are significant conclusions, divided into:

- Recommendations—Conclusions worthy of acceptance.
- Considerations—Conclusions that were not universally accepted but should be taken into account.
- Cautions—Conclusions that should be evaluated to minimize past risks and problems.

Appendices

Appendices C and D contain workshop participants' views on modularization and the consortium approach to nuclear construction. Although the participants' experience with these two approaches is limited, the appendices summarize the participants' ideas and views on the use of modularization and consortiums.

Definition of terms

Term	Definition
A/E	Architect/Engineer.
AFUDC	Allowance for funds used during construction.
ALWR	Advanced light water reactors.
AP-600	Advanced passive 600-MWe PWR plant design concept being developed by Westinghouse/Burns and Roe/Avondale team.
Bechtel arrangements (initial)	Basis of discussions in the second Designing for Constructability workshop. February 1988 version of the study on PWR general arrangements performed by Bechtel Group, Inc. as part of the development of EPRI's Chapter 6.
Bechtel arrangements (current)	Version of the Bechtel study on general arrangements which is contained in Revision 0 of EPRI's Chapter 6, issued November 1988.
Containment Constructability Study	Comparative Constructability Evaluation of Advanced PWR Containments study performed by Bechtel North American Power Corporation under the Design for Constructability Program.
BWR	Boiling water reactor.
DOE	United States Department of Energy.
DPCo	Duke Power Company.
EH	Equipment hatch.
EPRI	Electric Power Research Institute, Inc.
EPRI Document	Thirteen-chapter <i>ALWR Requirements Document</i> being developed in EPRI's ALWR program.
EPRI's Chapter 6	Chapter 6 of EPRI Document, titled <i>Building Design and Arrangements</i> .
HP	Health physics.
HVAC	Heating, ventilation, and air conditioning.
IE	Industrial engineering
ISO	Isometrics
NPSH	Net positive suction head.
NSSS	Nuclear steam supply system.
Offset	Reactor Pressure Vessel and Reactor Coolant System loop offset dimension from containment centerline on a PWR.
O/M	Operation/Maintenance
Owner	The licensee.
PAL	Personnel airlock.

PCS	Project control system.
PI	Performance indicator
Program	Design for Constructability Program. DPCo's DOE Contract Number DE-AC03-86SF16566.
QA	Quality Assurance.
SBWR	600-MWe boiling water reactor concept being developed by General Electric Company, Bechtel, and the Massachusetts Institute of Technology.
SG	Steam generator.
SWEC	Stone & Webster Engineering Corporation.
WBS	Work breakdown structure

Section 1.

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Schedule

Introduction

Purpose

As the centerpiece of project control, a comprehensive, stable schedule should organize the project logically to accomplish the project's objectives. A good schedule will:

- Integrate the project team.
- Serve as a communications tool to all members of the project team.
- Provide a means to monitor and measure project performance.

Communication and the integrated project team

The table below indicates ways of creating a project team that has the best understanding of the schedule and is the most committed to it.

Who	Does what
Management team	<ul style="list-style-type: none"> • Uses the schedule to communicate the team's vision to each participant, possible only if the schedule and scheduling organization are integral parts of the work management efforts. • Looks at the schedule as a "team plan" for completing goals in a cost-effective way.
Everyone involved in the project (the project team)	<ul style="list-style-type: none"> • Participates in developing the schedule. • Understands the schedule by: <ul style="list-style-type: none"> ○ Keeping informed of all aspects of the schedule. ○ Having their roles clearly defined. ○ Performing to the level necessary to meet the schedule.
Schedulers	<ul style="list-style-type: none"> • Work as a team rather than individually. • Provide the executive organization and supporting groups with daily and long-term direction on: <ul style="list-style-type: none"> ○ Priorities ○ Need dates ○ Impact evaluations ○ Analysis of, and recommendations for, problems

Measuring commitment, understanding, and performance

To achieve commitment to, and understanding of, the schedule, the management team should:

- Understand that meeting schedule dates is vitally important to measuring project performance.
- Make certain that:
 - The schedule is given to all project team members.
 - Each team member's role is defined clearly.
 - Performance levels are established for each level.
- Provide feedback on successes.
- When monitoring and enforcing the team's performance to the schedule, reward performances consistently and equitably.
- Keep contractors as accountable as in-house employees, and designers as accountable as constructors.

Definition of scheduling terms used in this report

Term	Meaning	What should be completed
Functional boundary	<p>A portion of a designed system that can be operated and tested independently. For example, a functional boundary could be a:</p> <ul style="list-style-type: none"> • Train of a multi-train system (e.g., safety injection system "A" train) • Operable zone (e.g., fire detection) <p>Operations can use functional boundaries to plan and accomplish meaningful work.</p>	
Partial turnover	<p>Formal transfer to operations of control of a functional portion of the system (functional boundary). When accepting the transfer, operations can establish administrative controls and begin pre-operational testing. Partial turnovers are designed to allow operations to begin testing as early as possible, <i>not</i> to allow the constructor to ignore problems because of pressure to complete the project.</p>	<p>All work and installation documentation <i>except</i>:</p> <ul style="list-style-type: none"> • Final design certification. • System-related generic components that do not affect testing and are unwise to install at the time (e.g. insulation, pipe coating, or seismic snubbers). • Items beyond the organization's control that do not prevent testing (e.g., a qualified instrument that is to be delivered late).
Systems final turnover	<p>Formal transfer to operations of control of a designed system.</p>	<p>All work and documentation for the constructor, including piping supports.</p>

Term	Meaning	What should be completed
Local area turnover	Formal transfer to operations of control of an area (e.g., room, elevation, building, or partial).	All constructor work and installation documentation.
Building final turnover	Result of all local area turnovers, accomplished with the last local area turnover. The term provides unified, logical ties to major events in the schedule. For example, the diesel building turnover, which could comprise several parts, would be a building final turnover required before the functional test of engineered safeguards.	All work—no exceptions

Techniques of good scheduling

- Create a detailed completion schedule first.
- Make scheduling information available in a user-friendly style and in various formats, regardless of the job phase or the user's level.
- Define each activity's work scope based on detailed design, using installation status from the production control system. (The system should provide punchlists and be able to roll to successively higher levels in the schedule.)
- Ensure that the schedule gives inventory needed dates to the materials procurement and delivery system.
- Schedule quality assurance requirements and associated documentation with turnovers with the same installation as testing.

Basic Schedule Structure

Breaking down activities to meet schedule needs

A schedule must:

- Clearly define the project's direction and how it is getting there.
- Focus appropriate attention on those areas that require special attention.

To meet these needs, the schedule:

- Begins with fundamental project objectives, called *milestones*.
- Breaks the milestones into smaller, more detailed levels of work, typically called *work packages* (see "Work Packages" on page 1-15), that can be easily defined and monitored to show the true project status.

Work breakdown structure

This progression of logically dividing projects into tasks and subtasks is traditionally called a *work breakdown structure*. Figure 1-1 on page 1-36 is an example of a work breakdown structure (but is not intended as an absolute definition).

Pyramid progression

A different but complimentary version of the task breakdown is a *pyramid progression*. The base of the pyramid represents the lowest level of detail; the peak shows the total project and its goal(s). Though it does not indicate how to arrive at the objective, a pyramid progression does illustrate that each level must "roll up" all activities below it. (See Figure 1-2 on page 1-37).

Building the pyramid's components

Assuming that 90% of design will be completed before construction begins, creating the top four layers of a pyramid should be possible before construction. The development of the fifth level, labeled as the work package, can then proceed in increments and still remain 3-6 months ahead of the start of area work. It is very important to ensure that sufficient lead time is included in the schedule to allow development of a well-planned work package.

Project Milestones and Milestone Schedules

Purpose of milestones

Milestones serve as the primary communicators of the project's overall objectives. Because ambiguous definitions can create the illusion that high-visibility schedule dates have been met, milestones must be strictly and clearly defined from the beginning. If the number of milestones is limited (10 to 12) and their scope is broad, milestones can:

- Become common knowledge and therefore serve as essential goals for:
 - Measuring success
 - Clearly demonstrating management's plan for completion
- Consolidate individual efforts into "the big picture."

Milestone schedules

One of the first management tools needed for a new project, a project milestone schedule includes major start-up and construction activities. The schedule must focus on key events that lead to the project objective—power production. Figure 1-3 on page 1-38 is an example of a milestone schedule.

Milestone dates

Dates for milestones must not be imposed arbitrarily. When management determines the project start date and resource levels, the schedule itself will provide dates.

Commodity Schedules

Commodity composite schedules

A commodity composite schedule:

- Documents the first step in the scheduling progression below the milestone level.
- Captures the planning that ultimately forms the full schedule.
- Provides an overview of major project elements.
- Shows the logic imposed by regulatory bodies or physical restraints.
- Reflects the earliest decisions on "what will be completed when" (in absence of total logic).

Note: These decisions show an intent on which to base the schedule. Therefore, they should be renegotiated only when they are proven as not being cost-effective.

- Predicts labor needs by:
 - Discipline
 - Overtime
- Gives rough cash-flow projections.
- Provides a bulk commodity schedule. (See below.)

Bulk commodities schedules

Developed from the project completion and commodity composite schedules, a bulk commodity schedule:

- Considers the timeliness of working each area/commodity.
- Sorts tasks by area/commodity to ensure the correct commodities are installed efficiently.
- Allows installation rates to measure production performance.

Milestone Packages

Definition

After commodity schedules are created, the next step in scheduling is to determine the requirements of each milestone. These determinations, brought into a *milestone package* (Figure 1-4 on page 1-39), begin the process of defining scope.

What a milestone package does

A milestone package, though still in broad terms:

- Organizes the project into understandable chunks.
- Allows priorities to be brought in.
- Clarifies:
 - Material need dates
 - Workforce projections that provide information to determine training needs, a significant factor in future projects
- Defines key activities that must be completed to successfully accomplish the milestone.

Milestone summary schedules

Milestone summary schedules communicate what is expected of project participants. Early in the project, the summary schedule may reflect only general inter-relations and target dates. Details should be added, however, as each milestone approaches. These details focus attention on the prerequisites for the project's next major event. (See Figure 1-5 on page 1-40.)

System/Area Boundaries

How do systems and areas become involved?

The milestone package's framework indicates when systems and areas are required to support project completion. At this stage, the planning moves from purist start-up logic to the project management area of:

- Optimizing starting time for system testing
- Maximizing efficient area completion

Scheduling systems

A good system schedule results in basic construction priorities and is the *primary component* in the schedule network. Shown below are methods to use when scheduling systems:

- Make certain the systems schedule gives operations functional portions of systems as soon as possible to:
 - Allow the following:
 - Performance and preoperational testing to occur
 - Partial systems to be put into service
 - Give operations a chance to:
 - Optimize their work force
 - Identify functional problems early
- Identify functional and testable portions, such as:
 - On simple systems, dividing the system by train.
 - Dividing work into several partial turnovers of testable independent elements.
- Once boundaries are identified, apply start-up logic to organize the following for preoperational testing:
 - Construction
 - Testing
 - Scheduling sequence

Scheduling areas

Shown below are techniques to use when scheduling areas:

- To define the sequence of erecting structures, break down area by buildings, elevation, and room.
- Use the following to dictate the scheduling sequence:
 - The accessibility of the area
 - The criticality of the components to be installed
 - Logic relating specifically to the area, such as completing areas farthest from the point of access
- Schedule completion primarily by the time at which most component work is completed in the area.

Note: This method of scheduling completion allows structural "cleanup."

Scheduling between system/area and detailed activity completion schedules

Before moving to the next level of scheduling, detailed activity completion, the optimized partial turnovers should be reassembled into final packages. The object of the system/area schedule was to gain the earliest turnovers possible; as a result, these turnovers must occur before completing design/as-built certification or verification. Therefore, system logic takes completion of the last portion, system/area, and schedules final documentation and review for a sequential completion of the original designed boundaries.

Administrative controls

At each stage of turnover, administrative controls must be in place for:

- Protecting personnel
- Controlling configuration
- Preventing damage to installed components

Detailed Activity Completion Schedules

Description

A detailed activity completion schedule (Figure 1-7 on page 1-41) is, essentially, the "scheduler's schedule." This schedule can cover 4-12 weeks or can fluctuate with the stage of the project. The schedule should:

- Cover the following:
 - All construction completion
 - Testing
 - Turnover events
- Focus on all interactions required.

Activities in the schedule

Activities can cover multiple work packages. Each activity represents a corresponding list of incomplete items that must be completed *or* justified to remain outstanding. In addition to work involving construction hardware items, tasks identified include inspection, documentation, and review—all aspects of activity. Support activities such as inspection and documentation are typically more critical, so make certain that responsible groups are held equally accountable for schedule performance.

Work Packages

When work packages are needed

Defining turnover and start-up logic assures that the parts are integrated with the "big picture." Once that definition is accomplished, those parts should be separated into smaller elements to allow efficient construction and short-term monitoring. This separation, which generally occurs through a systematic process of progressively narrower criteria, results in small and easily defined portions of the plant.

Purpose

- To increase project control and work management abilities.
- To provide field foremen/supervisors with all the necessary task definitions and documents to perform scheduled work (e.g., clear expectations).
- To enhance project control and work management to help monitor progress.
- To guarantee high-quality turnovers and system closeouts.
- To improve craft productivity.
- To allow retrieval of pertinent information if generic problems occur (e.g., material tracing and personnel work task sign-off activities).

Work package breakdown

As before, the small portions of work in this phase of scheduling should be broken into area and system as follows:

Aspect	Breakdown
System	Design boundary Functional boundary (as defined in "System/Area Boundaries") Building (where system components are located) Elevation Room (if applicable) Commodity: <ul style="list-style-type: none"> • Pipe • Support/restraint • Electrical • Instrumentation

Aspect	Breakdown
Area	Building Elevation Room (or defined column lines on large, unbroken elevation) Commodity: <ul style="list-style-type: none">• Structural• Lighting• Painting• Cleanup

Definition and scope

Work packages should:

- Be a clear, detailed definition of a manageable portion of work activities that a supervisor/foreman uses to meet schedule expectations.
- Provide a means to identify the appropriate materials, tools, and equipment needed for a work activity.
- Include all work of a given commodity within a particular area. (In system-related commodities, the final parameter is within a functional boundary).
- Include a single discipline.
- Be limited to specific plant areas to prevent inefficient traveling.
- Be small enough to close out relatively quickly (between 1-4 weeks) to avoid problems such as loss of paperwork.
- Be able to be rolled up to define all requirements for that aspect (e.g., area, milestone) of the schedule.
- Only include work items for tasks that will be completed within the expected time frame. (For example, do not complete grouting of equipment bases with the setting of equipment.) When scheduled construction activities within a work package are delayed or rescheduled, the activity and related documentation should be removed and placed in a separate package.
- Be structured to minimize exceptions.

Reminder: The procedures for developing, handling, and maintaining work packages are an important part of the work control process. Define specifics of authority and responsibility for the work packages.

What work packages should include

In addition to a definition of scope, a work package's contents are important and should include:

- An index of all documents included
- A component list (scope definition)
- BOM for parts required for installation
- Necessary drawings
- Process control travellers
- Procedures required during work
- Shutdown requests after turnover

Note: Accurate, complete work packages are essential to avoid inefficient use of craft. Necessary drawings should include only the scope of work needed to complete the work package. A flexible CAD system should be able to generate the defined scope of a particular commodity (such as piping isometric).

Results of dividing areas and systems into manageable portions

- Larger, more complex systems are separated into constructible pieces or *packages*.
- Control of the project is aided by defining scopes of work that are easier to "get your arms around."
- Discrete problem areas are simpler to identify and focus on.
- Personnel are familiarized with their assigned packages.
- Completed packages make progress more visible.
- A win-win situation is established for all parties.
- Communication is improved among interacting organizations.
- The program needed to manage the "change process" is better established and controlled.
- More difficult work will be completed in more manageable portions.
- Communication is simplified, reducing the potential for mistakes during changes in personnel.
- A hierarchy is established for document retention, filing, and retrieval (if needed).

Developing work packages

Every aspect of a project is assigned attributes to facilitate efficient scheduling. Assigning attributes to each plant component is the basis for developing work packages. These attributes are:

- System/area/commodity attributes
- A place in the overall schedule where the component is needed, establishing dates for receipt and installation
- Labor cost and installation time values, in unit rates

Using design flexibility prudently

Prudent use of design flexibility (e.g., using typical hangers) allows the constructor freedom to address specific site situations. With this flexibility, the constructor needs to finalize work activity requirements so that a complete work package can be issued to the supervisor/foreman.

Organizing work packages

Organize work packages based on the kind of work (commodity) and the stage of the project, as follows:

Type of item	Method of organization	Example
Structural items	Organize by commodity, then area.	Concrete on this elevation
System-related commodities	<ul style="list-style-type: none"> Initially -- Organize work only by area and type. Later -- Specify work to system or functional boundary. 	<ul style="list-style-type: none"> Initially -- basement, large-bore pipe Later -- Safety Injection System 1 instruments for this loop

Tailoring work packages

Given the purpose and items included, a work package should be tailored so that it is practical and efficient. Examples:

IF...	THEN...
Limiting to one area results in too many small work packages	Combine areas into proper sizes.
The package for work on Safety Injection System pipe on an elevation is too large	Break packages by rooms or other parts of area.
A supervisor has multiple work packages to finish all work of the discipline in an area	Make the schedule more efficient by staggering deadlines.

Work packages and the network schedule

Work packages can be inserted into a network schedule, but it may be more cost-effective to include only summary-level relationships with the following:

- Functional boundaries
- Local area turnovers

The work sequence in detailed work packages is more complicated, so it may be more practical to schedule these packages in a simpler way, such as independent "mini-networks." However, once early projects provide experience or records, networking all work packages should then be cost-effective.

Making work package programs effective

- Effectively present and sell the program using success stories and information from the Construction Industry Institute.
- Within the organization, develop the mindset to support the work package process.
- Establish that the planning process's up-front costs are much less than the cost related to a "reactive" work process.
- Unite the project team early enough to ensure that everyone accepts and supports the program's details.
- Make designs as complete as possible.

- Make the design organization accountable for interferences and construction accountable for erecting commodities according to drawings. (Construction should not use design to justify errors.)
- In preparing work packages, establish methods to ensure a quality review and signoff of the content and accuracy of work package information.
- Reference reports of outstanding problems (such as non-conforming items) within the affected work package to enhance the quality of system turnovers or closeouts.

Note: Work-place procedures have been used successfully in formalizing enhancements. Appendix B provides an example of Florida Power and Light's use of work-place procedures at St. Lucie.

Recommendations/Conclusions

Recommendations

The schedule is a key tool for establishing expectations and managing the time and work force to meet objectives.

Recommendation/Conclusion	Comments
<p>Make your schedule meet certain needs.</p>	<p>A schedule must:</p> <ul style="list-style-type: none"> • Be user-friendly. • Be available by system, area, and commodity. • Give objectives with scope definitions that are exact and measurable. • Include and integrate everyone involved in the project, such as: <ul style="list-style-type: none"> ◦ Prefabricators ◦ Major vendors ◦ Quality control ◦ Design • Provide the materials procurement area with dates for which material is needed. • Schedule documentation and inspections at the same time as installation.
<p>Use long-range scheduling to predict the needs of your work force.</p>	<p>If you can predict your work force, you can manage the schedule to levelize work force.</p>
<p>Make certain that schedule performance is:</p> <ul style="list-style-type: none"> • Monitored • Communicated • Enforced • Rewarded 	<p>Use performance indicators to assist in monitoring schedule performance.</p>
<p>Keep all project team members informed of short-term objectives and expectations in the schedule and project.</p>	<p>Keeping team members involved will ensure that they understand the schedule and will be committed to, and accountable for, staying on schedule.</p>

Recommendation/Conclusion	Comments
Because start-up logic influences bulk area and system schedules, establish start-up logic well before mechanical and electrical system construction begins.	Establishing start-up logic early will help properly sequence and plan for system turnovers to start-up personnel.
Make certain the schedule includes the entire period of the project.	
Develop the schedule with input from all departments involved in the project.	

Production Control

Introduction

Recognizing good practices of production control

The items in this section can be considered good practices of production control, as the participants in the workshop recognized their value and necessity. (For further information on the production control system, see Section 2, "Project Control System (PCS)" on page 2-1.)

Milestones are the basis of production control

As mentioned in "Project Milestones and Milestone Schedules" on page 1-9, a milestone schedule supported by the production control schedule:

- Makes the following possible:
 - Commitment
 - Motivation
 - Accountability
- Allows all members of the project team to focus on the same goal.
- Prevents efforts from diverging from the main goal.

Goals of a PSC

Summary of goals

- Develop the tools and documentation needed to:
 - Create and monitor schedules.
 - Maintain daily work flow.
 - Make adjustments when data indicates they are needed.
- Make certain the scope of project activities is minute, as this scope is the foundation of the production control plan. Represent this small detailing in the schedule by detailing and organizing the scope of project activities into work packages.
- Define and implement work packages to focus the organization and to keep people productive.
- Make certain that updates and status:
 - Use as much existing documentation as possible.
 - Are tied directly to the quality control process.
- Make the system flexible to enable project management to see information from various perspectives (e.g., commodity, system, or area).
- Evaluate production goals as actual rates become available.
- Use an online computer system and update system data continuously.
- Make certain that audits are in place to verify the accuracy of data required for production control.
- Ensure that production goals are established, achievable, and accepted by management and at the working level.
- Make managers accountable for achieving the goals.

Accomplishing the goals

Goal	How to accomplish the goal	Result
Get owner/utility representatives directly and actively involved in establishing the production control process. (The many decisions and judgments needed to develop and manage a production control system require the owner/utility to be involved.)		<ul style="list-style-type: none"> • Schedules will be met most cost-effectively. • Keeping the owners/utilities involved guarantees overall understanding and commitment to the process.

Goal	How to accomplish the goal	Result
<p>Establish the program to create a "win-win" environment between:</p> <ul style="list-style-type: none"> • Owner/utility • Designers • Constructors 	<p>Incentive contracts can be used to keep the aforementioned involved. The contract payments should be based on performance against goals in:</p> <ul style="list-style-type: none"> • Quality • Cost • Schedule 	<p>This environment will help create the feeling that groups are allies rather than adversaries.</p>
<p>Effectively determine the level of detail to measure and monitor.</p>	<ul style="list-style-type: none"> • Use the same progression as the schedule itself. • Remember that the level of detail to measure and monitor is critical. • Accommodate bulk production with system knowledge/direction. • Look to the definition of test boundaries for general direction. • From the beginning, focus the wholesale installation of bulk commodities toward the test boundaries and system. • Make the definition of <i>complete</i> consistent, as this definition is critical. • Match the level of detail with the complexity of the activity being controlled. • Provide progress reports to each level of the organization in appropriate detail. 	<p>For example, all commodities, systems, or areas should have specific identifier names loaded in a data base for sorting to satisfy a specific construction milestone need.</p>
<p>Document all decisions in development and execution of work control.</p>	<p>Make certain someone in the organization is responsible for keeping a record (diary).</p>	<p>Documentation will guarantee these decisions can be explained in a review.</p>

Goal	How to accomplish the goal	Result
<p>Throughout the project, establish and maintain the system's credibility through:</p> <ul style="list-style-type: none"> • Timeliness • Accuracy • User-friendliness 	<ul style="list-style-type: none"> • Define the project team's responsibilities to ensure their accountability. • Use the craft supervisors' first-hand knowledge of field status to verify the published data. • Avoid the syndrome of "nobody's business is everybody's business." 	<p>Commitment to use the data.</p>
<p>Have site managers and site supervisors aware of their responsibilities and authority.</p>	<ul style="list-style-type: none"> • Make certain site managers: <ul style="list-style-type: none"> ◦ Recognize their responsibility to make decisions using production control information. ◦ Have authority in production control. ◦ Use production control indicators to make decisions for which they are responsible. • Do not burden field supervisors with excessive reports. 	<p>Teamwork that focuses on one source of information.</p>
<p>Define production goals and units of measure.</p> <p><i>(Example: Counting cables by linear feet is inappropriate if management makes decisions by the number of cables.)</i></p>	<ul style="list-style-type: none"> • Let unit rates begin as targets, then adjust them as actual data becomes available. • Keep improvement in production as a constant goal, enhanced through approaches such as industrial engineering and work improvement teams. 	<ul style="list-style-type: none"> • Well-maintained production management records will be beneficial during subsequent regulatory reviews. • Future plants will have more historical data from which to begin.
<p>Design the production control system to:</p> <ul style="list-style-type: none"> • Provide project status from current information. • Include data used as performance indicators. <p><i>Note: The method of updating the production control system is a critical part of maintaining an accurate schedule.</i></p>	<p>Properly staff the production control system area with the resources necessary to maintain an accurate, up-to-date-system.</p>	<ul style="list-style-type: none"> • Status from current information ensures that the original schedule's production assumptions are corrected. • Performance indicators are useful when documenting and managing the performance of individual crews and supervisors.

Goal	How to accomplish the goal	Result
<p>Instead of project delays, use more frequent, less painful methods of measuring the effectiveness of the production control system.</p>	<ul style="list-style-type: none">• Use a variety of tools that will audit production control specifically and objectively (in other words, not just schedule delays), such as:<ul style="list-style-type: none">◦ Walkdowns◦ Absenteeism◦ Morale• To maintain system credibility, regularly review the documentation used to collect information on system effectiveness.	<p>Problems are identified earlier for better solutions.</p>

Cost Control

Cost Control's Integration With Other Aspects of Construction

Importance of integrating cost control with schedule and production control

Cost control directly relates to schedule and production control (as well as material management), so the importance of an *integrated* schedule/production control/cost control system cannot be overemphasized. The overall costs of projects are greatly influenced by how well a project team keeps on schedule. When implemented, a detailed cost control system will pay for itself because it will:

- Help avoid late startup.
- Reduce financing costs.

Integrating activities for productivity

An essential element in cost control, productivity is maximized by making certain that the schedule accurately and completely integrates all activities:

- Engineering
- Material availability at the work location
- Tools and equipment
- Labor

Results of the integration

Effective integration of all schedule activities:

- Eliminates the need for getting various labor areas to coordinate in order to function correctly and most efficiently.
- Permits craft supervisors or foremen to concentrate time and attention on directing the work in progress, *not* in chasing solutions.
- Allows each level of management to know precisely how work groups are performing, enabling managers to have direct, immediate effect on productivity.
- Permits primary elements of cost to be:
 - Predicted
 - Measured
 - Contained

Materials management and cost control

The materials management information below in "Materials Management" minimizes material costs by scheduling delivery dates to be "just in time" to field locations. This scheduling process can measure a group's use of consumable materials, which can also be used as an indicator of productivity.

When schedule control does not control cost

Many costly methods of meeting schedules do exist, so meeting the schedule does not always mean controlling costs. For example, schedules can be met using more personnel and overtime, but at increased costs. Details of how to build labor and labor costs projections and goals are addressed in Section 2, "Project Control System (PCS)" on page 2-1.

Materials Management

Introduction

The importance of materials management in construction efforts

The success of any construction effort depends greatly on materials management. In fact, some experts believe more is to be gained in labor efficiency with materials management than in any other area of improving productivity. For instance:

- Material costs make up a large percentage of overall project costs (e.g., 31%, excluding AFUDC, at Catawba).
- The availability of materials has a significant impact on productivity; experiences in constructing nuclear power plants in the 70s and 80s indicate that lost craft time often involved looking for, or waiting on, materials.
- Research has shown that a basic materials management system can improve craft productivity by 6% or more.
- Sophisticated materials management systems can be expected to save 12% or more in labor costs when the systems are part of an overall project control system.

Future constructors should research materials management systems in other industries because considerable time will have elapsed since the previous generation of plant construction.

Integrating materials management in the project control system

Integration of the materials management system with the rest of the project control system is essential. The integration's success can be measured by how well the project team gets the correct materials:

- To the right place
- At the right time
- With the lowest possible cost (including craft delays)

Simplifying and lowering the cost of materials

The design phase is the first place to significantly simplify and reduce the cost of obtaining, storing, and handling materials. Standardized, commercially available items should be incorporated in design specifications as much as possible, a benefit that carries into plant operation and maintenance. Having fewer types of items will help avoid the many problems in the 70s and 80s that were associated with unique, costly components that have long lead times.

Establishing a Materials Management System

Planning and communication

- Remember that proper planning and communication are requirements for an effective system.
- Before the project begins, clearly define the roles of the:
 - Owner
 - Engineer
 - Contractor
 - Subcontractors
- Establish the organizational responsibilities of all materials management tasks and make certain everyone understands them.
- Have detailed written procedures for performing and monitoring materials management activities.

Accurate materials identification

- Have an accurate bill of material for all tasks and drawings.
- Remember that using computer-aided design should simplify and increase the accuracy of identifying materials.

Vendor evaluation

- Develop a formal process for evaluating vendors, important since a new generation of suppliers may exist.
- Include these factors in the evaluation process:
 - Quality
 - Cost
 - Delivery
 - Services offered
 - Warranty
 - Financial vulnerability
 - Capability
 - Value added, based on past performance

Expediting

- Use effective, proactive expediting to:
 - Ensure that vendors meet their commitments.
 - Provide current delivery information to the site
 - Allow detailed work schedules to be adjusted in time to prevent craft delays and subsequently lower production cost.
- Use computer resources to:
 - Sum up priorities.
 - Identify critical items.

- Make certain that close, frequent communication exists between field personnel, expeditors, and vendors.
- Have technical personnel verify that vendors are meeting specifications.
- If necessary for major components and contracts, dedicate personnel full-time to verify technical compliance during manufacturing or assembly. This control will avoid previous problems of poor-quality or incorrect items being shipped.

Materials management after delivery

Note: Materials management is particularly crucial after material is received on site because of the vast number of items that will be stored in various project locations.

- Maintain accurate receiving reports to identify material status and location correctly.
- Control material issue against the quantity and need identified by the schedule and the production control system.
- Use "max-min" (maximum-minimum) systems whenever cost-effective to:
 - Avoid over-control—"spending a dollar to control a dime."
 - Provide an adequate inventory on hand at all times, based on projected usage.
- Locate satellite issue stations as close to the work place as possible, often the most effective approach for storing and issuing items that have high usage and low cost.

Allocation systems

- Use allocation systems to ensure need does not exceed availability.

Note: Inadequate control of allocated materials has been disruptive in previous nuclear construction projects. Because of inaccuracies in the 70s and 80s, there was a need to physically allocate rather than allocating by computers. However, the next generation of builders may have the discipline to use the material as specified by the computer rather than aborting the plan.
- Audit inventories periodically to verify that records are accurate.
- Make certain controls are in place to ensure that materials are used in their intended location, as indicated on the structure erection schedule.
- Keep records of when and to whom issues are made to promote accountability and assist in locating lost material.

Storage

- When designing facilities, allow for storage to ensure that the proper security and environment are provided. (Inadequate storage can quickly lead to material deterioration and losses.)
- Use an effective preventive maintenance program for equipment both in storage and in place. This control ensures that equipment will work for its designed life without excessive maintenance costs.

- Before material or equipment is received, have the designer or vendor specify detailed storage requirements, such as:
 - Humidity control
 - Lubricant maintenance
 - Indoors vs. outdoors

Data management

- Keep in mind that data management is perhaps the most important part of an effective materials management system.
- Use a data base to:
 - Manage the vast quantity of information in the system.
 - Provide the necessary communications path.
 - Track total quantity as it is:
 - Ordered
 - Received
 - Released
 - Allocated
 - Issued
 - Installed

Note: For more information on this topic, see Section 2, "Project Control System (PCS)" on page 2-1.

Getting the material to the user

- Make materials delivery part of the total materials management system.
- Use personnel trained in warehouse tasks and in handling material to:
 - Provide more efficient delivery.
 - Cut down on delivery cost by using handling personnel rather than craftsmen, who are typically paid higher wages.
- Plan deliveries based on daily work schedules so that craft supervisors can complete work rather than spend time locating material.
- Seriously consider using the latest, most technological material-handling equipment.

Construction tools and equipment

- Keep tools available and in good working condition to enhance productivity and work quality.
- Make identifying, controlling, and maintaining construction tools part of project planning.
- Deliver special tools or equipment to the work location at the same time as permanent plant deliveries.

Materials control system and procedures

- Keep a proper balance between control and availability.
- Make the system flexible enough to react to surprises, schedule changes, and human error.
- Make back-up systems and contingency plans available for times when electronic systems are out of service.

Purchases

- Base purchases on scheduled need and lead time; timely purchases are a key to overall success.
- Based on project milestones, plan major equipment purchases, (e.g., steam supply system, turbine generators) to occur before construction begins.
- Later in the project, use detailed scheduling to base decisions on material (e.g., piping and cable).
- Use the computer-based, integrated project control system to facilitate purchase decisions.

Benefits of an Effective Materials Management System

Costs vs. benefits

Establishing an effective materials management system requires significant expenditures and resources. As shown below, the benefits of a materials management system outweigh the cost involved.

Improved productivity

Productivity will improve by:

- Reducing starts and stops in work activities.
- Eliminating the costs of returning to work locations and completing unfinished items, which often costs more than the installation itself.

Reduced warehouse and storage space costs

If warehouse and storage space are reduced, costs will be reduced as well. Minimal storage time is required when materials are properly identified and purchased at the correct time. Fewer items to store at any one time reduces facility costs.

Savings from levelized cash flow

Cash flow levelizes, resulting in savings, when items are purchased at the latest possible time before installation. These savings could be substantial because of the cost involved in keeping material on hand.

Example: Insurance, taxes, and facility costs range between 30-40% of an item's total cost. A \$100 item kept in stock for a year could therefore cost an additional \$30-40.

Many variables do affect the manufacturing and delivery of materials; owners should establish a "cushion" for need dates but realize the costs involved.

Lowered surplus

Planning purchases based on the complete design and schedule needs will result in:

- A minimal surplus (1% or less) to be expected at project completion.
- Reduced costs for maintaining, marketing, or disposing of excess materials.

A reduced surplus would be an improvement over experience with existing plants, where early, large bulk orders were made when project plans were incomplete.

Recommendations/Conclusions

- Clearly define the roles and responsibilities of the:
 - Owner
 - Engineer
 - Contractor
 - Subcontractor
- Purchase materials based on the schedule needs and expected lead time.
- Maintain inventory and inventory allocation controls.
- Make certain that:
 - Accurate bills for material for all drawings or tasks are prepared.
 - Effective, proactive expediting methods exist to assure delivery as requested.
 - Effective programs are designed to protect and preserve materials and make certain that proper construction tools and equipment are available as needed.
- A system of distributing materials is developed in which warehouse and handling personnel are knowledgeable.

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SCHEDULE DEVELOPMENT MODEL

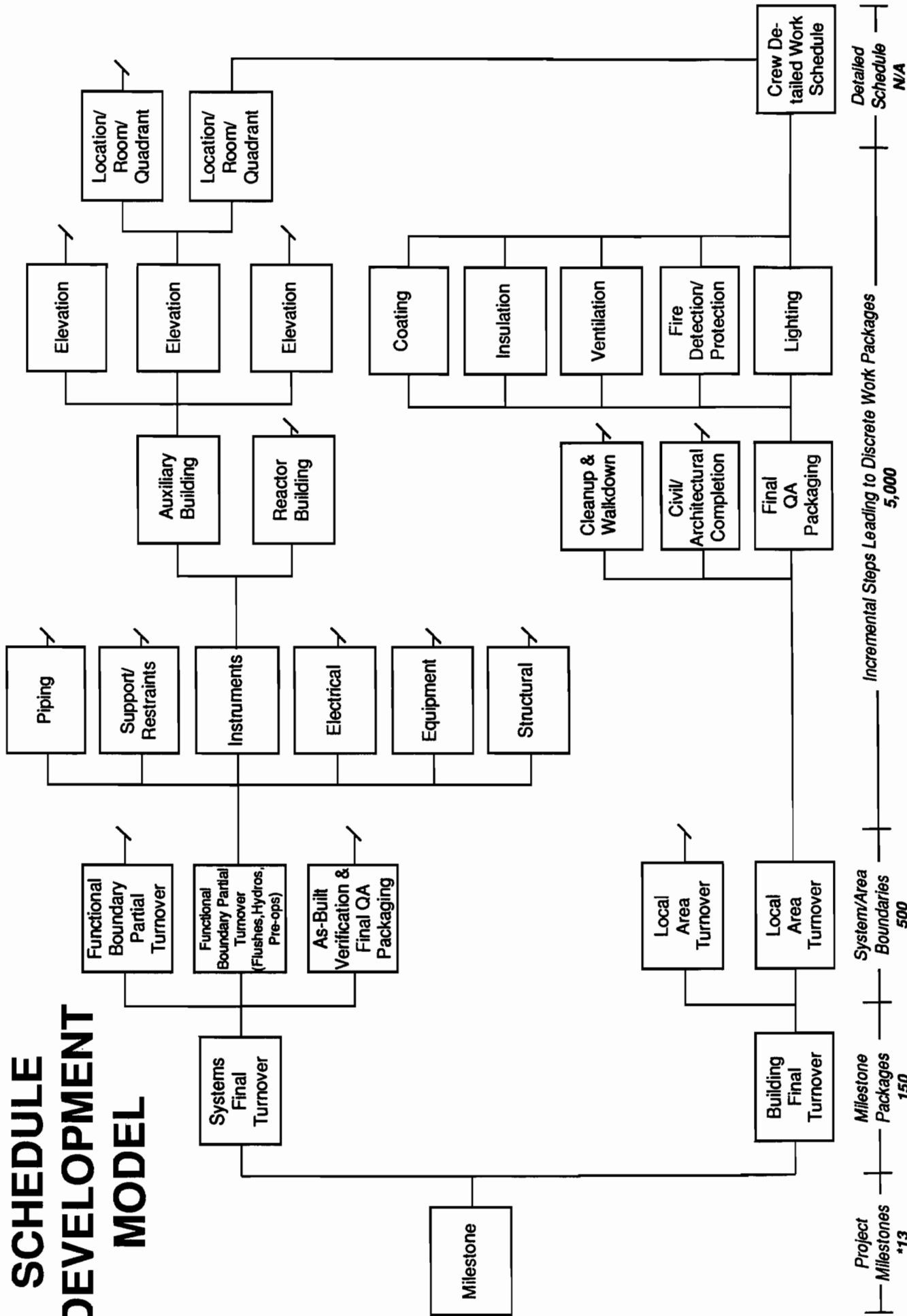


Figure 1-1

*Approximate number of elements for each level

PROJECT SCHEDULE HIERARCHY

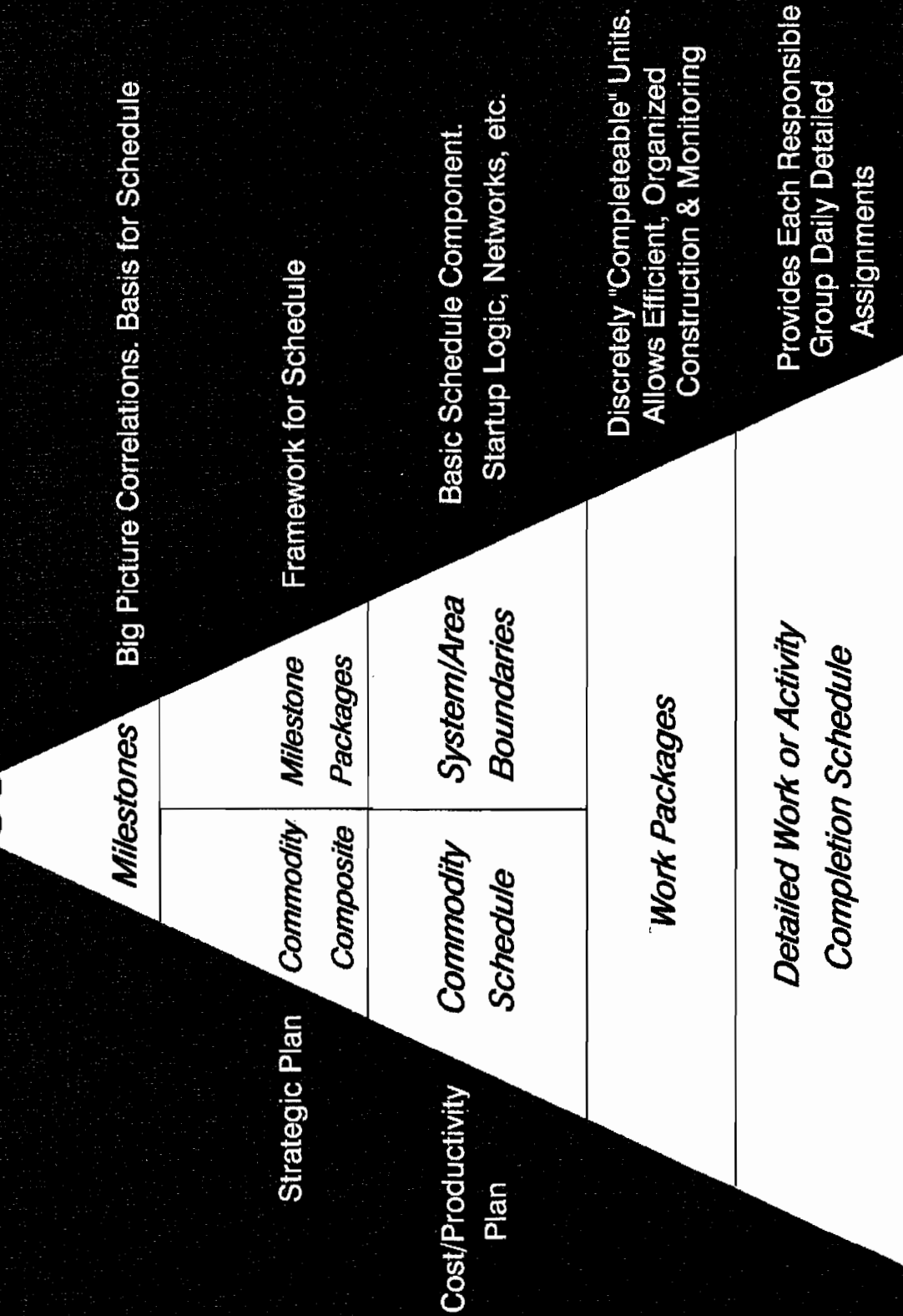


Figure 2



TOP

Example of a Milestone Schedule

	Milestone	* Date
1	Site preparation	-12
2	Start structural concrete	0
3	Start NSSS	12
4	Block power initial energization	26
5	Start mechanical system turnovers	29
6	Complete steam generator secondary side hydro	37
7	Complete RCS cold hydro	40
8	Emergency on-site power available or engineered safeguards Functional	41
9	Start hot functional testing	42
10	Start structural integrity test	44
11	Start fuel load	46
12	Initial criticality	49
13	Complete 100% warranty run	54

* Duration from project start, in months, is used in place of dates.

Note: This example is not intended to be a definitive list. Other, earlier major events can include licensing, financing, and design completion. This list should be kept short to focus attention on the most important steps toward project completion.

Figure 1-3. Example of a milestone schedule

EXAMPLE MILESTONE PACKAGES

Milestone 7 - RCS Cold Hydro

*R V Head Installed

- RCS Final Cleaning (Interior)
 - Safety Injection Flow Balance
- RHR (ND) & CVCS Pump Performance Tests
 - RHR (ND) Partial Turnover to Operations
 - Q.A. Review Turnover Package

*RCP's Aligned and Coupled

- RCP Motor No-Load Runs
 - Motor Oil System Operational
 - Motor Cooling Water Operational

Milestone 11 - Start Fuel Load

*Implement Security

- Employee Badging
 - Security/HP Training
 - Background Checks/Fingerprinting
- Security Systems Final Turnover to station
 - Q.A. Review Turnover Package
 - Final Document Assembly
 - As-Built Verification

*Area Completion and Turnover

- Walkdown and Acceptance
 - Q.A. Review Related Documents
 - Final Document Assembly
 - Final Coating

* Milestone Package Elements

- Details, progression indicated by indentation

EXAMPLE MILESTONE SUMMARY SCHEDULE

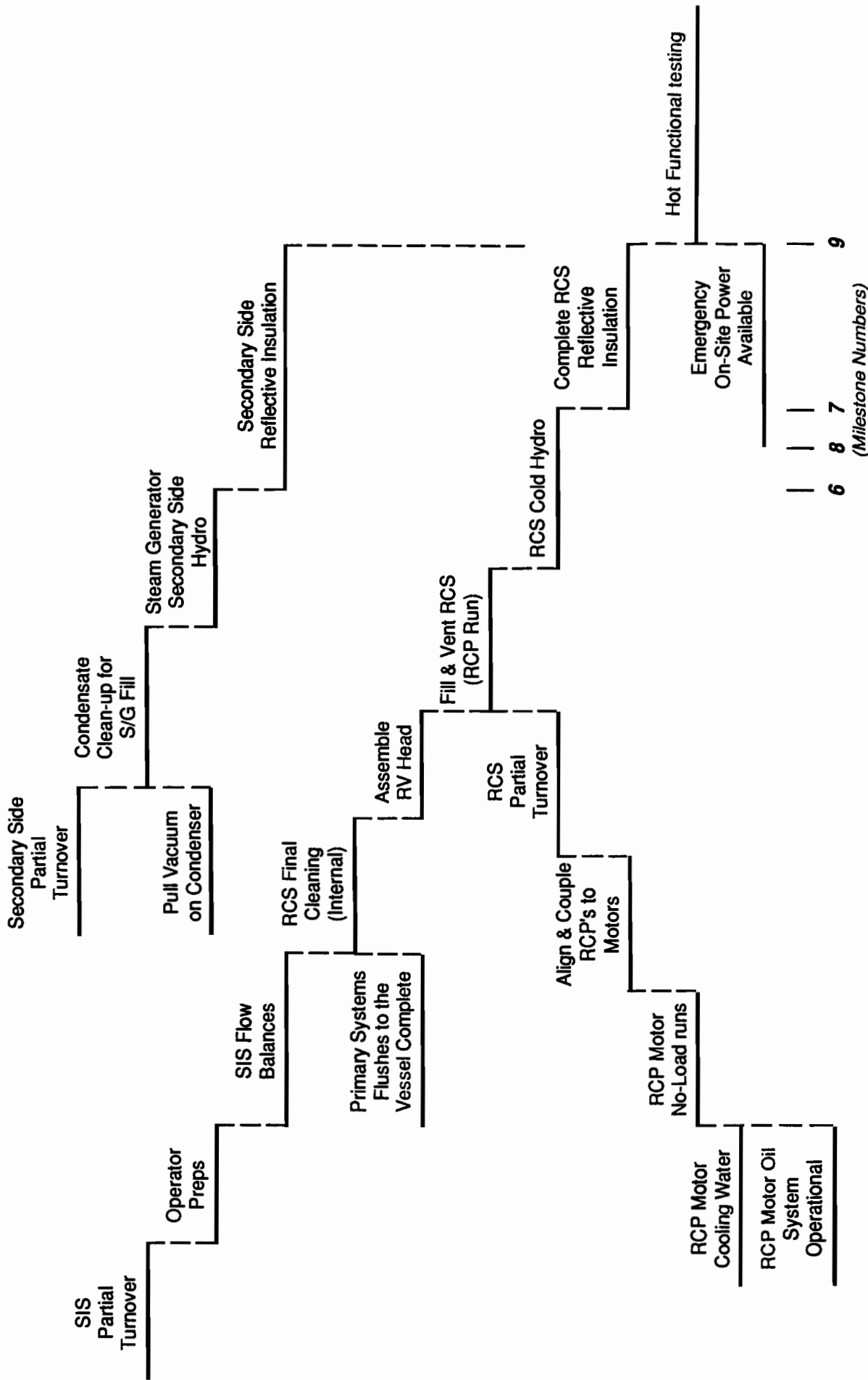


Figure 1-5

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EXAMPLE DETAILED ACTIVITY COMPLETION SCHEDULE

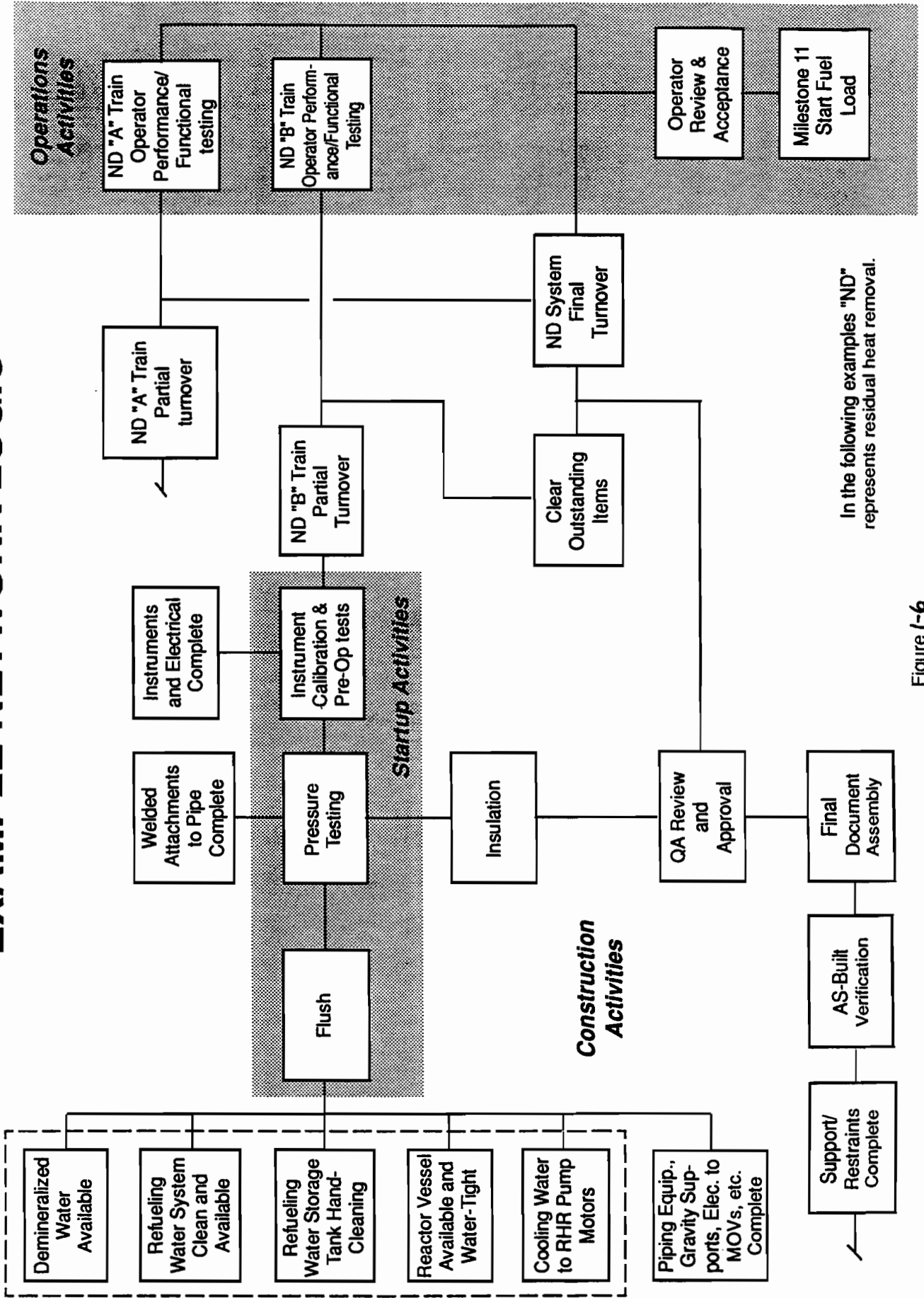
Week of:

Boundary Activities	Responsibility	XXXXX XXXXX XXXXX XXXXX XXXXX XXXXX
ND "A" Train Flush	Const. Test Group	XXX
Complete Piping	Aux. Bldg. Piping	XXXXX XXXXX
Complete Piping	Reactor Bldg. Piping	XXXXX XXXXX
Configuration Inspection	Quality Control	XXXXX XXXXX
Resolve Discrepancies	Building Eng.	X XXXXX XXX
Complete Gravity S/R's	Aux. Bldg. Hangers	XXXXX XXXXX XX
Complete Checkout-MOV's	Reactor Bldg. Elect.	XXXXX XXXXX XXXXX
Motor Rotation Check	Aux. Bldg. Electrical	XXX
Couple Pump/Motor	Aux. Bldg. Mechanics	XX XX
Verify Work Packages	Project Control	XXXXX
Turnover to Test Group	Project Control	XX

Figure 9



EXAMPLE NETWORK LOGIC



In the following examples "ND" represents residual heat removal.

Figure 1-6

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Introduction

Purpose of this section

This section describes an integrated project control system (PCS) for use in the construction management of future nuclear stations. Though somewhat conceptual, this PCS illustrates project control through integrated data management and uses examples based on experienced.

Basis of the PCS

This PCS:

- Is based on constructors' experiences with stations completed in the 70s and 80s.
- Recognizes one-step licensing and complete design before construction as concepts basic to this program.
- Is not intended to contain all records needed for construction project management and control.
- Demonstrates how any and all records can be systematically related both to one another and to the master plan.

Purpose of the PCS

- To organize all information required to manage the project construction schedule and labor cost by integrating information on:
 - Work scope
 - Labor
 - Unit rates
 - Schedule dates
- To provide management with objective data on performance, which can be used to make decisions and measure success based on results rather than personalities.

Integration of the PCS

Integration is the most important concept of a PCS. Managing the project details from the outset will:

- Eliminate conflicts between various schedule levels.
- Help avoid mistakes.

Planning a PCS

The most time-consuming task in establishing a PCS is schedule development, as much of the PCS's data can be generated during project design. More time for detailed planning is available because most of the design will be completed long before construction begins. Detailed planning is an iterative process requiring considerable time and effort.

Using a PCS

Managers should use the PCS by:

- Remembering that the PCS is *not* intended to manage the project on its own.
- Using the system's organized information to see what tasks need to be done when.
- Setting goals and monitoring progress.
- Recognizing achievements in performance.

A PCS's objective is to assist work. Any information or data manipulation that hinders that objective takes away the system's value.

Structure of a PCS

Introduction

Overview of the overall PCS

Figure 2-1 on page 2-22 illustrates the overall PCS. General information on this PCS is listed below:

- Knowledge of the plant's basic operation and start-up requirements is incorporated in the design process. This incorporation eliminates, as much as possible, the need to redefine systems in the field into constructible boundaries that operations can use.
- A *work breakdown structure* defines the elements (*commodities*) scheduled and controlled with other key dimensions (*system/area boundaries*).
- The designers' information on each commodity is entered in a data base containing:
 - Key dimensions for each entry
 - Technical data (e.g., size, inspection criteria, and material specifications)
- *Work packages*:
 - Are defined based on area, commodity, and boundary.
 - Are generated from the data base's technical information according to the schedule needs.
 - Include all information necessary to perform work.
- The project master network defines early start and late finish dates for each work package.
- Schedules are created by:
 - Using data base sorts (*commodity control sheets*).
 - Considering physical restraints and resource availability.
 - Entering actual schedule dates into the master network and, in turn, into the data base.
- While work is progressing, each commodity's status is reported to the data base, which generates cost and schedule status reports.
- Special punchlist sorts in the data base are used when an area, system, and/or boundary is nearing completion.

The Data Base

Introduction

The heart of the PCS is a multi-dimensional data base. Because a data base is an important tool for all aspects of future projects, a detailed study was undertaken to describe the generic requirements for a nuclear plant's information management system. The results of this study are in Appendix A.

Data base contents

For each uniquely named work item, the data base contains:

- These dimensions:
 - *Area*, for area management during bulk erection
 - *Commodity* or type of work (such as valve or cable)
 - System functional *boundary*
- Technical data needed for the item's installation.
- Fields for project control information such as:
 - Available dates
 - Schedule dates
 - Cost information
 - Status

Figure 2-2 on page 2-23 includes a list of technical data required for particular types of components in the data base.

Data evaluation

Enter and evaluate system data as early as possible, ideally during design, to:

- Simplify moving from bulk erection to system/area completion.
- Avoid redundancy in information.
- Eliminate manual take-offs for scheduling and estimating.
- Automate:
 - Bills of material
 - Process control
 - Status reports
 - Material delivery, according to the schedule

Data base design

When discussing the data base design, it is assumed that:

- The data base is part of an information management system as described in Appendix A.
- Computer-aided design techniques will allow data to be entered in the data base automatically during design, eliminating repetition of data entry.

With careful data base design, installing a component (e.g., a valve) will automatically indicate information such as the availability of associated cable terminals.

Work Breakdown Structure (WBS)

Purpose

- To provide a way to break down the project into discrete, manageable components.
- To establish a structure to allow anyone to determine where an individual component fits into the project scheme.

Developing the WBS

The WBS should be developed to establish a parallel cost breakdown structure; in other words, the final breakdown of the component level should be in terms of components with similar costs. This approach is essential for cost control and, if done correctly, will have the same structure as cost control.

Using the WBS's framework for data entry

Using the WBS's framework to enter data into the data base:

- Identifies the key parameters of area, commodity, and boundary for each item.
- Assigns each item a WBS number for the commodity type.
- If each WBS number has a separate table for cost values (unit rates), generates reports showing required work hours by:
 - Discipline
 - Area
 - System/boundary

Entering cost value leads to development of resource requirements and work force leveling.

Example of a simplified WBS

Figure 2-3 on page 2-24 shows a simplified WBS.

System Boundaries

Purpose for defining system boundaries

To break the project's systems into useful sections for plant startup and operation.

Defining system boundaries

Boundaries should be carefully defined and small enough to speed up the progress of meaningful start-up activities. Experience shows that a complicated and confusing system results when systems are broken down into parts so small that they were useless to schedule progression. To define boundaries, determine:

- *First* -- The boundary for start-up turnover.
- *Then* -- What further breakdown is required for activities leading to the turnover (such as cleaning and hydro testing).

Layering design information

The enclosed definition drawings illustrate the concept of "layering" design information through computer-aided design. This method eliminates sections of pipe or other information from one type of drawing while using the same base of design information.

Example: A hydro test drawing can be generated from an entire system flow diagram without creating a new drawing or marking up an existing drawing.

Establishing layers also applies to erection drawings, because the same basic design can be used, without cluttering or redrawing anything, for:

- Pipe installation
- Weld identification
- Support locations

Example of a system turnover boundary

This section contains examples of data relating to a system turnover boundary called 1ND1. If taken with the PCS description, the boundary further illustrates the PCS concept. This section contains:

Item	Description
Drawing CN-1561-1.0	A flow diagram of the entire Residual Heat Removal System as defined during design.
Turnover boundary drawing 1ND1	Using the above drawing as a starting point, this drawing shows operations what is included in the partial turnover.
Hydro testing drawings 1ND1H1 and 1ND1H2	These drawings define the two hydro boundaries making up 1ND1.

Item	Description
CN-1492ND-055-P, W, S, and H	<p>These drawings are the actual construction isometrics (ISOs) that would be included in work packages.</p> <ul style="list-style-type: none">• <i>P</i> is the piping ISO containing:<ul style="list-style-type: none">◦ BOM◦ Dimensions◦ Surface requirements◦ Other information needed by the pipefitting supervisor• <i>W</i> provides the location and number of field welds.• <i>S</i> shows supports and support locations.• <i>H</i> shows requirements for system heat tracing.
Commodity lists	<p>These lists (Figure 2-4 on page 2-25, Figure 2-5 on page 2-26, Figure 2-6 on page 2-27, and Figure 2-7 on page 2-28) are key components generated from the data base.</p>

Control Sheets

Definition

Control sheets are data base sorts tailored for a specific purpose, (e.g., commodity control sheets and punchlists).

Commodity control sheets

Commodity control sheets are reports of all like commodities (e.g., pipe) for a given area. These reports:

- Show remaining work for an area.
- Are used to schedule and control bulk erection by area.

When commodity control sheets are used with control sheets for related commodities, each item indicates whether it is available for work.

Punchlists

Punchlists are:

- Reports of all remaining commodities, regardless of type, for an area or system
- Used to manage system and area completion.

Punchlists provide a means to manage the final details and associated matters (e.g., inspections and records review). Theoretically, however, schedule integration from the start of the project should mean no transition is required from bulk erection to system completion. By sharing the same data base, the erection schedules support and agree with the systems turnover schedule.

Example of a control sheet

Figure 2-8 on page 2-29 shows an example of a control sheet for piping supports. (Punchlist sorts are included with the system model.)

Schedule Development

Introduction

Developing schedules for major construction projects

Major construction projects must have schedules developed in levels that communicate project objectives in understandable terms.

Example: The project manager must be able to monitor project progress continuously on an overall summary level, using milestones and events as indicators. *But* craft supervisors must know specifically what they are expected to do and complete during the week.

Integrating levels of schedules

These levels of schedules:

- Must be fully integrated.
- Though expressed in increasing detail, must not conflict with each other.

The structured PCS facilitates the integration by using the work breakdown structure to break down project components:

- Commodities are parts of work packages.
- Work packages are parts of system/area boundaries.
- Areas are parts of buildings.
- Boundaries are parts of complete systems.

Each piece of work is tied to the next larger grouping of which it is a part, clearly defining scope for each activity.

System testing and turnover

In the later phases of all construction projects, pre-operational testing and system turnovers control overall progress. Construction schedules have generally been targeted from construction start to completion, with little or no consideration for testing. However, *the key to a successful project is based on beginning power output rather than completing construction.* At St. Lucie II, the pre-operational testing group began working when construction was approximately 50% complete. Resolving problems early led to cost and schedule savings. Wolf Creek, Braidwood, and Millstone had similar successes.

Moving from area scheduling to system scheduling

Initially, bulk schedules were used to construct an area's major items. At some point during construction, the project switched to system planning to facilitate system turnover. An optimum point for this switch does exist. At St. Lucie II, detailed planning for the switch point was a big factor in achieving their relatively short schedule.

Overlapping structural, mechanical, and electrical work

On many projects, structural, mechanical, and electrical work has been overlapped as much as possible. Mechanical/electrical work begins after a certain percentage of the structural work is completed. Although it can shorten the overall construction schedule, this overlapping is not necessarily the most effective alternative. For example, overlapping has complicated the scheduling and construction processes, resulting in changes and lost work time. International constructors are also interested in overlapping structural, mechanical, and electrical work.

Nationality	Practice
Canadian	At Ontario Hydro, parallel work activity is maximized using a moderate amount of overlapping.
French and West German	Structural work is generally complete, including prime painting, before starting mechanical/electrical work.
Japanese	Use practices that resemble French and West German procedures, though the focus is on smaller areas. A level's mechanical/electrical work begins after structural work on the next level is complete. At Tsuruga II, the construction work force was smaller than at sites in the United States. The smaller size can be partially attributed to the Japanese practice of limiting multiple discipline work in an area.

Beginning construction before design completion

In the United States, a general practice has been to begin construction before design work is completed. United Engineers and Constructor's comparison study of domestic and international practices discovered that, at the start of construction, the average percentages of design completion were:

- 60%—Structural/Civil
- 40%—Mechanical
- 20%—Electrical/I & C

As with overlapping, beginning construction before the design was essentially complete frequently led to schedule changes and lost work time. International practice varies on beginning construction before design completion.

Nationality	Practice
Canadian and Japanese	Practices are similar to those in the United States: construction starts when design is partially complete. At Tsuruga II, however, the Japanese waited until a very large percentage of design was completed. Waiting, along with having a detailed plan, helped ensure that work was done correctly the first time and usually on schedule.

Nationality	Practice
French and West German	Practices usually have construction beginning only after most design is complete. The West Germans used this philosophy at Muelheim-Kaerlich to the extent of small-bore piping and hangers, engineered before installation by a dedicated design group using computer modeling. This special attention to detail led to positive results.

Recommendations

Recommendations	Comment
Remember that a significant scheduling issue is in the percent of design completed before construction begins.	<ul style="list-style-type: none"> • Structural design should be essential complete, and mechanical/electrical design near completion. • Ontario Hydro recommends that design be 75% complete before the initial concrete pour. • A high percentage of the design should be completed before construction starts to: <ul style="list-style-type: none"> ○ Minimize rework. ○ Optimize "ganghanging," even across disciplines. ○ Limit compounding of tolerances, from the manufacturer through final design and across system and discipline responsibilities. ○ Optimize use of typical designs of items such as pipe supports and cable trays. ○ Optimize layout and use of embedded plates in place of anchor bolts. ○ Optimize the layout of permanent reserved access aisles and shafts and reserved work areas for fabrication, maintenance, and laydown.
Include design, construction, and pre-operational testing in the integrated schedule	<ul style="list-style-type: none"> • Construction's ultimate goal is to support the earliest possible operation of a quality plant, not to complete construction. • Each phase of a project should be keyed to the needs of the downstream organizations. • Pre-operational testing is critical to system turnover and startup as part of the integrated plant. • Organizational focus on supporting the testing schedule has been a shortcoming on most projects. • Significant savings can be achieved by: <ul style="list-style-type: none"> ○ Effectively defining test boundaries. ○ Scheduling items that support testing. ○ Early in the project, involving personnel responsible for testing. ○ Effectively communicating testing requirements.

Recommendations	Comment
Use a one-step licensing process to facilitate the sort of integrated schedule recommended above.	<ul style="list-style-type: none">• The current two-step process allows for regulatory design reviews and hearings during construction.• Using a standardized plant design would also help achieve an integrated schedule.
Use bulk (area) and system scheduling.	<ul style="list-style-type: none">• During the early construction stages, bulk installation would allow major components to be built.• At some point, switching to a system installation schedule would focus work on system completion and turnover.• Detailed planning is required to select the point at which to change from a bulk schedule to a system schedule.
Overlap structural, mechanical, and electrical construction, but not to the extent that congestion, confusion, and rework are created.	<ul style="list-style-type: none">• At Tsuruga II, the Japanese used a proven, successful alternative by completing structural work on a second level before beginning mechanical and electrical work on the first level.

Bulk Commodity Schedules

Purpose

- To lay out an optimum production rate supporting each boundary completion date, as identified by the detailed activity completion schedule.
- To profile the work force required for each area and commodity, because estimated hours are known for each item.

When to prepare bulk commodity schedules

When required commodity completion dates are known after:

- All commodities are entered in the data base.
- System boundary milestones are established.

Schedule design

A bulk commodity schedule is:

- Organized by commodity by area.
- Expressed as a volume or quantity to be completed weekly in each boundary.
- Developed using summary reports from the data base.

Developing bulk commodities schedules is an iterative process. When developing the schedule, remember that:

- Optimizing one commodity or area can negatively impact another.
- Space and other physical constraints must be considered, such as the maximum number of workers who can effectively occupy one area.

Using production rates

Production rates developed in bulk commodity schedules can:

- Be used to establish required work-force levels.
- Be shaped or limited by existing or planned work-force levels.
- Help reduce overtime.

How the rates are used depends on whether schedule or resources are the limiting factor. The production rates also become part of the production control portion of the system.

Example of a bulk commodity bar chart

Figure 2-9 on page 2-30 is an example of a bulk commodity bar chart.

Detailed Weekly Schedules

Definition

As the lowest level of schedule hierarchy, detailed weekly schedules describe work to be done within a week to support the requirements of the commodity rollup schedules. This schedule, with the detailed activity completion schedule, is a critical part of the control system and fundamental to managing the project schedule.

Contents

Detailed weekly schedules should contain activities for craft, support, and inspection groups.

Purpose

To ensure that:

- The right components are installed at the right time.
- Necessary documentation is completed and filed.

Developing weekly schedules

Use bulk commodity schedules and commodity control sheets as sources to develop detailed weekly schedules. The bulk commodity schedule describes the area's required volume. With the control sheets' details, the scheduler chooses the correct items to be worked with input from the crew supervisor.

Schedule structure

The schedule should:

- Though updated and issued each week, contain at least two weeks' work to develop appropriate backlogs.
- Reflect the "real" current plan for the crew and *must not* be used to denote missed work.
- Include planned work hours from unit rate data and other history.
- Productively occupy work hours available to the supervisor.
- Separate the current schedule from performance reporting—how previously scheduled work was completed (cost and schedules).

Example of a detailed weekly schedule

Figure 2-10 on page 2-31 is an example of a detailed weekly schedule.

Production and Cost Control

Introduction

Definition of production control

Used here, *production control* describes the means to control the schedule for bulk commodity fabrication and installation. Because those activities have no true milestones other than start and finish, measurements of intermediate progress must be developed. Production control provides the means for bringing together the schedule and cost control.

Key elements of a good production control system

- Status reporting
- Production rates
- Productivity monitoring
- Root cause analysis of productivity trends

Status Reporting

What status reporting includes

The items to be tracked and monitored in status reports are:

- Determined by the WBS.
- Included individually in the data base as commodities.

Status reports should be as simple as possible because complete information accuracy is essential to the system. Discrepancies must not occur between actual progress and progress as reported by the system.

Defining task completion

Complete must be just that: a task should be entirely completed, including inspection, acceptance, and documentation.

Updating the data base

An existing paper trail, such as inspection documentation, should be used in updating the data base. The data base should be updated at least daily, though advanced computer technology will probably allow hourly updates. If kept current, the data base becomes the source for all production control reports.

Execution supervision—the source of status information

Execution supervision must be the source of status information and therefore accountable for information accuracy. To realize these needs, methods such as the following can be used:

- Process paper trail
- Daily review by the scheduler with the supervisor
- Walkdowns to verify completion

Production Rates

Definition

Production rates are the result of a formula using available work hours and targeted unit rates, tempered with physical schedule restrictions and common sense.

When rates are developed

The rates are developed for each area and commodity when bulk commodity bar charts are developed.

Monitoring production rates

- Roll production rates for each area/commodity into the familiar S curves.
- Plot actual performance against the scheduled curve.
- Use the relationship between the scheduled line and actual line as an indicator of performance. In theory, being under the line indicates *one* of the following:
 - Work force was less than planned.
 - Productivity was less than expected.

Graphs

Though not clearly indicating performance, graphs (Figure 2-11 on page 2-32) give early warnings of problems. The graph is just one way of illustrating and communicating progress. Different methods are appropriate for each level of the organization.

Monitoring Productivity

Purpose

- To bring cost control into the picture.
- To pinpoint problem areas.

Monitoring productivity

As discussed earlier, target unit rates are established for each of the lowest-level breakdowns in the WBS. Actual rates from reported work hours and quantities, should be compared continuously with the targets. Actual vs. targets should be:

- Measured for each supervisor.
- Used in performance management.

Labor and cost control

Labor is a large cost consideration for the construction management team. Managing costs through unit rates is extremely important. For example, changing target rates when targets are not being achieved should be done *only* with high-level authority, since doing so accepts a higher construction cost.

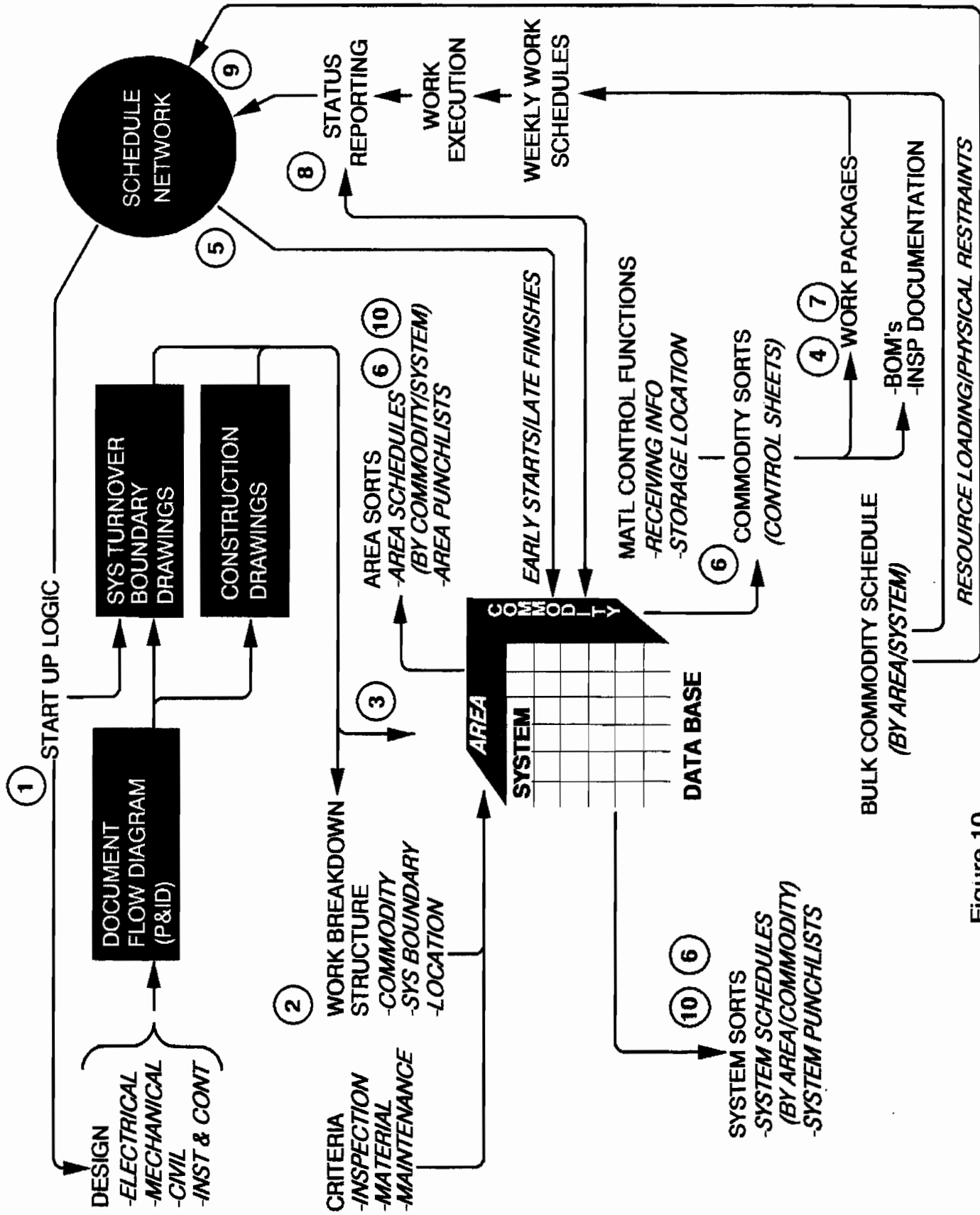
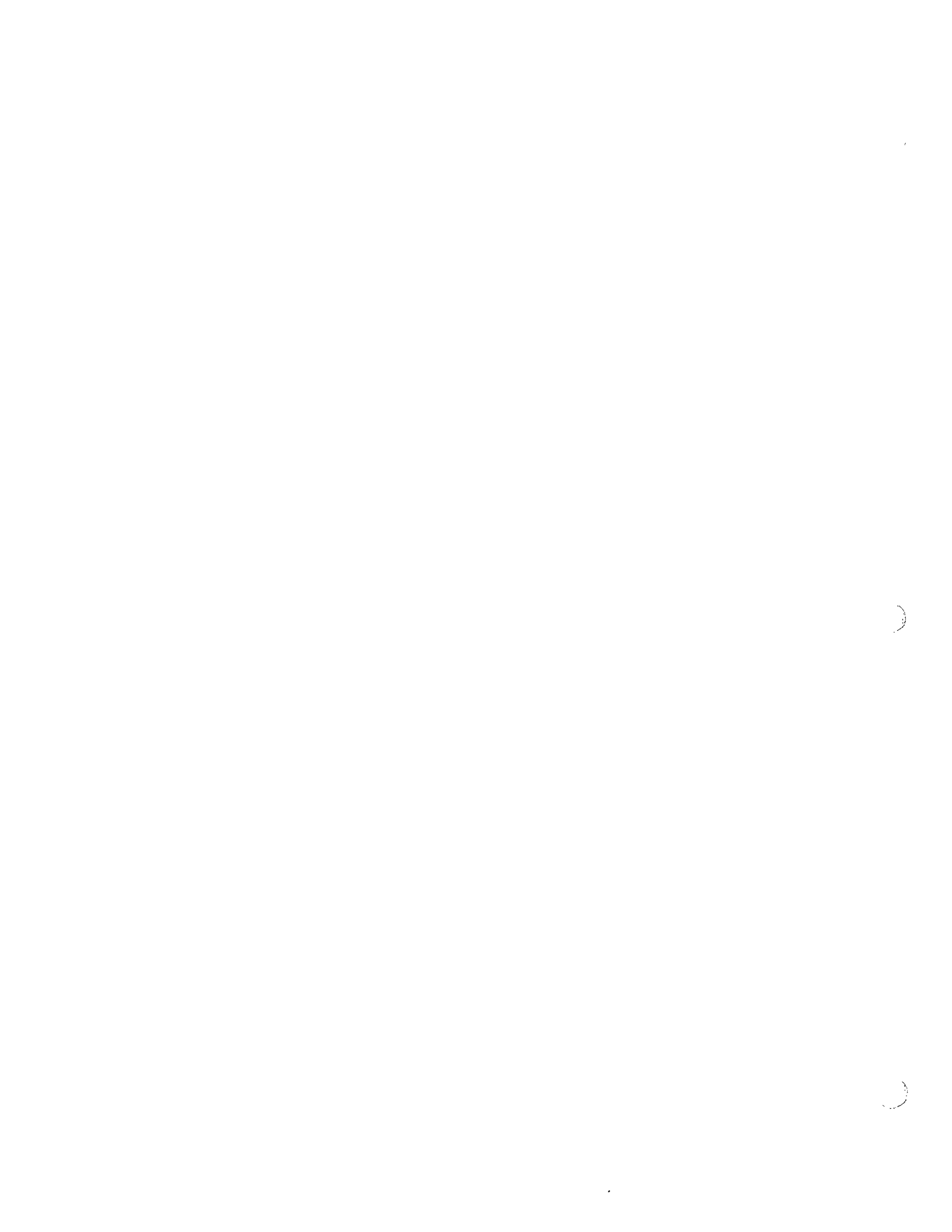


Figure 10



TYPICAL DATA BASE RECORDS

ELECTRICAL

EQUIPMENT FILE

Location
 Equipment Name
 Equipment Type
 System
 QA Condition
 Boundary
 Date Installed
 Inspection Completed
 Boundary
 Cable #
 QA Review Completed
 Documents Filed

CABLE

Cable Number
 Cable Type
 Equipment Location (To)
 Equipment Location (From)
 Cable Length
 Pull Status
 Cable Reel Number
 Workhours Pull
 Termination (To)
 Termination (From)
 Boundary
 Inspection Completion
 QA Review Completed
 Documents Filed

BREAKER

Breaker Name
 Location
 System
 Breaker Load
 Boundary
 Inspection Completed
 QA Review Completed
 Documents Filed

INSTRUMENTS

Instrument #
 Location
 Type
 Use Code
 Boundary
 Tap Installed
 Root Valves Installed
 Install. Inspect. Complete
 Cable #
 QA Review Completed
 Documents Filed

MECHANICAL

VALVES

Valve #
 Type
 Size
 System
 Class
 Operator Type
 Operator Set Up
 Breaker #
 Cable #
 Location
 QA Review Completed
 Documents Filed

PUMPS

Name
 Location
 System
 Breaker
 Cable #
 Boundary
 Set
 Grouted
 Alignment Complete
 QA Review Completed
 Documents Filed

MOTORS

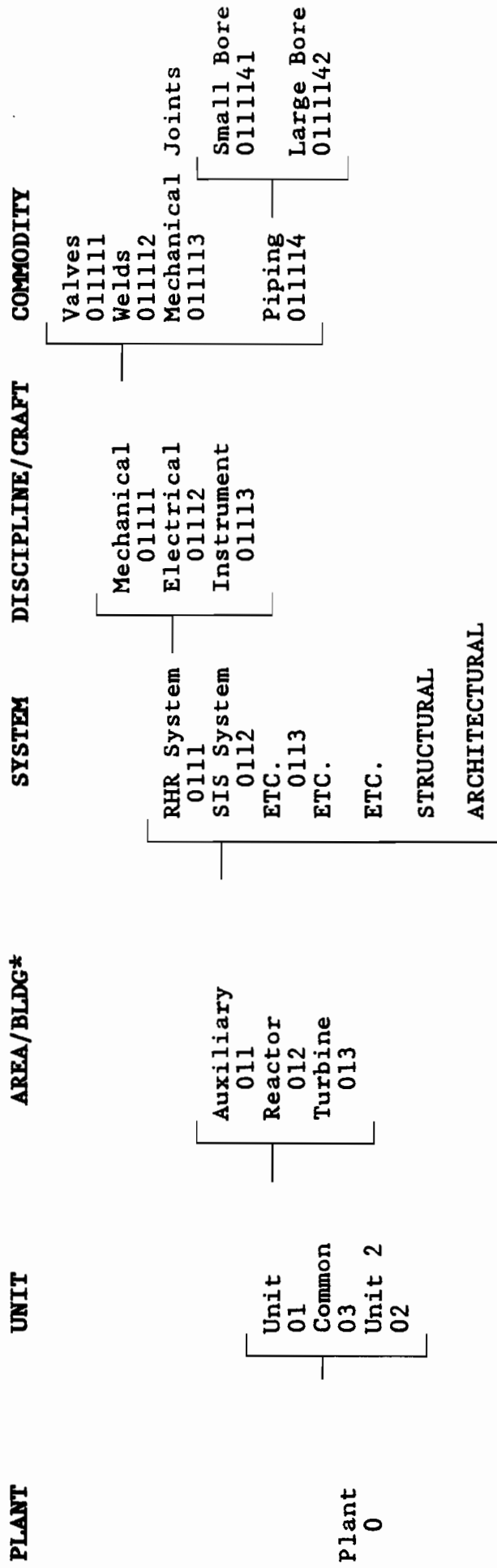
Name
 Location
 System
 Boundary
 Date Installed
 Breaker #
 Cable #
 Rotation Checks
 Lubrication Dates
 QA Review Completed
 Documents Filed

WELDS

Weld #
 Pipe Size
 Pipe Schedule
 Pipe Material
 NDE Requirements
 ISI
 Iso #
 QC Complete
 Pipe Length
 QA Review Completed
 Documents Filed

FIGURE 2-2

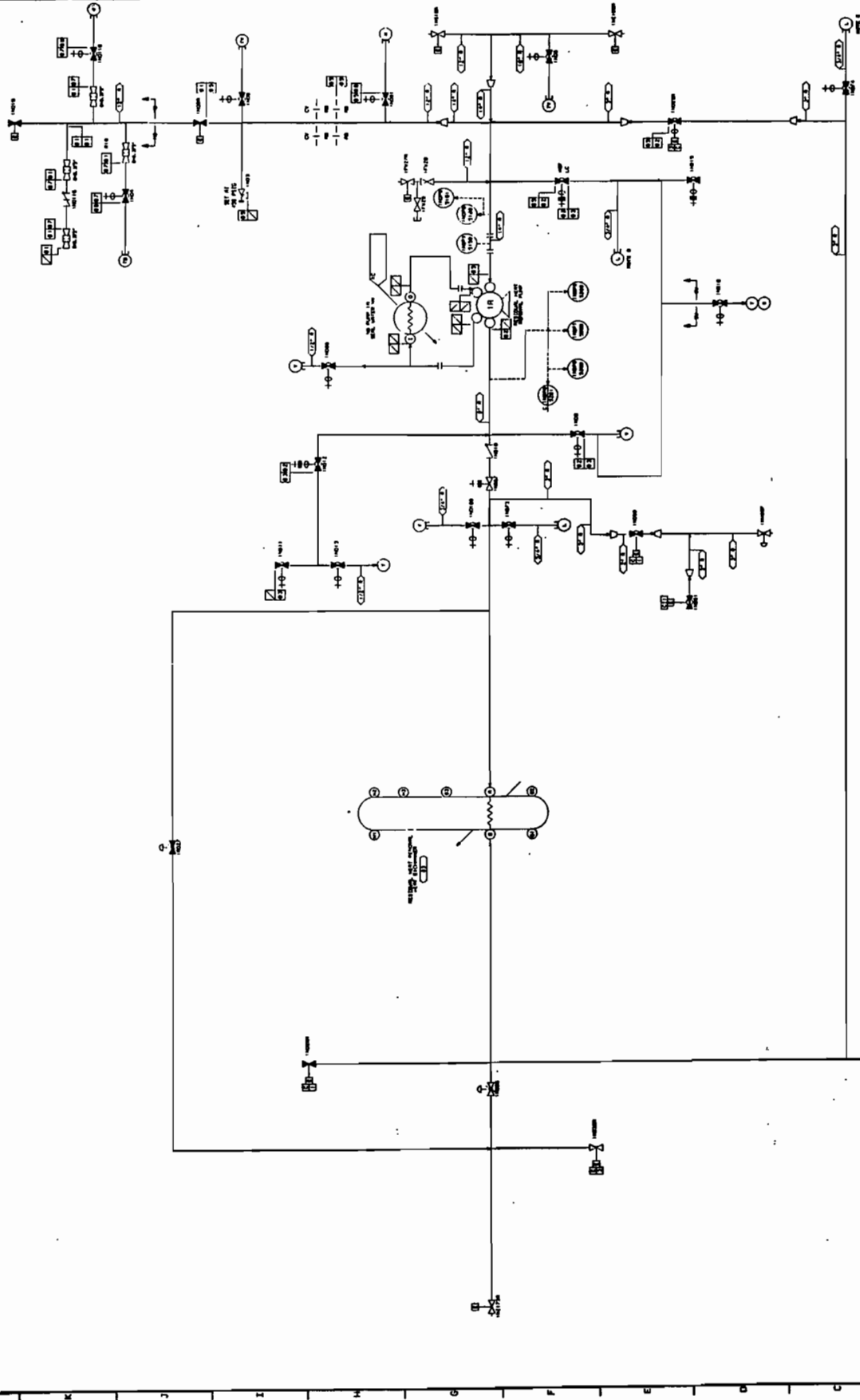
**EXAMPLE
WORK BREAKDOWN STRUCTURE**



*AREA/BUILDING CAN BE FURTHER BROKEN DOWN TO SMALL AREAS, OR AN ADDITIONAL BREAKDOWN FOR AREA MAY BE INCLUDED

FIGURE 2-3

14 13 12 11 10 9 8 7 6 5 4 3 2 1



TURNOVER BOUNDARY DRAWING
-IND-1

Duke Power Company Clinton Nuclear Station Unit 1 Flow Diagram of Reactor Heat Removal System (RHS)	
NO.	REVISIONS
1	Issue
2	Issue
3	Issue
4	Issue
5	Issue
6	Issue
7	Issue
8	Issue
9	Issue
10	Issue
11	Issue
12	Issue
13	Issue
14	Issue

VALVE POSITIONS	
VALVE	POSITION
100	CLOSE
101	OPEN
102	CLOSE
103	OPEN
104	CLOSE
105	OPEN
106	CLOSE
107	OPEN
108	CLOSE
109	OPEN
110	CLOSE
111	OPEN
112	CLOSE
113	OPEN
114	CLOSE
115	OPEN
116	CLOSE
117	OPEN
118	CLOSE
119	OPEN
120	CLOSE



DESIGN APPROVALS	
DATE	INITIALS
1/1/80	
2/1/80	
3/1/80	
4/1/80	
5/1/80	
6/1/80	
7/1/80	
8/1/80	
9/1/80	
10/1/80	
11/1/80	
12/1/80	

SCALE: AS SHOWN

DATE: 1/1/80

BY: [Signature]

CHECKED BY: [Signature]

APPROVED BY: [Signature]

DESIGNED BY: [Signature]

PROJECT: Clinton Nuclear Station Unit 1

REVISED: 1/1/80

SCALE: AS SHOWN

DATE: 1/1/80

BY: [Signature]

CHECKED BY: [Signature]

APPROVED BY: [Signature]

DESIGNED BY: [Signature]

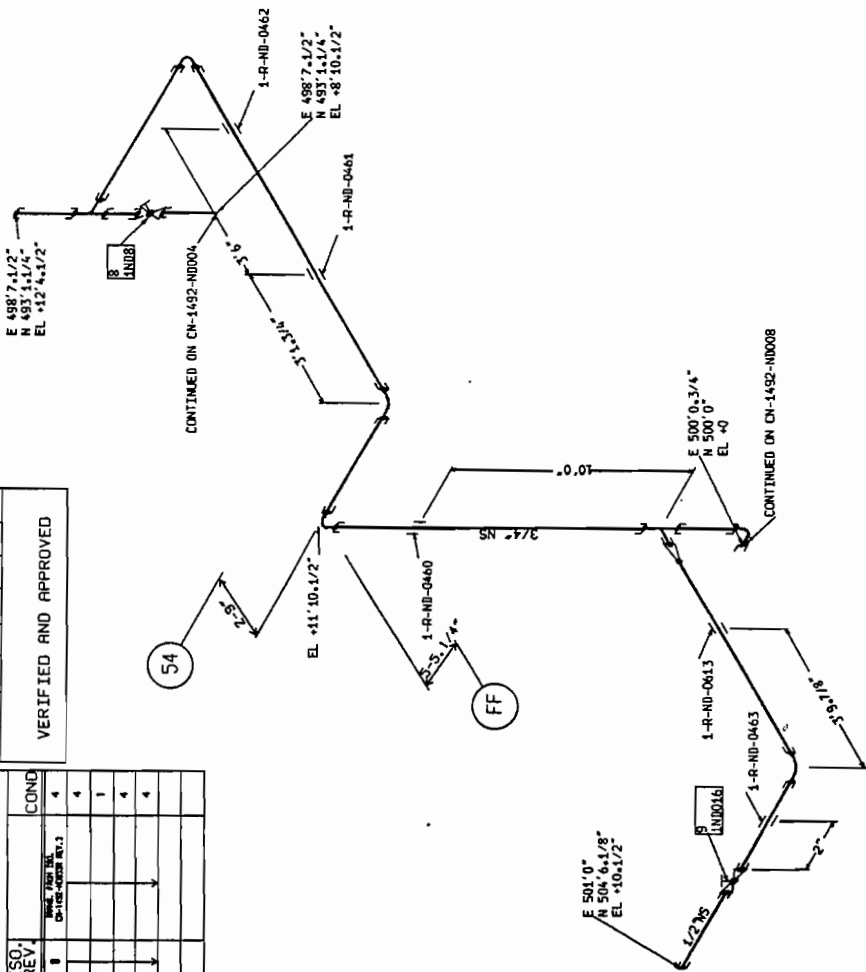
PROJECT: Clinton Nuclear Station Unit 1

DWG NO. CN-1492-ND-055-S REV. 0

REV. CHK. APP. DATE REV. CHK. APP. DATE
 VERIFIED AND APPROVED

S/R STATUS		COND	
SUPPORT NO.	ISO. REV.	COND	REV.
1-R-ND-0460	0	4	4
1-R-ND-0461		4	4
1-R-ND-0462		1	1
1-R-ND-0463		4	4
1-R-ND-0464		4	4

N



VALVE LIST		PIPE SPEC	
MARK NO	ITEM NO.	DRAWING NO.	SIZE

PIPE CLASS	
PIPE CLASS	REF. TABLE

NOTES:

OR CONDITION 1,4

DUKE POWER COMPANY
 CATAPAWB NUCLEAR STATION

AUXILIARY BUILDING
 RESIDUAL HEAT REMOVAL SYSTEM

DESIGNED	DATE	CHKD	DATE

DATE: 09 MAY 89
 BATCH REF: RESIDUAL HEAT-REMOVAL
 PIPING SPEC: CNS-PS-601.4

CN-1492-ND-055-S

NO.	REVISION	DRWN	CHKD	APP	DATE	CIVIL/ELEC	MECH	INSPECTED
016	RELEASED FOR CONSTRUCTION							

PIPE NO.	CLASS	SIZE
374	3/4"	3/2"
263	2"	5.5"

EXAMPLE

WELD LIST
BOUNDARY: INDI

SCHEDULED T/O DATE

WELD#	SIZE	SCHE	MAT'L	NDE	ISI	BNDRY	LCO	SYS	CLASS	WP#	PIPE SPEC	AREA	WBS	WKHR EST	SCHED AVAIL	ACT AVAIL	SCHED COMP	ACT COMP	QC COMP
1ND55- 1	1/2	40	SA312	60A	NO	IND1	FF-54	RHR	E	RHR-A-	601.4	A-12	0210	6	04-01-97	05-15-97	09-28-97	09-28-97	11-04-97
1ND55- 2	1/2	40	SA312	60A	NO	IND1	FF-54	RHR	E	RHR-A-	601.4	A-12	0210	6	04-01-97	05-15-97	09-28-97	09-28-97	11-04-97
1ND55- 3	1/2	40	SA312	60A	NO	IND1	FF-54	RHR	E	RHR-A-	601.4	A-12	0210	6	04-01-97	05-15-97	09-28-97	09-28-97	11-04-97
1ND55- 4	1/2	40	SA312	60A	NO	IND1	FF-54	RHR	E	RHR-A-	601.4	A-12	0210	6	04-01-97	05-15-97	09-28-97	09-28-97	11-04-97
1ND55- 5	1/2	40	SA312	60A	NO	IND1	FF-54	RHR	E	RHR-A-	601.4	A-12	0210	6	04-01-97	05-15-97	09-28-97	09-28-97	11-04-97
1ND55- 6	1/2	40	SA312	60A	NO	IND1	FF-54	RHR	E	RHR-A-	601.4	A-12	0210	6	04-01-97	05-15-97	09-28-97	09-28-97	11-09-97
1ND55- 7	3/4	40	SA312	60A	NO	IND1	FF-54	RHR	E	RHR-A-	601.4	A-12	0212	8	04-01-97	05-15-97	09-28-97	09-28-97	11-09-97
1ND55- 8	3/4	40	SA312	60A	NO	IND1	FF-54	RHR	E	RHR-A-	601.4	A-12	0212	8	04-01-97	05-15-97	09-28-97	09-28-97	11-09-97
1ND55- 9	3/4	40	SA312	60A	NO	IND1	FF-54	RHR	E	RHR-A-	601.4	A-12	0212	8	04-01-97	05-15-97	09-28-97	09-28-97	11-09-97
1ND55-10	3/4	40	SA312	60A	NO	IND1	FF-54	RHR	E	RHR-A-	601.4	A-12	0212	8	04-01-97	05-15-97	09-28-97	09-28-97	11-09-97
1ND55-11	3/4	40	SA312	60A	NO	IND1	FF-54	RHR	E	RHR-A-	601.4	A-12	0212	8	04-01-97	05-15-97	09-28-97	09-28-97	11-10-97
1ND55-12	3/4	40	SA312	60A	NO	IND1	FF-54	RHR	E	RHR-A-	601.4	A-12	0212	8	04-01-97	05-15-97	09-28-97	09-28-97	11-10-97
1ND55-13	3/4	40	SA312	60A	NO	IND1	FF-54	RHR	E	RHR-A-	601.4	A-12	0212	8	04-01-97	05-15-97	09-28-97	09-28-97	11-10-97
1ND55-14	3/4	40	SA312	60A	NO	IND1	FF-54	RHR	E	RHR-A-	601.4	A-12	0212	8	04-01-97	05-15-97	09-28-97	09-28-97	11-10-97
1ND55-15	3/4	40	SA312	60A	NO	IND1	FF-54	RHR	E	RHR-A-	601.4	A-12	0212	8	04-01-97	05-15-97	09-28-97	09-28-97	11-14-97
1ND55-16	3/4	40	SA312	60A	NO	IND1	FF-54	RHR	E	RHR-A-	601.4	A-12	0212	8	04-01-97	05-15-97	09-28-97	09-28-97	11-14-97
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1ND55-21	3/4	40	SA312	60A	NO	IND1	FF-54	RHR	E	RHR-A-	601.4	A-12	0212	8	04-01-97	05-15-97	09-28-97	09-28-97	11-15-97
1ND55-22	3/4	40	SA312	60A	NO	IND1	FF-54	RHR	E	RHR-A-	601.4	A-12	0212	8	04-01-97	05-15-97	09-28-97	09-28-97	11-15-97

EXAMPLE

WELD LIST
BOUNDARY: 1ND1
SCHEDULED T/O DATE

WELD#	SIZE	SCHE	MAT'L	NDE	ISI	ENDRY	LCO	SYS	CLASS	WP#	PIPE SPEC	AREA	WBS	WKHR EST	SCHED AVAIL	ACT AVAIL	SCHED COMP	ACT COMP	QC COMP
1ND55- 1	1/2	40	SA312 304	60A	NO	1ND1	FF-54 522	RHR	E	RHR-A- 15P	601.4	A-12	0210	6	04-01-97	05-15-97	09-28-97		
1ND55- 2	1/2	40	SA312 304	60A	NO	1ND1	FF-54 522	RHR	E	RHR-A- 15P	601.4	A-12	0210	6	04-01-97	05-15-97	09-28-97	10-01-97	11-04-97
1ND55- 3	1/2	40	SA312 304	60A	NO	1ND1	FF-54 522	RHR	E	RHR-A- 15P	601.4	A-12	0210	6	04-01-97	05-15-97	09-28-97	10-01-97	11-04-97
1ND55- 4	1/2	40	SA312 304	60A	NO	1ND1	FF-54 522	RHR	E	RHR-A- 15P	601.4	A-12	0210	6	04-01-97	05-15-97	09-28-97	10-01-97	11-04-97
1ND55- 5	1/2	40	SA312 304	60A	NO	1ND1	FF-54 522	RHR	E	RHR-A- 15P	601.4	A-12	0210	6	04-01-97	05-15-97	09-28-97	10-01-97	11-04-97
1ND55- 6	1/2	40	SA312 304	60A	NO	1ND1	FF-54 522	RHR	E	RHR-A- 15P	601.4	A-12	0210	6	04-01-97	05-15-97	09-28-97	10-03-97	11-09-97
1ND55- 7	3/4	40	SA312 304	60A	NO	1ND1	FF-54 522	RHR	E	RHR-A- 15P	601.4	A-12	0212	8	04-01-97	05-15-97	09-28-97	10-03-97	11-09-97
1ND55- 8	3/4	40	SA312 304	60A	NO	1ND1	FF-54 522	RHR	E	RHR-A- 15P	601.4	A-12	0212	8	04-01-97	05-15-97	09-28-97	10-03-97	11-09-97
1ND55- 9	3/4	40	SA312 304	60A	NO	1ND1	FF-54 522	RHR	E	RHR-A- 15P	601.4	A-12	0212	8	04-01-97	05-15-97	09-28-97	10-05-97	11-09-97
1ND55-10	3/4	40	SA312 304	60A	NO	1ND1	FF-54 522	RHR	E	RHR-A- 15P	601.4	A-12	0212	8	04-01-97	05-15-97	09-28-97	10-05-97	11-10-97
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EXAMPLE

VALVE LIST
BOUNDARY: INDI

SCHEDULED T/O DATE _____

VALVE #	SIZE	TYPE	CABLE	ENDRY	CLASS	LOC	OPER	SYS	BKR #	WP #	AREA	WBS	WKHR EST	SCHED AVAIL	ACT AVAIL	SCHED COMP	ACT COMP	OPER SET-UP
IND16	1/2	GL	N/A	IND1	E	FF-54 522	M	RHR	N/A	RHR-A- 15P	A-12	0115	10	04-01-97	05-15-97	09-28-97	10-01-97	N/A
IND8	3/4	GL	N/A	IND1	B	FF-54 522	M	RHR	N/A	RHR-A- 15P	A-12	0118	12	04-01-97	05-15-97	09-28-97	10-11-97	N/A
IND25A	2	GL	1*IND167	IND1	B	GG-54 522	EMD	RHR	1EMXK F04B	RHR-A- 15P	A-12	0120	20	04-01-97	05-15-97	09-28-97	06-01-97	06-03-97

EXAMPLE

INSTRUMENT LIST
BOUNDARY: INDI

INSTR #	SYS	LOC	BNDRY	USE- CODE	TAP COMP	RT VLV COMP	WP #	CABLE #	AREA	WBS	WKHR EST	SCHED AVAIL	ACT AVAIL	SCHED COMP	ACT COMP	QC COMP
INDP65200	RHR	66-54 522	IND1	6	09-01-97	09-15-97	RHR-A-15I	N/A	A-12	0302	10	08-01-97	09-15-97	09-21-97	09-27-97	12-15-97
INDP65201	RHR	66-54 522	IND1	6	09-01-97	09-15-97	RHR-A-15I	N/A	A-12	0302	10	08-01-97	09-15-97	09-21-97	09-30-97	12-01-97
INDPT5090	RHR	66-54 522	IND1	9	09-01-97	09-15-97	RHR-A-15I	1*WD316	A-12	0302	10	08-01-97	09-15-97	09-18-97	09-18-97	11-25-97
INDP5090	RHR	AA-59 594	IND1	9	N/A	N/A	RHR-A-19I	1*WD416	A-63	0302	10	10-02-97	10-10-97	10-25-97		
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INDP65100	RHR	FF-54 522	IND1	6	11-16-97	11-20-97	RHR-A-15I	N/A	A-12	0310	30	12-01-97	11-30-97	12-15-97	12-10-97	12-26-97
INDP65101	RHR	FF-54 522	IND1	6	11-16-97	11-20-97	RHR-A-15I	N/A	A-12	0315	25	12-01-97	11-30-97	12-15-97	12-10-97	12-26-97

COMMODITY CONTROL SHEET
SUPPORT/RESTRAINTS

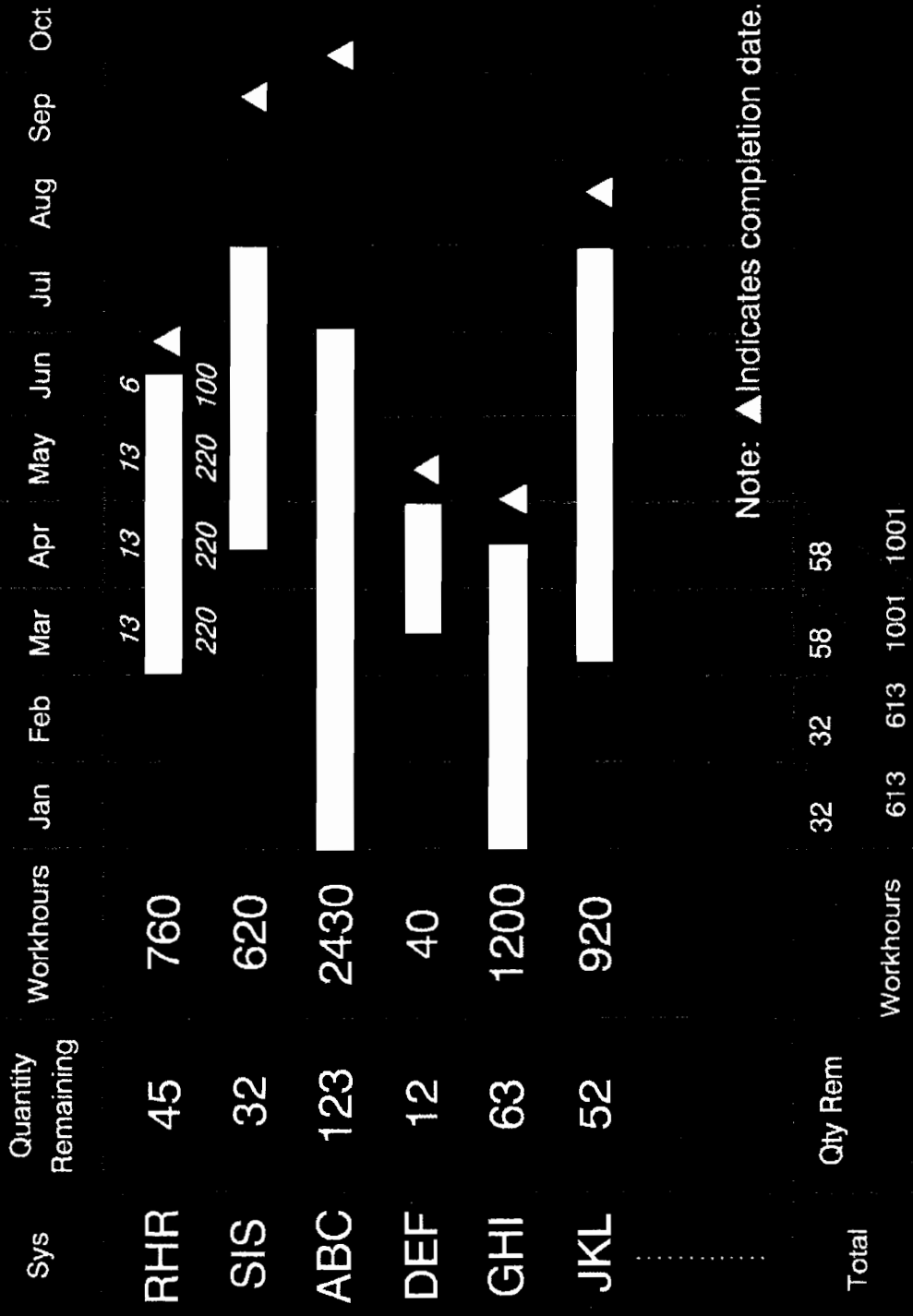
AREA A12

AREA: A12
AUXILIARY BLDG/ELEVATION 522
SUPERVISOR: COBB

SUPPORT#	SYSTEM	ISO	BOUNDARY	LOCATION	WP#	Y-STOP	WELDED ATTACH	WBS	WKHR EST	SCHED AVAIL	ACTUAL AVAIL	SCHED COMP	CRAFT COMP	QC COMP
1-R-MD-0463	RMR	55-S	1-MD-1	FF-54	RMR-A 15 S	Y	N	0101	80	10-01-97	11-16-97	11-20-97	11-28-97	11-28-97
1-R-MD-0613	RMR	55-S	1-MD-1	FF-54		Y	N	0101	80	10-01-97	10-03-97	11-20-97	11-28-97	11-30-97
1-R-MD-0460	RMR	55-S	1-MD-1	FF-54		N	Y	0105	100	10-01-97		11-20-97		
1-R-MD-0461	RMR	55-S	1-MD-1	FF-54		Y	N	0103	40	10-01-97	09-05-97	11-20-97	11-12-97	11-14-97
1-R-MD-0462	RMR	55-S	1-MD-1	FF-54		N	Y	0106	60	10-01-97	09-20-97	11-20-97	11-18-97	11-21-97
1-R-MD-0601	RMR	54-S	1-MD-2	GG-56	RMR-A 16 S	N	Y	0105	100	10-15-97	10-03-97	12-01-97		
1-R-MD-0620	RMR	54-S	1-MD-2	GG-56	RMR-A 16 S	Y	Y	0105	100	10-15-97	10-06-97	12-01-97		
1-R-MD-0450	RMR	54-S	1-MD-2	GG-56	RMR-A 16 S	Y	N	0103	40	10-01-97	10-06-97	12-01-97	11-16-97	
1-R-MD-0320	RMR	54-S	1-MD-2	GG-56	RMR-A 16 S	N	Y	0101	80	10-01-97	10-10-97	12-01-97	11-05-97	11-07-97
1-R-MD-0610	RMR	54-S	1-MD-2	HH-56	RMR-A 16 S	N	N	0106	60	10-15-97	10-20-97	12-01-97		
1-R-MD-0615	RMR	54-S	1-MD-2	JJ-56	RMR-A 16 S	N	N	0101	80	10-15-97		12-01-97		
1-R-MI-0400	SIS	16-S	1-MI-4	GG-53	SIS-A 12 S	Y	N	0105	100	12-15-97		02-05-98		
1-R-MI-0410	SIS	16-S	1-MI-4	GG-53	SIS-A 12 S	Y	N	0106	60	12-15-97		02-05-98		
1-R-MI-0420	SIS	16-S	1-MI-4	HH-53	SIS-A 12 S	N	N	0106	60	12-15-97		02-05-98		
1-R-MI-0440	SIS	16-S	1-MI-5	EE-56	SIS-A 13 S	N	Y	0105	100	12-15-97		02-05-98		
1-R-MI-0460	SIS	16-S	1-MI-5	EE-56	SIS-A 13 S	N	N	0103	40	12-15-97		02-05-98		
1-R-MI-0480	SIS	16-S	1-MI-5	FF-54	SIS-A 13 S	N	N	0104	75	12-15-97		02-05-98		
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FIGURE 2-8

EXAMPLE
COMMODITY ROLL-UP SCHEDULE
COMMODITY: CABLE PULLING
AREA: A3



Note: ▲ Indicates completion date.

Figure 14



nev+

EXAMPLE
COMMODITY INSTALLATION GRAPH
CABLE PULLING
AREA: A3

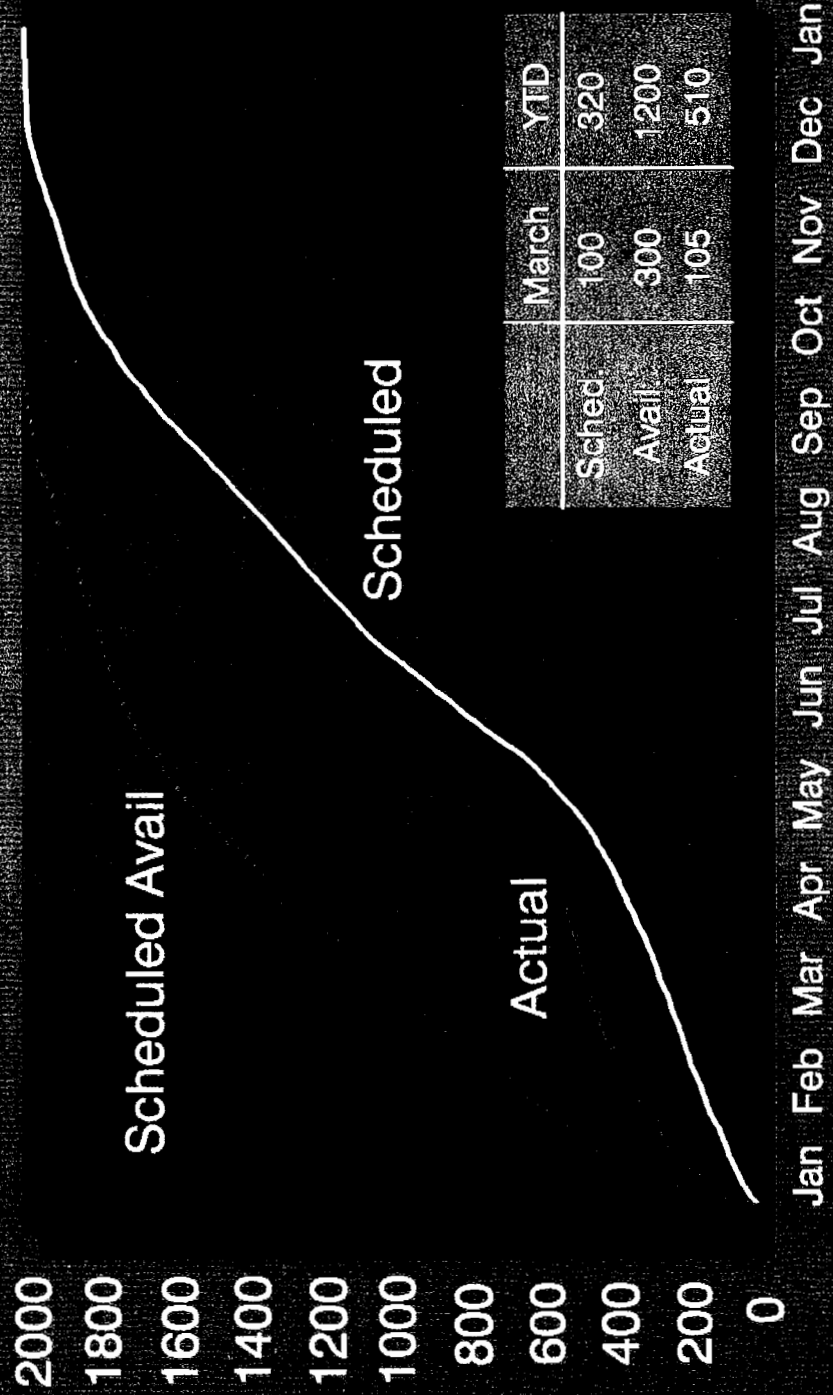


Figure 16



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Personnel

Project Organization

Project-dedicated organization

Designed to be oriented to work tasks, traditional line organizations have evolved into project-dedicated organizations. Changes in the regulatory environment are one cause of this evolution: design requirements usually vary between plants. A major advantage of the project-dedicated organization is an improved team philosophy.

Roles of management in the project

Who	Does what
The owner	<ul style="list-style-type: none"> • Must have a high overall involvement to ensure the success of this major financial project. • Clearly convey expectations. • Demonstrate commitment to the project schedule. • Consistently hold the management team accountable for meeting: <ul style="list-style-type: none"> ○ Quality ○ Schedule ○ Cost targets <p><i>Note:</i> This step is critical given the reduced durations required for the next generation of nuclear power plants.</p>
Site project manager	<ul style="list-style-type: none"> • Is responsible and accountable for the project management team. • Should report directly to the owner group.

Who	Does what
Project management team	<ul style="list-style-type: none"> • Should report directly to the site project manager. • Should include: <ul style="list-style-type: none"> ○ Integrated scheduling ○ Design ○ Materials ○ Construction ○ Quality control and assurance ○ Startup ○ Major vendors • Most importantly, must use the available information from the performance indicator program and project control system to: <ul style="list-style-type: none"> ○ Identify critical items. ○ Make decisions that affect the schedule, cost, and quality.

Key management’s role in project success

The experience of workshop participants indicated that much of the projects’ success was directly attributed to the capabilities of employees in key management roles. “Characteristics of Key Management Personnel” on page 3-15 summarizes characteristics that:

- Are shared by successful managers.
- Should be useful in selecting management for future projects.

Using experienced personnel

Employees experienced in the nuclear industry contribute to a project’s success. Skilled employees with nuclear construction experience (including utility personnel, A/Es, and constructors) are great assets in the organization.

Employee qualifications/training

Employee qualifications and training will be major concerns for a credible return to nuclear construction. Obtaining the necessary number of qualified workers is a challenge that will escalate as the present, self-imposed moratorium continues. Training programs in skill and knowledge areas must be in place long before the project begins. Obtaining and training the following nuclear-qualified personnel will be a key concern:

- Welders
- Pipefitters
- Control electricians
- Quality control inspectors

Additionally, all personnel should be trained to meet the QA program. (For more information on training, see “Skill Development and Training” on page 3-20.)

The importance of quality assurance

With regulatory stabilization achieved, refining and managing the quality assurance program becomes essential to project success. Preparing well in advance for plant construction should provide enough time to develop an integrated program for everyone involved on site. For more information on this area, see "Quality and Documentation" on page 3-26.

On-site engineering

On-site engineering groups have also enhanced teamwork. The relationship between engineering and construction personnel improves with personal contact rather than communication predominantly via telephone or mail. On-site engineering can also help resolve problems faster.

Regulatory personnel and vendors

The teamwork concept has generally not extended to on-site regulatory personnel. Part of the reason for this exclusion is the regulatory environment's instability, which often results in adverse relationships. Vendors have also had difficulty being "part of the team."

Contracts and contractors

Successful contract and labor negotiations will likely be key issues in arranging project financing. Shown below are techniques for dealing with contracts and contractors. (For information on contract alternatives, see "Contract Alternatives" on page 3-22.)

- Instead of using add-on incentives, negotiate contracts to include payment for performance in schedules, quality, and cost.
- Structure contracts so that contract participants do not profit from problems.
- Make contractors accountable for meeting standards and sharing risks.
- To meet performance areas and minimize effect on other areas:
 - Involve owners.
 - Make timely decisions.
 - Monitor performance closely.
 - Act quickly to correct deficiencies in performance.

International project organization

A United Engineers and Constructors' study suggests why international plants are built with fewer man-hours and shorter schedules than domestic plants. One finding is that all participants in international plant projects cooperated to meet a common objective. In other words, the participants were part of one team. The teamwork concept encourages employees to work with others for the common good. International experiences in the nuclear industry have been successful, especially when standardization is used to improve cost and schedule performance.

At Muelheim-Kaerlich

- On-site engineering helped speed up turnaround time on engineering questions and problems.
- Engineering personnel were also involved in:
 - Pre-operational testing
 - Setting major components
 - On-site meetings on status, schedule, and planning
- Regulatory personnel, assigned permanently to cover all major disciplines, were involved in resolving problems on a timely basis.
- Major component vendors were fully responsible for receipt inspection, erection, and checkout.
- Vendors used experienced personnel and were concerned about their reputation.
- The prime contractor did not have to train and provide construction engineers for major components.

Recommendations

Project team

- During construction, use a project-dedicated team comprising these groups:
 - Design
 - Construction
 - Vendor
 - Regulatory
 - Quality assurance
- To develop this team:
 - Train design personnel at the site.
 - Use the concept of a steering committee.
 - Have operations personnel at the design office developing operating procedures.
 - Use a constructability/operability checklist for designers.
 - Transfer personnel among the represented groups..
- Have team members work together, not against each other.
- Establish cooperation between project groups.
- Emphasize the common goal of producing a quality plant, with the lowest cost and shortest schedule.
- Make certain that all workers understand the importance of their individual work tasks and how the tasks fit into the project's success.

On-site engineering

- Use an on-site engineering group during construction. Domestic and international experiences confirm the importance of this group's presence.
- Benefits of an on-site engineering group include:
 - Quicker turnaround time on problems and questions.
 - Improved relationships with other on-site groups.

Vendors and regulatory personnel

- Make vendor and regulatory personnel a part of the project team.
- Have vendors involved on site to provide support during their components' inspection, erection, and checkout.
- Establish a positive relationship with on-site regulatory personnel—they should be involved with construction as part of the team, not as adversaries.

Owner/utility

- Provide one experienced, knowledgeable person to lead, direct, and control an integrated team.
- Guarantee that communication channels:
 - Allow efficient flow of information.
 - Focus each individual's actions toward overall project goals.
- Base contract payment on performance.
- Recognize, and be responsive to, project dynamics.

Project management team

- Should be in place well before early construction dates to develop detailed plans for managing the project.
- Include individuals responsible for managing:
 - Design changes
 - Materials
 - Procurement and control
 - Construction
 - Quality control and assurance
 - Project startup and operation
- Use project control information for appropriate management decisions.
- Be accountable for:
 - Detail of project management
 - Good community relations
 - Influencing public opinion
 - Employee morale
- Have clearly defined responsibilities.
- Provide work-force training before work begins.
- Prepare work-place procedures before establishing training requirements.

Work force considerations

- Use long-range labor agreements to increase productivity. The Nuclear Power Construction Stabilization Agreement can provide a good beginning for these agreements.
- Make certain the the agreement includes factors such as:
 - Payment for productivity
 - Incentives
 - Strike inhibitors

- Use work force schedules to benefit workers and facilitate project completion. For example, rolling (or alternating) work schedules of four 10-hour days a week for craft personnel:
 - Have advantages that should far outweigh the disadvantages.
 - Lessen fatigue and absenteeism.
 - Allow employment of workers from other geographical areas.
 - Have disadvantages such as the need for a larger area work force and flexible supervisory coverage.
- Reduce peak site population to maximize productivity.
- Use other recommendations in this report (e.g., detailed planning, standardization) to offset potential schedule losses resulting from this reduction in peak-site population.

Project Management

Project management and schedule delays

Project management practices have contributed tremendously to delays in construction schedules. Problem areas have included:

- The inability to adapt to changes encountered during construction
- A failure to manage effectively the shift from bulk (area) to system installation.

Methods of helping project management succeed

Method	Comment
Adequately handle problem areas, such as those listed above.	
Use communication, nuclear experience, and delegation of authority.	For example, a successful practice at River Bend Nuclear Station was relocating higher management personnel to the site.
Use an independent assessment group.	These groups can: <ul style="list-style-type: none"> • Provide additional understanding of project status and condition. • Make recommendations that will lead to beneficial changes. • Provide a good means for auditing different aspects of a project.

Craft personnel's productivity

Productivity of craft personnel relies on project management. Losses in productivity on projects have been attributed to:

- Unavailability of material and tools
- Congested work areas
- Rework
- Inspection delays

These losses have lead to sizable cost increases and schedule delays. Long periods of scheduled overtime also cause problems because:

- Workers become fatigued.
- Absenteeism and accidents increase.
- The work pace decreases.

Improving productivity through management techniques

Productivity and savings can improve through management techniques such as:

- Rolling four 10-hour day work schedules
- Improved communications
- Supervisory training

Benefits from these techniques have demonstrated the potential savings that can be accomplished using project management.

Productivity measurement programs

Productivity measurement programs have been developed to improve productivity. These programs (e.g., work sampling) are aimed at quantifying productivity, especially in low-productivity areas.

River Bend's productivity improvement program

River Bend Nuclear Station's productivity improvement program, the Quality Accountability Program, ensured that many activities were completed on time and within budget. In this program, the craft supervisor made certain his crew's work was completed according to the drawings and procedures. Management's enforcement of the program prevented many re-inspections and much rework.

Using project management to motivate

A lack of motivation is usually accompanied by frustration and poor attitude. Project management techniques for motivating employees have produced more productive employees. Tools that have helped motivate workers include:

- Round-table meetings
- Open houses for workers and their families
- Questionnaires and follow-up

Employee morale and public opinion

Both employee morale and public acceptance of nuclear power are critical parts of any project. The table below shows this importance and how to work toward high morale and public acceptance.

Who	Does what
The project management team	Must accept a role expanded to include responsibility for employee morale and influencing public opinion.
The project manager	Must be allowed the flexibility to include on his team representatives from other areas and organizations, such as: <ul style="list-style-type: none"> • Nuclear Steam Supply System (NSSS) vendor • Communications groups • Public relations • Independent or internal review groups

Who	Does what
Both management and labor	<ul style="list-style-type: none"> • Must show and emphasize: <ul style="list-style-type: none"> ◦ Stewardship ◦ Commitment to the community • Should be allowed to share success and decision-making to maintain morale.

Examples of international successes

International nuclear construction’s project management successes and problems resemble domestic successes and problems. Examples:

- At Tsuruga II, attention to detail and planning carried over to project management.
- At Muelheim-Kaerlich, turnkey contracts facilitated delegation of some project management work.

Recommendations

Recommendation	Comment
Remember that successful project management practices are characterized by schedule and employee traits such as: <ul style="list-style-type: none"> • Adaptability to change • Ability to shift from bulk (area) to system installation • Effective communication • Nuclear experience • Delegation of authority • Cooperation 	<ul style="list-style-type: none"> • These traits should be part of a nuclear project’s project management team. • A commitment to these traits must be made up front and carried through project completion.
Independently assess different aspects of the projects.	<ul style="list-style-type: none"> • These assessments could include project management practices. • The assessments can result in: <ul style="list-style-type: none"> ◦ A greater understanding of project status and condition. ◦ Changes employed based on recommendations.
Improve management techniques to increase productivity.	<ul style="list-style-type: none"> • Managers must initiate measures to improve productivity, such as promoting each employee’s completion of the assigned task. • Every effort should be made to increase a supervisor’s time in the field, possibly by reducing paperwork and time for meetings. (A stable regulatory environment should help reduce paperwork by ensuring only appropriate documentation is retained.) • Managers must also take the lead in making effective communication a part of the job.

Recommendation	Comment
<p>Make certain that efforts to allow workers to focus on specific tasks do not cause a need for more workers.</p>	<ul style="list-style-type: none"> • "Support" workers may do nothing more than transfer workhours to different accounts, falsely indicating improvement in productivity.
<p>To improve productivity, effectively measure and monitor performance (e.g., using a program that checks performance levels and identifies potential problem areas).</p>	<ul style="list-style-type: none"> • The cost and benefit of this sort of program must be considered. • Programs that measure and monitor work can generate resentment and feelings that the organization is merely "checking up on its employees." • One consideration is using work sampling as a tool for first-line supervisors. • The productivity monitoring program must be more than demonstrating and documenting management's prudence. • Both manual and non-manual workers should be accountable for productivity. The program's emphasis should be on improving conditions to support productivity.
<p>Use an integrated plant data base to help measure productivity.</p>	<ul style="list-style-type: none"> • This data base can use simple, user-friendly software programs that interact with all computers. • Information included in the data base should be keyed toward improving productivity.
<p>Remember that motivation is essential to productivity, especially for union work forces.</p>	<ul style="list-style-type: none"> • The overall objective is ensuring commitment to project goals. • A visible, involved high-level management should work with project personnel. • Employees should have both individual and group recognition for good work (e.g, a cookout for meeting a milestone). • In the field, craft personnel should be involved in decision-making and advanced planning to bring new ideas and experiences. Incorporating these ideas boosts moral while providing a way to make craft personnel part of the team. • Other benefits such as family days and open houses can also be beneficial.

Characteristics of Key Management Personnel

The importance of selecting project management personnel

The processes of project planning, scheduling, and constructing can be described as scientific or objective. However, selecting project management personnel for each organization level is *subjective* and perhaps the most important aspect in project management: selecting people who can work as a team and make a positive, distinct difference.

Goals in selecting project management personnel

Though the process is subjective, selecting project management personnel has very definite goals and objectives that cannot be overemphasized. The overall goal, of course, is to build a high-performance, successful project team by integrating individual strengths and weaknesses. The quality of the selection should be enhanced by:

- Systematic processes
- Clear understanding and agreement on desired qualities

Desirable characteristics

In total, the characteristics shown in the table below compose a project's Top Management "wish list." In reality, a mixture of these characteristics will be used to fill specific jobs in the organization, from the site project manager to first-line supervisors.

Example: All site managers should have a strong *completion commitment*. But as defined below, *perception* is not as important to first-line supervisors as it is to upper-level managers.

Distinctions should be made between management characteristics at each management level, but the table below shows the common denominators in effective nuclear construction managers.

Characteristic	Description
Quality-mindedness	<ul style="list-style-type: none"> • An ability to see and understand the overall systems ("big picture") quality issue, while attending to the minute details critical to nuclear safety. • An appropriate emphasis on the importance of product quality rather than on negative aspects (e.g., defects).
Completion commitment	<ul style="list-style-type: none"> • A thorough understanding of the desired end product with a drive to complete the work on time and under budget. • Understanding and commitment to the idea that "complete means complete" (including inspection records).

Characteristic	Description
Integrity	<ul style="list-style-type: none"> • Demonstrated ability to make the difficult technical and human-resource decisions to inspire confidence and trust throughout the organization. • A recognition of the need for, and willingness to, hold oneself and others accountable for the project.
Judgment	<ul style="list-style-type: none"> • An ability to use project experiences for the best solutions to current problems. • Recognition of the issues involved and "getting to the truth" without being blinded by symptoms, even when the issues involve oneself.
Interpersonal skills	<ul style="list-style-type: none"> • An ability to communicate effectively expectations, ideas, and decisions both orally and in writing. • Application of communications skills to establish and maintain effective professional relationships with labor, owners, and the public toward successful project completion.
Leadership/empowerment	<ul style="list-style-type: none"> • An ability to establish: <ul style="list-style-type: none"> ◦ Quality-mindedness and completion commitment to accomplish work effectively through others. ◦ Workforce norms so that everyone feels accountable and in charge of the quality of his work and project success. • An ability to convince others to "follow" as appropriate. • Dedication of time to walking around and communicating with employees to gain a true sense of the job, thereby enhancing communication and establishing the work-force norms.
Perceptive	<p>An ability to:</p> <ul style="list-style-type: none"> • Assess employees' strengths and weaknesses. • Recognize problems. • Develop solutions for long- and short-range project impact. <p><i>Note:</i> Not all problems are evident from control data or elevated from within the organization. The skill is in recognizing and dealing with less obvious problems.</p>
Transition/change	<ul style="list-style-type: none"> • An ability to: <ul style="list-style-type: none"> ◦ Recognize where changes may be necessary for the organization. ◦ Effectively rally the project team to implement changes and move forward. • Willingness to support any and all decisions and changes, even when they are different from one's own opinions.
Intellectual	<p>A critical ability to deal with large volumes of information while maintaining a clear, focused understanding of project status and goals.</p>

Characteristic	Description
Experience	A solid foundation in technical knowledge and actual work experience.
Team player	The willingness and skills needed to be part of a high-performance team, including a strong commitment to the project "mission."
Customer orientation	A commitment to customer/owner satisfaction.

Selecting key personnel

A variety of processes can be used to select key management personnel. The table below shows one process, which addresses the above characteristics, to evaluate candidates. Other selection processes, such as assessment centers, could be equally or even more effective but might require substantial time and money.

Who	Does what
Manager who knows the candidate (if an internal candidate)	Evaluates the candidate for specific jobs against a list of management characteristic indicators.
Manager with staffing need	<ul style="list-style-type: none"> • If evaluating an external candidate, uses in-depth interviews and references to verify characteristics. • Conducts a meeting to discuss all candidates with a Human Resource representative who serves as a recorder and facilitates the process.
Meeting attendants	<ul style="list-style-type: none"> • Discuss and rank each management characteristic indicator for each candidate. • Make a final selection using factors such as: <ul style="list-style-type: none"> ○ Rankings with other candidates ○ "Fit" within the team ○ Risk ○ Candidate availability ○ Development needs

Work Force

Special work force considerations

Special work force considerations include:

- Contract negotiations
- Employee qualifications
- Public credibility

These areas may present special problems because of the time lapse between the past and future generations of projects. To ensure the project is started positively:

- Resolve these problem areas early.
- Include the areas in milestone schedules.

Consideration	Description
Peak site population	<ul style="list-style-type: none"> • Is higher for domestic plants (approximately 3500 people) than international plants, according to United Engineers and Constructors' comparison of domestic and international construction experiences. • Averages 1.4 persons per kWe in France, compared with the worst-case average of 6.5 persons per kWe in the United States (based on single-unit plants). <p><i>Note:</i> Additional workers can improve schedules but result in congestion and lost work time.</p>
Long-range labor agreements	<ul style="list-style-type: none"> • Have reduced the peak site population. • Have improvements productivity. • In the United States, have included project agreements and the Nuclear Power Construction Stabilization Agreement (see below), which have: <ul style="list-style-type: none"> ○ Allowed workers to understand the "ground rules" up front. ○ Prevented many problems while providing a way to address problems that do occur. • Include topics such as: <ul style="list-style-type: none"> ○ Work stoppage (strikes) and schedule ○ Overtime ○ Absenteeism ○ Safety ○ Travel ○ Penalties for faulty craftsmanship
Project agreements	<ul style="list-style-type: none"> • Have been used on many domestic nuclear plants. • Though plant-specific, generally address the same items. • Include union craftwork. • Have been used successfully by Perry and Grand Gulf.

Consideration	Description
Nuclear Power Construction Stabilization Agreement (NPCSA)	<ul style="list-style-type: none">• Was developed to improve productivity while benefitting management and craft personnel.• Provides management benefits by:<ul style="list-style-type: none">◦ Eliminating potential problem areas (e.g., strikes).◦ Providing a more stable work force.• Includes labor benefits such as better safety and work schedules.• Contributed greatly to the success of River Bend. Gulf States Utilities alternated four 10-hour work days with 4 days off to obtain experienced labor from outside their immediate area. Absenteeism was low and morale remained high. The only work schedule problems were in planning supervisors' work shifts.
Merit (open) shop approach	<ul style="list-style-type: none">• Allows union or non-union labor.• As with long-range agreements, provides "ground rules" up front.

Skill Development and Training

Introduction

Locating qualified personnel is a major challenge facing the next generation of power plant constructors. Acceptable site locations will probably not provide the required number of skilled people ready to work.

Order-of-magnitude projection

Figure 3-1 on page 3-63 is an order-of-magnitude projection of basic skills required by year. The projection, based on previous projects, does *not*:

- Include significant changes in technology or methodology (e.g., large-scale, off-site modularization).
- Separately address the personnel who may be dedicated to maintaining the anticipated information management system.
- Include non-craft or professional needs.

Assumptions for site support group functions

The order-of-magnitude projection approximates site support group ratios based on these functions:

Function	Description
Engineering	<ul style="list-style-type: none"> • Field support • Process control generation and review • Liaison with designer • Technical reviews and consultation
Project Planning and Control	<ul style="list-style-type: none"> • Planning • Scheduling • Coordination • Cost control and budgets • Project analysis and integration
Materials and Equipment	<ul style="list-style-type: none"> • Site procurement • Receiving • Storage • Allocation • Delivery to the field • Equipment maintenance and repair (e.g., welding machines, power tools)
Human Resources/ Personnel	<ul style="list-style-type: none"> • Employment • Administration • Employee relations • Safety • Security

Developing craft supervision skills

Although craft supervision is listed as a craft skill in Figure 3-1 on page 3-63, emphasizing this classification reaps significant benefits to the project. The importance of supervisory skill development cannot be overemphasized because first-line supervisors have the greatest impact on areas such as worker morale and productivity.

Literacy

Literacy, both computer and general, will significantly influence the work force's ability to produce in the nuclear power plant environment, which centers on documentation and information. Ensuring this literacy could pose additional challenges to the employer.

Recruitment and training

As the projection's numbers indicate, recruiting and training personnel is a major pre-job activity that could begin as much as 1-2 years before official start dates. Shown below are things to consider when recruiting and training qualified workers.

- Keep in mind that project location will affect both wage scale and methods of recruitment and training.
- As early as possible, begin cooperative efforts with local technical schools, colleges, and even high schools.
- Recruit "core" qualified veterans, if any are available.
- Develop specialized in-house training programs.
- Consider developing industry-wide training and certification programs, in cooperation with construction trade groups, to:
 - Increase the pool of qualified personnel.
 - Ensure consistent qualifications.
- Think of operating nuclear stations as training opportunities, as they are regularly maintained and modified. Such training may provide the most significant nuclear-grade field experience for the industry's future.
- Understand and anticipate the mandatory need to plan for the cost of investing in up-front training and recruitment.

Contract Alternatives

Why contract alternatives are important

Experiences with nuclear plant design and construction demonstrate:

- The importance of completing the design up front
- The need for regulatory stabilization

Design, scope, and regulatory changes make cost control and vendor accountability difficult. These factors require careful review and evaluation to minimize costs and maintain desired schedules.

Options on contract type

Contract types include:

- Fixed price
- Cost plus percentage
- Cost plus fixed fee
- Unit price

These options are frequently combined. Incentive and escalation clauses can also be included and often benefit both owner and vendor. Shown below are these options and terms.

Fixed-price: A contract in which the contractor agrees to work for a stated dollar amount. For this compensation, the contractor must fulfill all obligations under the contract, even if the contractor's cost may exceed the stipulated payment. Generally the contractor is compensated in partial payments rather than receiving the entire amount after work is completed and accepted. The owner's staff monitors work and verifies that work is completed when the contractor reports completion. This contract benefits the owner because the bid shows exactly what the contract will cost. Contractors seldom agree to a fixed-price contract when design, scope, and regulatory changes are likely to occur. The design, therefore, needs to be finalized to the benefit of owner and manager, and changes must be clearly defined and priced accordingly.

Cost plus percentage: A contract in which the contractor agrees to work for expense reimbursement plus a percentage of all expenses. With this type of contract, the owner is uncertain of final cost and the contractor faces little risk. Cost plus percentage contracts are often used on projects for which:

- Design is incomplete
- Unstable regulatory climate can cause a change in scope

Cost plus fixed fee: A contract similar to cost plus percentage contracts, with stated fee paid instead of a percentage of expenses.

Unit price: A contract in which work is paid for based on *one* of the following:

- Quantities of work actually completed
- Materials furnished or used by the contractor

Each quantity is multiplied by the contractor's price for the unit of work or materials. Earthwork excavation is typically handled in a unit-price contract.

Incentive: A contract clause motivating the contractor to complete work before an agreed date. The contractor would be reimbursed for meeting the terms of the incentive. Though meeting the incentive's terms is optional for the contractor, both owner and contractor can gain from this type of clause.

Escalation: A contract clause to allow for material and labor escalation over the project's duration.

Factors to consider when selecting a contract type

Several factors will influence the contract types of all ALWR projects. The value of preselecting any contract type for future projects is questionable at best. Shown below are experience-based factors to consider for future projects.

Factor	Considerations
Unions	<ul style="list-style-type: none"> • Union activities need to have clearly defined project agreements. • Unions should "buy in" at the local level. • Up-front, planned negotiations on handling changes minimize the impact of unions on the job site. The approach should be to make the union part of the project team. To help address and remove jurisdictional disputes and associated issues: <ul style="list-style-type: none"> ◦ Negotiate an agreement between owner and internationals of unions. ◦ Have negotiations at the local level (with initial personnel assignments and personnel changes) and/or at the national level, as appropriate. (The level of negotiation may depend on the construction site's location.) ◦ Obtain a Site Stabilization Agreement signed at the national level and agreed upon at the local level. • In non-union situations, the availability of a qualified work force is a major consideration. In some cases, craft personnel may need to be trained and qualified after they are hired. On employment, management handles with the individuals: <ul style="list-style-type: none"> ◦ Policies ◦ Benefits ◦ Compensation ◦ Work expectations
Contract structure	The contract must be structured so that participants do not profit from problems.
Assigning personnel	<ul style="list-style-type: none"> • Management should have a review and approval process for initial personnel assignments and personnel changes during the project. • The motivation and capabilities of assigned contract personnel will be the most significant factor in making the contract agreement successful.

Factor	Considerations
Fast-track engineering	<p>Scope and details must be evaluated thoroughly to overcome bad contract experiences with fast-track engineering. Even if design completion is a prerequisite to awarding the contract, management of "out-of-scope" items should not be taken lightly. Experience shows that fast-track engineering cannot support lump-sum contracts.</p> <p><i>Example:</i> For a project canceled at one year and approximately 60% complete, the contract settlement was about 50% above the original lump-sum price because of numerous rebar interferences and other changes largely caused by fast-tracking.</p> <p>Some fast-track engineering projects <i>were</i> successful when the A/E, construction manager, and constructor were on cost reimbursement plus incentives. The incentives were based on support of project objectives (e.g., schedule, quality, and unit rates). The projects did encompass unit-price and fixed-price contracts for specific, well-defined scopes of work. Cost reimbursement has not always worked well on major civil/structural, piping/mechanical, and electrical contracts because of:</p> <ul style="list-style-type: none"> • Scope increases • Owner cash problems • Regulatory instability • Multiple layers of quality inspections
Unit-price contracts	<p>Unit-price contracts have had limited success on insulation and instrumentation work. However, up-front, essentially complete engineering and design should eliminate or minimize these concerns on future projects.</p>
Fixed-price with incentive contracts	<ul style="list-style-type: none"> • Award fees should be based on positive and negative performance. • Contractors must be kept to commitments to make money while the project is progressing. • Fixed price should be based on a mediocre profit. The incentive allows for a superior profit. • Standards, expectations, and measures must be clearly defined. • An atmosphere that "hides" performance problems must be avoided. • CII findings on incentive programs should be reviewed.
Turnkey agreements	<p>ALWR projects are not likely to have the option of turnkey contracting agreements, in which the contractor agrees to perform all project activities—engineering, purchase, installation, and test—and "hand over the keys." These agreements allow minimal owner staffing <i>but</i>:</p> <ul style="list-style-type: none"> • Reduce the owners' hands-on knowledge of plant operations, since the owners are not involved in system testing and calibration. • Relinquish much of the owners' control of the project. • Reduce the ability to observe and correct adverse trends.
Control and owner risk	<p>Control of quality, cost, and schedule and minimization of owner risk are major considerations.</p>

Muelheim-Kaerlich's project/contract

Muelheim-Kaerlich's turnkey project/contract contributed to the project's success. Incentive and penalty features for engineering, procurement, construction, and start-up from one prime contractor resulted in good overall performance. Important aspects of turnkey contracts include:

- Fixed pricing causes consideration of efficiencies. Cost plus contracting does not.
- Incentive/penalty arrangements easily assign a cost value to schedule time. Decisions can therefore be made based on cost and benefit.
- Only one chain of command was involved in decision-making. Typical domestic plants involve several management hierarchies.
- No arguments occurred over which party owned a problem and its costs, so no long investigations were made on who was responsible.
- The streamlined, uncomplicated organizational structure vastly reduced the amount of paperwork required to accomplish some tasks.
- Financial risks involved caused an early design "freeze." The customers were allowed only a few changes.
- At any time, only one organization—therefore, one individual—responsible for a system or component. For example, when a system was transferred from construction to startup, the start-up engineer had complete responsibility and authority over the system, including operation until accepted by responsible operations personnel.

Performance

Quality and Documentation

Introduction to the QA program

A single quality assurance (QA) program for all site activities is one of regulatory stability's most important benefits. Before work begins, the QA program clearly defines for all project participants (e.g., contractor, suppliers):

- Expectations of the actual code/regulatory requirements
- Associated interim and permanent documentation needs

The owner's part in QA

To have an effective QA program, the owner should:

- Try to standardize the program as much as possible.
- Minimize quantities of paperwork to be managed.
- Use the latest proven technology.
- Ensure that data management is tied into the overall production control system.
- Develop a method to correct minor discrepancies without generating large amounts of paperwork (e.g., detailed nonconforming item reports).

For more information on establishing a successful QA program, see "Guidelines for establishing a QA program."

Benefits of a standardized, computerized QA program

- Offers more flexibility if the preoperation testing goal of 100%, as-scheduled system completion is not met.
- Accommodates partial/conditional turnovers in the event of last-minute, isolated problems.
- Creates criteria from the beginning to minimize the number and severity of noncompliances.

Guidelines for establishing a QA program

The standardized QA program must be developed during the design phase, before construction begins. The table below shows guidelines for QA programs.

Guidelines	Comments
<p>Develop the QA program up front to:</p> <ul style="list-style-type: none"> • Avoid the difficulties of using and managing a program that is being developed or changes during construction. • Allow each project participant to be oriented and trained in the QA program as necessary. • Develop effective work place procedures by giving project participants a clear understanding of the QA program. 	<p>If the program is not developed up front, the result is a set of information that is extremely large, diverse, and hard to manage.</p>
<p>Make the program straightforward and easily understandable.</p>	
<p>Base the program on actual requirements, separating clear definitions of actual requirements from administrative details. In other words, define what is to be done but not necessarily how to do it—leave administration to the administrators.</p>	<p><i>Example:</i> The ASME Boiler and Pressure Vessel Code has a material identification requirement for pressure-retaining parts. The QA program should specify that materials carry distinguishable identification marks until installation to ensure the specified material is used. However, the program does not have to address how this requirement is met (e.g., by specifying adhesive labels or color coding).</p>
<p>Have the project participants' management develop these administrative guidelines in the workplace based on preferences for accomplishing basic code and regulatory requirements.</p>	<p>Combining actual and administrative guidelines makes:</p> <ul style="list-style-type: none"> • An unwieldy program unsuitable for everyone involved. • A burdensome commitment with both areas appearing to be required for the user.
<p>Make certain the designer establishes inspection and documentation criteria on the applicable codes and standards.</p>	<p>These criteria must be clear enough to preclude interpretations in the field that:</p> <ul style="list-style-type: none"> • Create confusion and inconsistencies. • May lead to problems in the latter stages of construction, such as incomplete activities or paperwork.

Guidelines	Comments
<p>Use a standardized approach (including standardized forms) to help with defining relatively finite requirements that:</p> <ul style="list-style-type: none"> • Are known from project start to completion. • Minimize the need for individuals to interpret them. 	
<p>If possible, develop one standard QA program that suits all project participants.</p>	<p>Accomplishing this goal requires a concerted advance effort to:</p> <ul style="list-style-type: none"> • Solicit input. • "Buy in" from the contractors and suppliers. <p>Not involving the contractors and suppliers could cause increased charges or refusals to participate in the program.</p>
<p>Let the individual contractor or subcontractor develop the detailed workplace or process control procedures, basing the procedure on organizational needs and procedural preferences.</p>	<p>The contractor/subcontractor should develop procedures before work begins so that the owner can assure that the general QA program requirements are met throughout construction.</p>
<p>Integrate the QA program with the plant information management system to minimize large quantities and varieties of paperwork.</p>	<p>Paperwork can then be:</p> <ul style="list-style-type: none"> • Coded with a unique identifier during project organization. • Used for both production and quality control. • More easily retrieved when needed.
<p>Have precise configuration control (the latest plant/system parameters) to give accurate, up-to-date plant/system design to:</p> <ul style="list-style-type: none"> • Fabricators • Installers • Inspectors 	
<p>Make final reviews and approvals of paperwork another component in the overall production schedule.</p>	<p>This process must be highly visible, as reviewing the large quantities of paperwork is itself a major work task. Waiting until the final stages of the project may mean that someone involved in a minor discrepancy is unavailable to be interviewed, so that something minor becomes something major.</p>

Guidelines	Comments
Make QA management responsible for their production rates.	
Schedule and integrate QA activities with craft activities to lessen production delays.	QA inspections must follow installation immediately to prevent creating an unknown wave of rework that could adversely affect the critical sequence of scheduled activities.
Develop means to provide proper feedback after inspections to the craft personnel.	Proper feedback should: <ul style="list-style-type: none"> • Improve the quality of craft work. • Reduce potential rework.
Ensure that project management personnel direct quality/inspection production efforts without impacting inspectors' judgments or decisions on quality.	
Periodically conduct independent program reviews/audits to maintain high quality.	<ul style="list-style-type: none"> • Understand that: <ul style="list-style-type: none"> ◦ The installing organization is responsible for quality. ◦ Quality cannot be inspected into work. • Create an atmosphere in which craftsmen: <ul style="list-style-type: none"> ◦ Take pride in their work. ◦ Demonstrate final product ownership rather than considering the job done when it is turned over to Quality Control for inspection.
Avoid duplicating problem areas by ensuring that quality trends communicate both the good and the bad to the work force.	Previously, quality assurance training has too frequently concentrated on nonconformities rather than root causes.

Summary of quality and documentation goals

- Establish a standardized quality assurance program for all project participants.
- Tie data management into the overall production control system.
- Remember that the Quality Assurance organization is accountable to the project manager for maintaining the schedule pace.
- Use data base computer programs.
- Make certain that the designer:

- Before work begins, establishes inspection criteria that:
 - Minimizes, or at least restricts, interpretation in the field.
 - Remains fixed throughout the construction.
- Establishes the type of documentation and the level of detail required.

Note: The designer should establish these needs as early as possible, because the production control program should tie into these data needs.

Inspection

Standardizing inspection

Inspection is currently much too subjective. The industry needs to develop objective standards, such as weld samples, and build in quality, rather than "inspecting it in." Skilled craft personnel should perform the initial inspection and be trained with inspectors. This training would help inspectors and craft personnel learn the same standards and develop mutual respect.

Removing interpretations

Because they have been too subjective, inspections have been perceived as giving a "limited quality of return." If the tendency to interpret standards is removed, inspections will become more objective. A reasonable tolerance band methodology (similar to the Visual Weld Acceptance Criteria Program) should be applied to all inspections. Standards should also be consistent between manufacturer and installer.

International experiences

International nuclear construction's inspection programs have not emphasized documentation as much as domestic construction programs:

- Japan and Canada—Programs have generally been small and relied on workers and supervision to "build in" quality.
- West Germany—Quality has been built in and verified using a commercial "third party" testing organization.
- France—Refinement of quality is achieved from series to series of replicate plants.

At Tsuruga II, liner plate inspection amounted to approximately 60% of total workhours. This ratio is high, especially considering the reliance on the workers and supervision to build in quality. Reasons for the high ratio included:

- The containment construction was new for the Japanese.
- Construction and inspection are approached with great care and attention to details.

At Tsuruga II, inspection record-keeping was handled efficiently. Photography simplified inspections and avoided misinterpretations. Rebar splices were photographed, along with the workers involved and the inspection team. A record of the activity was also part of the documentation.

Recommendations

Program

- An inspection program should be developed to ensure quality construction without creating increased costs and schedule delays.
- Inspectors need to be part of the project team, not the opponent.
- Inspection concerns should be addressed before they escalate.

- Improvements are needed in all aspects of inspection, including inspected documentation.

Documentation

- A minimal number of inspection documents should be developed.
- Inspections should ensure quality products rather than excessive documentation.

Requirements

- Reviewing necessary requirements can minimize over-conservatism.
- With minimal requirements established, an effort to standardize industry inspections should be pursued.
- Requirements should be interpreted consistently.
- The plant location's NRC region must not be allowed to make overly stringent interpretations of requirements compared with other regions.

Communication

- Reasonable requirements and acceptance criteria should be well-defined and communicated to craft personnel and inspectors. This process should be handled up front to avoid misinterpretations by inspectors.
- Communication between organizations is necessary.

Methods

- Building reference points should be adequate, meaningful, and measurable.
- Qualified technical judgment should be allowed in the inspection process.
- Photographic inspections can reduce the amount of documentation and simplify inspections.
- Alternative inspection methods should be considered, such as:
 - Self (or peer) inspections
 - Shop inspection/testing/audits of welds, supports, and subassemblies
- Installers and inspectors need to use the same tools of measurement.

Vendors

- Inspection concerns for vendors must be addressed:
 - Products must be provided with quality compatible with other project items.
 - Tolerances must be compatible with interfacing plant items.
 - Extensive use of modularization complicates these concerns.

Planning

Introduction

This section discusses the effects of planning the construction process. "Planning Through Design" in Volume IV describes the effects of planning during design and how it can enhance productivity. Though different in some ways, the 2 planning processes are not independent. Planning should begin at a project's initiation and continue until completion.

Benefits of up-front planning

Planning has been described as a major contributor to project success. Before a project begins, the owner must commit substantial resources to areas such as:

- Identifying and resolving problems early
- Work package planning
- Scheduling
- Training

Up-front planning and standardization, even as specific as detailing work packages, has far-reaching benefits. As discussed earlier, labor is a major cost contributor; an appropriate work package will reduce labor costs by:

- Reducing craft delays.
- Providing alternative work.
- Allowing management to more easily redirect the work force when needed.

Performance indicators are important tools in monitoring and acting toward targeted objectives and results.

Approaches to planning

- A systems approach to construction planning supports start-up testing. Some experience indicates that the development of the overall plant construction schedule should begin with a detailed, achievable schedule for system completion, testing, and turnover.
- Careful planning ensures that the required tools, materials, documentation, and personnel are available for a given task.
- Prepackaging helps ensure that:
 - Work areas are accessible.
 - Work tasks are simplified.
 - Unproductive time is minimized.

Meetings

Much thought should be given to, and structure established for, meetings. On a project of this magnitude, meetings become "a way of life," but too many meetings are counterproductive to project goals.

Example: For maximum productivity, craft supervisors need to spend most of their time directly supervising the crew rather than attending project status meetings.

Meetings should make communications consistent so that the project runs smoothly. Electronic communications systems should preclude many of the meetings that were necessary in the 70s and 80s.

Float

Float is the difference between when work *can* be done (all resources available) and when it *must* be done to avoid project delay. The project's critical path will have no float unless management builds it in by:

- Setting earlier targets *or*
- Deferring committed completion.

Handling float: Other project activities will have varying amounts of float. To handle float:

- Initially schedule each activity at the earliest time it can be completed.
- With top management approval, move activities around within their float time to make the most of resources within parameters set by management.
- Establish who can use float and under what conditions. Do not let schedulers or field personnel use float at their discretion, resulting in a tendency to delay work and thereby increasing the number of critical activities. Each critical activity jeopardizes the overall schedule.

Float and vendors: The project owner "owns" float until it is sold. In other words, if need dates for deliveries are established as the 0 float date, the float then belongs to the vendor. It is much more advantageous to the owner to establish need dates for delivery or completion of service that maintain the desirable float.

International planning successes

Many international nuclear plants have found that up-front, detailed construction planning leads to a smooth work flow and limited idle time. Planners can provide workers with a daily package of all required tools, materials, and documentation for the scheduled activity.

Tsuruga II

These daily packages were used at Tsuruga II, where cost and schedule were controlled with a thorough, detailed plan and a commitment to keep within the design. Selecting and boxing tools at the site before they were required meant individuals did not need access to the tool bin. Lost time was therefore minimized, since workers could work rather than locate tools. Detailed planning has helped in construction areas such as:

- Rebar placing
- Concrete placing
- Material handling

Recommendations

Recommendation	Comment
Detailed planning can provide significant benefits if begun early in the project and integrated into the design phase.	
Attention to detail and a commitment to stay within the plans are important in construction planning.	
Contingency planning should be built into the basic planning.	
A systems approach to planning helps ensure pre-operational testing schedules are met.	<ul style="list-style-type: none"> • An approach that integrates engineering, construction, and testing should also be used.
As much as possible, planning should minimize movement of workers in different plant areas.	
Tools, materials, and documentation should continue to be prepackaged.	<ul style="list-style-type: none"> • Significant time has been saved by limiting unproductive time and simplifying construction work. • Prepackaging facilitates extensive use of prefabrication and modularization. • Though not as applicable to system installation, prepackaging can still be beneficial because: <ul style="list-style-type: none"> ◦ Supervisors would have more time for field supervision. ◦ Laborers would have more time for actual work. • Potential disadvantages to prepackaging include: <ul style="list-style-type: none"> ◦ The possibility of increased procedures and paperwork on the process ◦ Prepackaging's tremendous dependency on the capabilities of preplanners and prepackagers.
Significant savings and improvements result when handling equipment (cranes and monorails) is installed early enough to be used during construction.	<ul style="list-style-type: none"> • Early installation helps improve productivity, especially in congested areas. • Only detailed planning can maximize handling equipment's use and effectiveness.

Performance Management

Work-force management programs

Management needs a good work-force management program for:

- Planning
- Establishing goals
- Implementing and controlling work
- Minimizing delays
- Removing obstacles to productivity

To best use work force, project controls must be supplemented with employee motivational programs and an industrial engineering program.

Motivational programs: These programs, essential to maintain and control productivity, should:

- Include a Human Resource group.
- Evaluate performances.
- Motivate employees to higher performance levels. Examples:
 - Project communications
 - Picnics
 - Sports
 - Incentives for perfect attendance
- Reward employees for achieving those levels. Examples of rewards:
 - Recognition in project newsletters and on bulletin boards
 - Distinguished service awards
- Identify areas where improvement is necessary.

Industrial engineering (IE) programs: Studies show that as much as 85% of process cost can be eliminated through IE programs that:

- Make the most of resources by integrating people, equipment, and technology.
- Provide information to assist management in making decisions.
- Use industrial engineers' specialized talents to:
 - Design systems that eliminate duplicate and unnecessary effort.
 - Develop well-defined goals and process planning.
- Review and structure into a plan such elements as:
 - Workflows
 - Information flows
 - Technology
 - Resources

Combining organization and control methods

Combining the organization structure with control methods should result in:

- A systematic flow of activities
- Increased communication
- Focus on objectives

To make the combination effective:

- The organization should be ready to make changes and show responsiveness, accountability, and effective communications.
- These three attributes should be:
 - Measured each time organizational performance is evaluated.
 - Fed back to all groups for corrective action.
- This process should occur continuously because of objectives changing during a project.
- A properly chartered Human Resource group should be able to evaluate the organization's effectiveness.

Ensuring and measuring organization effectiveness

- Measure the organization's responsiveness by its flexibility at various project stages. In other words, manage projects in both dimensions (bulk commodity and system completion), with emphasis shifting from bulk to system as the project progresses.

Example: In the past, nuclear construction management had difficulty deciding when to change from bulk commodity to system completion. In actuality, no specific time exists for such a change. Start-up testing logic defines requirements for system completion, which in turn provides the basis for bulk installation schedules.
- Regarding details:
 - Make the project management team accountable for managing details from conception to completion. (Small details delay jobs or cause rework.)
 - Ensure that details are documented, managed, and controlled.
- Focus each individual on the project objectives and goals. (See "Performance Indicators (PIs)" on page 3-39.)
- Verify that communications flow responds to change and progress, necessary because compressed schedules and around-the-clock operations complicate communications in areas such as:
 - Schedule updates
 - Material moves
 - Problem solving
 - Administrative information
- Consider management's presence on all shifts a necessity.
- Measure communication's effectiveness by primary performance factors:
 - Schedule
 - Productivity

- Rework
- Absenteeism
- Employee morale

Performance Indicators (PIs)

Definition

Measurable expectations derived from the organization's goals and objectives to achieve desired results. (On the ALWR, these results relate to project schedule, cost, and quality.)

Purpose

Using ratios and measurements, PIs provide management with the information to monitor employee performance. By evaluating this information, management can then develop strategies for decisions and future requirements, therefore continually focussing the PIs toward the desired results.

How management uses PIs to balance the information flow

One of management's most important undertakings is keeping concise and real-time information flowing effectively. On the ALWR, the difficulties associated with managing an aggressive schedule will require extensive up-front planning and more timely information on:

- Schedules
- Cost
- Vendor performance (including module assemblers)
- The overall work force

At the same time, however, management must avoid an overload of information from data that has little relevance to the project's cost, schedule, or quality. To balance the information flow, management must develop an obvious, available process with:

- Established project expectations
- Data that indicates performance against those expectations.

This balanced process should use PIs to function correctly.

Levels at which PIs should be incorporated

Level	Description
Project	<p>The time at which the project management team establishes project goals, with 3 strategic concerns:</p> <ul style="list-style-type: none"> • Controlling cost • Schedule progression • Quality of work performed <p>If control is lost in one of those areas, the other two can be drastically affected. Responsibilities are also established here. On the project level, PIs give the owner a way to ensure the project team's effectiveness. From this data, future expected costs are forecast.</p>

Level	Description
Management	<p>This level provides a more defined breakdown of the PIs established at the project level. Management uses this breakdown as a tool to:</p> <ul style="list-style-type: none"> • Monitor and evaluate the efficiency and effectiveness of the project plan's implementation. • Pinpoint factors affecting cost and schedule at all project phases. <p>Each work group's performance can also be monitored using:</p> <ul style="list-style-type: none"> • Progress reports • Schedule and cost data • Other production control information
Group (supervisor or crew)	<p>This level breaks down even further the PIs related to individual crew and supervisor performance when implementing the project plan. Management uses these PIs to target areas on the crew level that need improvement.</p>

Performance indicator process

To ensure a project's success, the PI process must be repeated many times throughout the course of a project. Figure 3-2 on page 3-64 illustrates the process as described in the table below.

Step	Action
1	The project management team establishes the objectives to achieve the desired results (goals). These goals must be flexible because results may need to adjust on different organization levels for various project phases.
2	Strategies are set to outline how to achieve the goals.
3	PIs are developed to objectively measure progress toward the goals. These PIs must be adaptable to changing goals (e.g., appropriate for project phases). (For PI categories and examples, see "PI categories and sub-indicators" on page 3-41.)
4	PIs are established and integrated throughout the organization to focus on all levels. (See "Levels at which PIs should be incorporated" on page 3-39.)
5	<p>During PI integration:</p> <ul style="list-style-type: none"> • Accountabilities are defined. • Each employee's role in using the PIs is communicated.

Step	Action
6	<p>Information related to the PIs is gathered and reviewed to allow management to:</p> <ul style="list-style-type: none"> • Expose problems (such as quality issues) before they become crises. • Forecast future schedules and cost. • Set new goals to: <ul style="list-style-type: none"> ◦ Define actions to be taken. ◦ Refocus on the desired results. • Adjust PIs to communicate these actions and goals to each organizational level.

Selecting appropriate PIs

The PI process's success depends largely on selecting appropriate indicators that give information mirroring site activities' organization and processes. If the indicators do not consistently expose problems, the wrong information was identified initially. In this case, adjustments should be made to reflect the organization's:

- Vital signs
- Abilities
- Performance

PI categories and sub-indicators

The table below shows:

- The broad-based categories:
 - At which most goals are targeted
 - Which influence the future cost of the project
 - To which target levels of improvement should be set to reduce or meet estimated project cost.
- For each category, potential sub-indicators providing information that management uses to focus on positive or negative trends.

Category	Sub-indicators
Cost	<ul style="list-style-type: none"> • Variance analysis • Cost of predictable schedule delays • Vendor costs • Material and labor costs (direct and indirect) • Expediting costs • Cost for each group/section • Tooling cost • Equipment cost

Category	Sub-indicators
Schedule	<ul style="list-style-type: none"> • Percentage of meeting schedule start and complete dates • Productivity measured by estimated hours vs. actual hours • Meeting system and turnover dates • Vendors meeting commitment dates • Meeting modular components and fabrication schedule dates • Meeting attendance targets
Quality	<ul style="list-style-type: none"> • Field inspection acceptance percentages • Rework amounts, in time and dollars • Scope changes • Field changes • Incident reports
Productivity	<ul style="list-style-type: none"> • Unit rates • Direct work percentages • Loss time activities • Overtime
Quality of work life	<ul style="list-style-type: none"> • Turnover rate and cost • Dollar return of work improvement team's recommendations
Safety	<ul style="list-style-type: none"> • Lost-time accidents • Near-miss accidents • Medical cases

Result of the PI process

The PI process results in a pyramid of information crucial to project operations. This pyramid provides the core information necessary to manage the project. Regardless of the management level, this basic core information should be used to ensure goals and objectives are standard throughout the organization.

Compensation tools for vendor contracts

Target indicators are used to monitor and administer vendor contracts. Therefore, a set of common indicators that are consistent with project goals should be developed for vendor contracts. The most frequently used indicators are:

- Productivity
- Quality (amount of items accepted the first time)
- Safety

Each level of performance is awarded based on predetermined targets, so vendor goals should be set and integrated in the project planning process.

Increasing Productivity

Improving environment

Improving the workers' environment improves productivity. Productivity is affected by the working area's:

- Heat
- Humidity
- Lighting
- Congestion
- Cleanliness

A controlled, stable environment positively affects workers' productivity and the need for rework. Additionally, cleanliness may promote worker pride and limit rework.

Erection by area

Erecting all discipline commodities by area would:

- Improve housekeeping.
- Potentially reduce labor, because scaffolding would have to be erected only once.
- Allow Quality Control to provide dedicated support in one area, reducing time for inspections and signoffs.
- Familiarize construction engineers with limited work scope, so that completion details are not overlooked.

Commodities

Commodities must be installed correctly in proper locations. Erecting commodities correctly the first time will save manpower required to resolve any resulting erection problems.

Completing work in one shift

Benefits should be evaluated for completing assigned work in one shift. The evaluation should be based on overtime vs. the paperwork generated to finish partially completed tasks (e.g., weld rod tickets, preheat, QC) on the following day. Productivity could then be measured in units of length of weld per time unit.

Eliminating excuses for poor standards

Supervision should be responsible for eliminating excuses for not meeting standards (e.g., the welding machines not working properly). Supervisors would then be held accountable for their crews' work.

Communication

Why communication is essential

Effective methods of communication are very important and necessary, particularly across different organizations. Misunderstandings (e.g., differences in the intended use of, and specifics on tolerances) or lack of communication has hampered the construction process. Confusion has emerged when groups use varying terms, descriptions, and tracking mechanisms.

Field communications

Wireless telephones should be used for field communication during construction. Replace radio waves with infra-red waves to prevent activating plant equipment accidentally.

International problems and successes

Communication problems have been similar to those in domestic plants. Some successes with communications have occurred in international projects. One example is Tsuruga II workers' extensive use of headsets during construction.

Recommendations

Recommendation	Comment
Remember that effective communication throughout the project is essential.	
Make certain that design, construction, and operations organizations establish, and agree upon, an effective format for communication in the early project phases.	<ul style="list-style-type: none"> • This format should include consistency in: <ul style="list-style-type: none"> ○ Names ○ Descriptions ○ Tracking mechanisms of items • Key aspects of construction (e.g., <i>complete</i>, <i>rework</i>, and <i>inspect</i>) must also be clearly defined.
Before construction begins, have construction and operations organizations review the applicable design standards that will be used.	<ul style="list-style-type: none"> • This review ensures an overall understanding of actual requirements. • Design requirements need to be necessary and reasonably achievable. • Design documentation should also be reviewed to ensure reasonable, well-defined requirements exist. • These reviews should clearly define and communicate tolerances, so misinterpretations are minimized.
Use a grid system over the entire site as an effective way to communicate location, especially in the reactor building and yard area.	

Recommendation	Comment
Use a bar code system similar to those used in supermarkets to identify material for inventory and tracing, which benefits employees in receiving, warehousing, and inspection.	
Define boundaries and scope.	<ul style="list-style-type: none"> • Test boundaries and associated construction milestones must be established with consistency early in the project. • Defining boundaries and scope is important for: <ul style="list-style-type: none"> ◦ Issue dates of design information ◦ Layout of items requiring earlier installation
To help improve communication, use on-site engineering groups and train and cross-transfer personnel.	<ul style="list-style-type: none"> • Training can help individuals understand other areas and the needs of employees in those areas. • Cross-transferring—placing people in different areas—improves understanding among the various organizations.

Access Recommendations

Cranes

- Use more small, mobile cranes rather than a few larger, fixed cranes. (The industry has generally used a small number of large cranes on a project. These cranes are not as efficient as smaller cranes for handling light loads. Smaller cranes are also quicker and easier to maneuver.)
- Use polar cranes for construction lifts.
- Study crane use at Tsuruga II, where only one large, fixed crane was used. Numerous mobile cranes, available for use throughout the site, were used extensively.
- During construction planning, investigate making crane layout similar to the layout at Japan's Takahama 3 and 4.
- Use Lampson-type cranes for:
 - The containment vessel
 - NSSS erection
 - Containment line assembly
 - Free-standing containment assemblies
 - Dome assemblies
- Evaluate the cost benefits of assembling out-of-the-hole modules large enough to require Lampson cranes for placement. When this procedure is not cost-effective, size the structural modules for a standard tower crane.

Scaffolds

- Use lightweight metal decking, as was used at Tsuruga II, because it:
 - Can be handled by one worker.
 - Can be reused extensively.
 - Is part of a standardized design.

Production Tools

Ideas from craft personnel

Tools developed by craft personnel (e.g., socket-weld fit-up tools for 1/16" bottom-gap fitup jigs) can be used. Ideas should be obtained from craft personnel, as they may be the best source of information.

Tools

The electrical field also has many labor-intensive, specialized tools. Several tool innovations (e.g., cable-pulling and lugging machines) are in the "trouble-shooting" development phase.

Construction Tolerances

Suggested developments

To simplify the area of tolerances while allowing craft personnel additional leeway during construction, use well-defined tolerances that are effectively communicated and understood by the designer, constructor, and inspector.

International experiences

International nuclear construction projects have also had problems with tolerances. Some practices that have helped reduce problems include:

- Commitment to detailed plans.
- Use of standardization/replication.
- Lower overlap of civil/mechanical/electrical construction than found in domestic plants.

Caution

Construction tolerances have been a major contributor to rework and schedule delays. Craft personnel must communicate through their management the difficulties in areas in which tolerances are specified but cannot be practically achieved.

Design Change and Corrective Action

Suggestions

- Decision-making should be located on site (e.g., using an on-site engineering group).
- While the goal is to minimize change, craft personnel should have some flexibility to be as efficient as possible.
- The corrective action chosen must include evaluation of impacts on cost and schedule.

International experiences

Overall philosophy

- Implement when convenient.
- Consider the cost and schedule impacts.
- Attempt to maintain series uniformity when using standardization and replication.

Muelheim-Kaerlich: The project's turnkey nature facilitated a simplified process for design change. Minimal design changes were made because of the financial risks involved. One organization was responsible for a particular system or component, so changes were easier to handle.

Tsuruga II: The Japanese had a similar commitment to minimize design changes. When changes were made, this approach ensured that all aspects of the changes were considered.

Technology

Introduction

Innovations

The industry needs to review international ideas and innovations. Incentives for innovation in techniques and processes has declined in parallel to the U.S. nuclear industry. For construction technology to advance and equal the challenge of the future ALWR, international research must be tracked and reviewed for compatibility.

Using technological advances

New construction techniques have enhanced nuclear construction. Technological advances have lead to new tools that assist workers, and advances have been made in construction processes. Further developments will continue to enhance construction, so current developments in methods, tools, and processes for new approaches should be reviewed early in a project. International advances in construction techniques also warrant investigation. Construction specialists can be used to review current developments and pursue new innovations by working with:

- Educational institutes
- Technical societies
- Vendors
- International utilities and companies

Automation considerations

- Through developments in computer technology and robotics, automation has been used successfully in some applications.
- Automation can also contribute to future projects.
- An **integrated plant data base** is now a recommended practice because of current computer technology.
- Plant data bases have enhanced:
 - Design
 - Purchasing
 - Inventory
 - Tracking
- Potential applications of this data base include:
 - Definition of test and milestone boundaries
 - Bulk/system tracking
 - Detailed configuration and material control
- **Robotics:**
 - Is related to computer development.

- Can decrease time spent on certain construction tasks.
- Have been used to automate welding and rebar tying.
- Include successful uses such as tensioning machines, remote cameras, automatic welding, and rebar tying.
- Automation has been used successfully, especially in Japan. Robotics have been used in:
 - Fireproofing
 - Painting
 - Concrete finishing
 - Rebar installation

Structural

The concrete and rebar process

- Although advances in construction techniques have improved concrete work (e.g., using rebar cages, slip-forming, and jump-forming), the concrete and rebar process should be evaluated. For example, rebar cages may be suitable for modularization.
- Because rebar splicing has required significant resources, alternatives to rebar splicing and concrete forming should be investigated. One possibility is to use steel liners as formwork, such as in the refueling canal. (In this application, the liner would be sized to a thickness that ensures no external stiffeners are required.)
- Some organizations have successfully used expanded metal bulkheads (instead of wooden bulkheads) for forms, but others have returned to wooden bulkheads because of difficulties with metal bulkheads.
- Concrete pumps and conveyors have improved the pouring process.

Japanese practices

Japanese practices in concrete/rebar include using:

- Pumps to place concrete
- The same workers to place rebar and vibrate the concrete
- Multiple vibrators to prevent overheating

Though minor points, these practices have contributed to successes in placing and vibrating concrete.

Rebar congestion: Techniques used at Tsuruga II reduced concrete process time. The largest rebars available in Japan are 51 mm in diameter, compared to 57 mm in the United States. Although rebar congestion could have occurred easily, the care taken in planning, detailing, modeling, and placing the bars actually resulted in less congestion.

Job tool: At Tsuruga II, rebar was bent onsite using a job tool. The tool was fabricated as a single-function tool, although tools can usually be made for multiple functions. This fabrication allowed the tool to be safer and more easily handled.

Concrete placement: Concrete placement was another efficient process. Concrete was delivered by truck mixers from the site batch plant to placement locations, where pumps were used principally to place the concrete. Vibrators were handled by the same workers who placed the rebar, as these workers:

- Had the best idea of the rebar layout.
- Could maximize the vibration process with the least possibility of displacing rebars.

The Japanese used numerous vibrators to prevent overheating.

Welding

Introduction

The industry must recognize that welders are unique in their limited interactions with co-workers. A large amount of a welder's work week can be performed at a quality level with minimal interaction with other groups and management.

Compensation

Welding is the most skilled and specialized craft using conventional techniques—welders' compensation should be commensurate with this skill level. One possibility is basing pay scales on the welder's number of certifications. Additionally, a welders' union would allow workers to:

- Be more specialized.
- Concentrate their abilities in the field of welding.

Potential difficulties include:

- Incentive pay could affect quality, a primary consideration with any approach chosen.
- Pay based on certification could pose problems if an employee is over-certified for specific assignments.
- Troubles could exist with certifications that are not maintained and used through practical applications.

Entry-level requirements

For welders, entry-level requirements may need to be revisited. When needed for machine and automatic welding, machine operators should:

- Be drawn from a pool of trained machine welding operations.
- Not be expected to have extensive manual welding experiences.

Unqualified welders cannot be expected to run automatic equipment—it is much better to use welders with some skill levels. Entry-level qualifications should be parallel with anticipated work; in other words, welders should be more specialized instead of qualified for basic processes as they are now.

Welding Procedures

Standardizing procedures

To help standardize welding procedures:

- Use data bases to administer welding specifications and procedures during construction, reducing problems with selecting welding procedures during installation.
- For standard plants, employ standard procedures and specifications.
- As later projects develop, standardize specifications throughout the industry to:
 - Ensure consistency between vendors and installers.
 - Simplify enforcement to requirements.
 - Help multiple-contractor projects.
- Review, and possibly revise, codes (ASME Section IX).
- Standardize welding techniques to an even greater extent than current techniques.

Installation procedures

Installation and construction procedures should be well-written. To avoid confusion, installation procedures should avoid technical jargon. Ideally, these would be standardized installation procedures for all plants to be constructed.

Computerized welding procedures

As a starting point for future projects, previous sites' welding procedures should be reviewed. However, these reviews will probably be streamlined, because too many procedures currently exist. Computer technology may help in this area: a computerized system could help constructors efficiently access, revise, and maintain procedures. The system could also choose and assign a qualified procedure for a specific application.

Training and Certification

Encouraging certification

Certification is a very costly process for welders. As described in "Work Force," certification could even be a basis for workers' compensation. Qualifications and demonstrated welding proficiency could be used to segregate welders into nuclear and nonnuclear. Incentives (e.g., additional pay) can encourage welders to improve proficiency and upgrade classifications. To qualify for different processes, welders should show initiative. Rewards should be based on demonstrated proficiency.

Welder certification data base

Some discussion in the workshops centered around a "National Certification Tracking Program." This industry-wide data base could be:

- A list of welders' standardized certifications and last requalification.
- Recognized and accessible at any job at which the welder is employed.
- Advantageous but would also require drastic changes such as:
 - National standardization of certification guidelines
 - An extensive tracking program to ensure effective communications
 - Impacts on current code requirements
- Developed early, at locations in which a pool of certified welders is available before the nuclear industry is remobilized.

Certification program

An industry-wide training organization could be used to establish a standard welder certification program. Welders could then receive nationally recognized certification in various processes. Periodic requalification should also be required.

Quality

Minimizing concerns on weld quality

To minimize concerns on weld quality, welds performed in a "shop environment" should be maximized. Modularization supports this approach, as does effective on-site prefabrication. The design process can also reduce the number of required welds through the use of bends and efficient pipe routing. Welders could be required to stencil all of their welds to make them accountable for work quality. Another concern is with portable automatic welders, which tend to vibrate excessively when welding tubing.

Improving weld quality

To improve weld quality, use:

- A sampling approach to statistical controls to determine:
 - Difficulties for a particular process.
 - Places in which more or less quality attention (and inspection) may be needed.
- Established criteria for an acceptable rejection rate, based on class or importance to an item's safety.
- Pay incentives through a formula that encompasses both production and quality. (These incentives must be consistent and apply equally to production and quality.)
- Performance standards for supervision—base salaries on these standards.
- Reviews of code interpretations—don't always accept what is there.
- Assertiveness to challenge code committees.
- Selection of material, consumables, processes, and preheating to review and/or eliminate items such as post-weld heat treatment (PWHT).
- Preplaced inserts, with welder skills developed to break down inserts. (Proper fitting methods to ensure insert cleanliness, especially with carbon steel.)

Welding engineers

Degreed welding engineers—proven welding experts—should solve welding problems. Too many people assume **they** are experts, so using welding engineers in the field is highly beneficial.

Welding Equipment

Guidelines

Guideline	Result
For temporary equipment, use 8-pack welding machines.	<ul style="list-style-type: none">• Increased flexibility.• Reduced impact of equipment downtime.
Use purge dams.	<ul style="list-style-type: none">• Reduced purging times.• Elimination of problems with butt-welding stainless-steel pipes.
When practical, consider using specialty tools such as: <ul style="list-style-type: none">• Coupon cutting and bending tools• Individual vacuum pump suction pads for track alignment on stainless steel• Portable lightweight welding units	<ul style="list-style-type: none">• Reduced man-hours.

Pipe Fab Shop

Necessity of prefabrication

Prefabrication should be used extensively. Prefabricating pipe spools and support structural components has improved piping and support construction. Changes in regulations have complicated work in this area, so construction techniques still need to be improved.

Need

An on-site pipe fab shop is essential for flexibility, even though the amount of the shop's use is debatable. Decisions must be made on the amount of on-site fabrication vs. off-site prefabrication. Many workshop participants believe off-site prefabrication should be maximized.

Evaluating an on-site shop

As plans are formulated for the next site, constructors should evaluate the use of a pipe fab shop based on:

- Cost
- Shipping capabilities
- Schedule impacts
- Administrative control

Possible applications

- Piping preassembly
- Support structural components
- Pipe bending
- Perform valve welding
- Fabricated tubing racks
- Making module connections
- Better, safer use of automatic equipment

Note: A lack of N-Stamp vendors would necessitate more on-site prefabrication.

Pipe Bending

Recommendations

- Install piping and associated hangers simultaneously to reduce effort in installing and removing temporary support. This installation is easily achievable though early design completion.
- Carefully arrange the site fab shop to maximize productivity and material flow through the shop.
- Whenever possible, prefabricate pipe hangers in the site fab shop.

Considerations

- Pipe and support installation should be coordinated to minimize past problems with rework and pipe removal for hanger installation. Modularization and early design completion should help alleviate these problems.

Pipe Installation

Installing piping and restraints

A concerted effort is needed to better coordinate installation of piping and associated restraints. In many situations, installed piping had to be removed to install the support and nearby associated components. If the modular approach is adopted, both piping and supports should be part of the module.

Suggestions for piping and supports

- Pipe support installation programs such as "tack in place" and "red line" should be investigated for advantages, including:
 - Preliminary installations allowing workers to reserve space.
 - Intermediate inspections.
 - Design changes marked on field documents to avoid time studying corrective documentation.
- As examples of successful support installation techniques, these programs have:
 - Fixed minor problems without time-consuming corrective documentation. In the tack-in-place/weld-in-place (TIP-WIP) program at Braidwood, engineering approved changes in the field, then craft personnel erected supports before an interference occurred. Braidwood's program began with small-bore piping supports and was expanded into electrical and structural areas.
 - Had disadvantages which include the potential for reduced design control.

Power Sources

Providing sufficient power supply

The designer must provide a dependable and adequate power supply throughout the entire plant, considering the power sources' locations during design.

Note: Construction must provide the majority of input on this topic to ensure the design is sufficient.

Power and grounding systems

Permanent plant power and grounding lines:

- Should be installed during construction to eliminate stray grounding associated with welding.
- Must be strategically placed to aid construction activities.
- Can be used for repair operations when the plant is operational.
(Maintenance personnel often must "pull" too much temporary power.)

Evaluate crimped (rather than fused) grounding wire splice. Fused splice appears to require more labor.

Construction Techniques

Electronic components

- When using more sensitive electronic components, make certain climate control and housekeeping are improved during construction.

Trains

- Find ways to identify different trains (e.g., painted armor or color-coded jackets on cable).

Cable pulling

- Standardize cable specifications so that all vendors are working with the same guidelines. This standardization will avoid having different requirements (bend radius and pull tension) for different cable suppliers. Nuclear-grade cable is not required, but each vendor should produce cable meeting a minimum set of criteria.
- Establish industry standards for cable-pulling tension loads. The utilities and A/Es need to force vendors to reevaluate their conservative allowances for sidewall pressure on cable. A recent EPRI study shows a higher tensile strength could be used.
- Use pull strings to ensure that pulling tension is not exceeded.
- Identify pulling tension and bend radius that can be maintained in the field—don't use the cable vendors' conservative estimates.
- Use pulling cable devices to facilitate power cable installation.
- Use the computer to identify cables with similar routes, then pull those cables simultaneously. This step eliminates craft set-up time.
- Improvements are needed to reduce the amount of work required for pulling cable. Technology for this cumbersome task has changed very little since the 1970s.

Marshalling

- Consider marshalling (installing multiple cables in many locations to allow for unidentified terminations) only as a last resort, to remedy poor or incomplete design. Although marshalling allows early cable installation, it also causes a mixture of circuits in the same cable.

HISTORICAL SKILL REQUIREMENTS

CRAFT SKILL	AVERAGE BY YEAR				
	1	2	3	4	5
Brick Layer	50	30	30	30	10
Carpenter	700	900	600	400	200
Cement Mason	35	50	30	30	20
Operating Engineer (Crane Operator)	80	100	90	80	50
Boilermaker (including Millwrights)	200	900	1500	1800	900
Welder	200	700	800	850	400
Electrician	80	400	500	700	400
Painter	60	130	130	150	180
Ironworker	190	250	250	250	150
Truck Driver	10	10	12	20	10
Laborers	400	500	500	500	200
First-line Supervisor (Craft)	200	300	300	500	300
Craft Managers	30	40	40	60	40
TOTALS	2235	4310	4782	5370	2860

Site Support Group Ratio to Craftspeople (Less Supervision & Management)

Engineering Technicians	1:18
Project Planning & Control	1:40
Materials & Equipment	1:25
Human Resources Personnel	1:50
QA/QC	1:40

Total Support Ratio 1:6
(Excludes Supervision & Management)

FIGURE 3-1

PERFORMANCE INDICATOR CYCLE

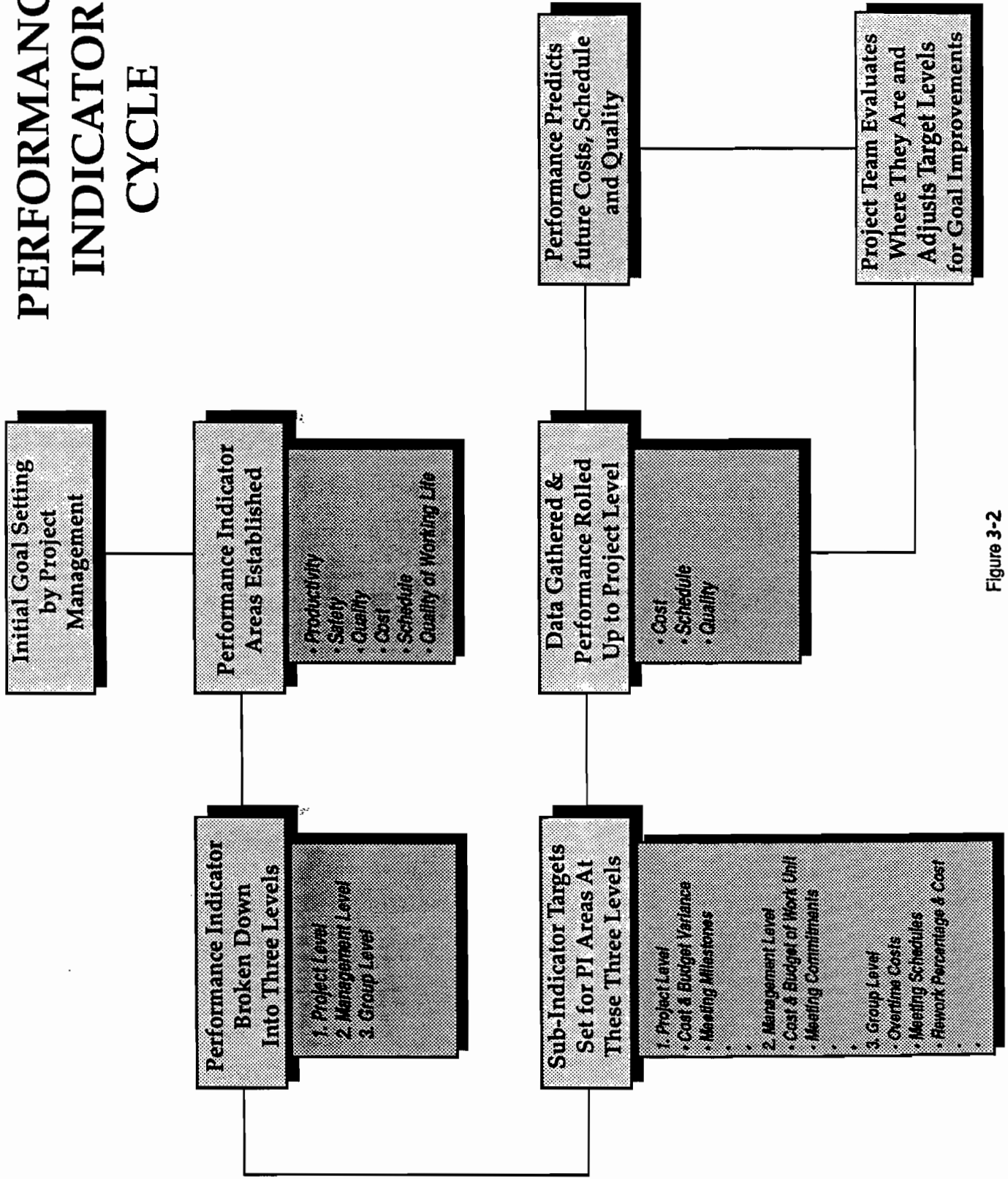


Figure 3-2

Appendix A. Requirements for an Information Management System

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FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

1 INTRODUCTION

1.1 BACKGROUND

It is anticipated that the design of the Advanced Light Water Reactor (ALWR) will rely heavily on computers. In the future, it is likely that all information necessary to design, build, and operate the plant will be recorded on machine-readable media.

In the past, when the plant design was completed and turned over to construction and operations, the information necessary was in the form of hard-copy documents. It is recognized that there would be considerable benefit in both construction and operation if this information were in the form of a computerized and usable technical data base.

Because it is expected that the ALWR Plant Designers (AE, NSSS supplier, etc.) will be using some form of computer-aided engineering in the design process, it follows that a suitable computerized technical data base should be readily available. Unfortunately, many of the systems routinely used by these designers are stand-alone systems, the output of which are diverse and do not communicate. Therefore, it is unlikely that they will meet the needs of the utility over the life cycle of the plant unless these efforts are guided by a common set of requirements and integrated in what is referred to here as an **information management system (IMS)**.

In order to fulfill the electric utility need for an integrated technical data base which can be utilized throughout the life cycle of the plant, the IMS requires a comprehensive plant data model. The definition and guidelines for the development of such a model are provided in EPRI Report NP-5159, *Guidelines for Specifying Integrated Computer-Aided Engineering Applications for Electric Power Plants*. This document defines the activities, entities, attributes, and relationships of the plant data model to be utilized in the development of the IMS.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

Requirement

Rationale

1.2 PURPOSE

The purpose of this document is to provide a definition of the functional requirements for a cost effective, state of the art, and fully integrated **information management system (IMS)** for use in the design of the ALWR and to define how the system is transformed from a design tool to a construction tool and, finally, to an operational tool for the plant owner.

The document is intended to provide direction to the Plant Designer. Emphasis is placed on what the system is expected to do, i.e., performance requirements, rather than on a complete system definition suitable for procurement. It is expected that the Plant Designer will develop more detailed hardware and software specifications and procedures, based on these requirements, as necessary.

PURPOSE

The requirements are considered to be the minimum required to meet ALWR program objectives for improved constructibility and technology expected to be available at the time of application. Depending on timing and advances in that technology, some adjustment in requirements and features as described herein may be appropriate at the time of application.

The term "Plant Designer" is used as a shorthand means of describing the entity responsible for the ALWR plant design. It includes the functions generally provided by both an NSS supplier and an Architect Engineer (AE) and could its corporation with time. Since the Plant Designer is the initiator and integrator of the plant design, it follows that the Plant Designer is in the best position to develop and manage during the design phase of the IMS.

It is assumed that some provision will have been made regarding utility/owner/constructor participation during the design of the ALWR standard plant and expanded when the design is applied to a specific site. This participation is necessary to ensure that decisions made at the beginning of the project adequately consider the performance and usefulness of the IMS throughout the life of the plant. These include considerations such as initial size, characteristics and planned growth of hardware and software, and the approach taken to security and data integrity.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

Requirement

Rationale

1.3 OBJECTIVES OF THE IMS

OBJECTIVES OF THE IMS

1.3.1 The Plant Designer shall utilize appropriate computer hardware and software to establish, manage, and operate an information management system (IMS) during the design process and provide for turnover of the IMS to the Utility for use during construction and operation.

Development of a computerized technical data base which is vitally needed for successful ALWR construction and operation must begin early in the design process.

1.3.2 The main objectives of the IMS are as follows:

- To make maximum use of computer aided design and engineering during design and construction, and after the plant is turned over to the operator.
- To provide for efficient implementation of the PIN, as described in Section 11.7.
- To utilize the computer in configuration management.
- To provide via a computer a means to acquire, store, retrieve and manipulate the data necessary to construct, start up, operator, and maintain the plant.
- To assure that information needed by construction and operations is in the computer and available when the plant is turned over to the owner.

- Early planning and integration of IMS with computer aided design and engineering will maximize benefits to all users.
- The PIN cannot be effectively implemented without the computer technology of the IMS.

- Traceability and change control are two of the areas where the IMS will be very beneficial.

- Efficient use of the vast amount of the available technical data requires extensive use of computers.

- Constructors and operators have a strong need for computer aids and a computerized technical data base to assist their work.

1.3.3 At the time of plant purchase, the Plant Designer shall make the IMS available for joint use by the constructor and the utility during construction. At an appropriate time before plant turnover, the Plant Designer shall turn over to the utility an operating IMS containing all data necessary for operation and maintenance of the plant.

The technical data base and the computer capabilities of the IMS must be available to the constructor and utility for successful management of the project.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

Requirement

Rationale

1.3.4 A project information network which meets the objectives of EPRI NP-5159, *Guidelines for Specifying Integrated Computer-Aided Engineering (CAE) Applications for Electric Power Plants*, shall be established which defines the activities, entities, attributes, and relationships for the total plant cycle. This network is to be utilized by all ALWR plant design participants in organizing and identifying the products of the design process effort.

The referenced EPRI document is the result of an industry-wide effort to develop a standard approach to utilizing CAE in formulating a system structure and a project information network (PIN). The PIN methodology provides for a systematic organization of the technical data, taking advantage of available CAE design processes to build a technical data base which can be utilized in many ways through the life cycle of the plant. It is the basis for the information management system described in Section 11.12.

The project information network (PIN) shall provide the following:

- A logical segmentation of the ALWR plant design into a number of systems and system groups.
- A plant data model which serves as a framework for the plant technical data base.
- A systematic method for entering the information into the technical data base.
- A systematic method for organizing data for retrieval.
- A standard identification approach for systems, equipment, components, and facilities as well as all documentation.
- A logical design structure is absolutely necessary in planning and organizing work activities and design products.
- A plant data model is necessary in order to provide for logical, uniform identification and use of data.
- Computerization of the design process and generation of the technical data base must be based on systematic and logical rules to facilitate automation and to assure consistency and reliability.
- Attention must be given in developing the PIN to this key activity; the value of a data base is often keyed to retrievability of information by the user.
- The PIN and plant data model provide for a logical identification system.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

Requirement

- A technical data base from which — through the information management system described in the following section — the user can obtain data (i.e., system and equipment attributes) as well as documents, directly, via the computer.
- Provide, to the extent practical, a single official source of all technical data.

Rationale

- Direct access to data, coupled with the ability to manipulate that data (as provided by the IMS) gives the users (i.e., designers, constructors, operators) a powerful tool. This method is much more efficient than extracting the information from documents. The extent to which this can be accomplished has a strong bearing on the value of the technical data base.
- This should be considered a very desirable objective. It requires that data which appears in several documents be keyed in some manner to identify which is "official"; this may be accomplished through the relationships between entities and attributes which is a key part of the PIN development.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

1.4 SCOPE AND ORGANIZATION OF THIS DOCUMENT

The scope and organization of the IMS requirements document is as follows:

- Section 1 provides background, objectives, and relations to other ALWR requirements.
- Section 2 defines responsibilities for the IMS.
- Section 3 describes use of the project information network (PIN) in developing the IMS.
- Section 4 defines the functional elements to be provided in the operating IMS.
- Section 5 specifies requirements to be followed in generating the IMS technical data and operating features to be included in the system.
- Exhibit A provides a description of typical software packages for computer-aided engineering and data management currently available in the industry. It is provided for better understanding of the requirements and is not intended itself to be a requirement.
- Exhibit B describes one possible approach which may be taken by the Plant Designer in dealing with the likely problem of diverse computer systems being utilized by various design team participants.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

2 RESPONSIBILITIES FOR THE IMS

The Plant Designer is responsible for the development of the IMS and for the generation of the technical data base during the design process. (The Plant Designer is intended to represent the entity having responsibility for development and completion of the design. It is recognized that, in reality, the plant design will be performed by more than one organization; however it is intended that the effort be managed by a singular, integrated process.)

The Plant Designer shall include in the IMS, in the appropriate form and format, information generated by other project participants which is required to be in the data base.

The Plant Designer shall provide the technical data base and the IMS hardware and software needed by the constructor and operator of the plant. Further definition of the timing of this turnover and the scope of hardware, software, and training to be provided is given in Section 4.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

3 PREPARING THE IMS SPECIFICATION

The Plant Designer shall prepare a specification for the IMS which integrates the requirements of this document and additional requirements as necessary to produce a system which can efficiently meet the stated objectives.

EPRI NP-5159M, *Guidelines for Specifying Integrated Computer-Aided Engineering Applications for Electric Power Plants*, shall be used by the Plant Designer as a guide in preparing the IMS specification. The specification shall be based on the project information network (PIN) prepared by the Plant Designer for the ALWR.

The PIN shall contain the following major components (see EPRI NP-5159M for further description):

- **Activity List:** A list and short description of all activities occurring throughout the life cycle of the plant.
- **Activity Documentation Package:** A package for each activity utilized in the design process which contains the activity scope, major data items, interfaces to other activities, and a data model for the activity.
- **Plant Data Model:** A compilation of all data models into one comprehensive model of plant data. It includes a list of all data names and definitions and the relationship among the data.

In developing a specific ALWR PIN and plant data model, the Plant Designer shall include specific ALWR requirements for the design process and shall be consistent with the ALWR plant design and scope. The former includes requirements for a plant system structure, standardized identification of components and documents, and configuration control. The PIN and plant data model, as described in the EPRI document, shall be modified as required, which will necessitate adding, deleting, and changing activities, entities, attributes, and relationships to suit the ALWR.

The ALWR plant data model shall be integrated into the software packages required to carry out the functions described; all data produced as part of the IMS shall be consistent with this model.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

4 FUNCTIONAL ELEMENTS OF THE IMS

This section describes a minimum set of fully functional modules that shall be a part of the IMS during the design process and that shall be available to the plant owner during the construction and operational phases of the plant life.

4.1 INFORMATION PROCESSING AND CONTROL

All information is processed and controlled through the application of special purpose software. For this purpose, a Data Management Software Module (DMSM) or its equivalent shall provide access methods which permit integration of the various IMS system functions, and engineering and design packages or modules as well as the functional aids, described in the following paragraphs. The method selected to meet these requirements shall include provisions for the addition of new functions, packages or modules, as they become available. Software modules shall include a single executive control which provides graphic or keyboard access to any IMS function, package, or module. Search, retrieval, and linking capability shall include rule base and induction, i.e., not limited to keyword searches. (See explanation below.)

In addition, the software modules shall have provisions for access and security (including multiple level access codes), messaging, back-up and recovery, archiving and restoring and system administration.

The DMSM software package shall be designed to centralize, manage, and secure design project data within a mainframe environment. The DMSM must include the ability to store and retrieve a large number of files and drawings, authorize data access, ensure project security, issue project status messages, and manage databases. The DMSM software must also provide comprehensive revision and release control, change-order tracking, definition of user tables, and the ability to view CAE-CAD graphics on mainframe terminals or work stations.

The DMSM shall enable CAE-CAD operators to transfer components and drawings to and from the mainframe environment with simple commands. The DMSM shall be coupled to CAE-CAD software so that data transfer occurs automatically. The DMSM shall also accommodate data other than CAE-CAD data, such as information important to project management, licensing, construction and maintenance functions.

The DMSM shall provide for user definition of information blocks with assignments of responsibility for each block. The user shall be able to assign entities, attributes and relationships to any component in the NPP, as defined in Section 3.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

Explanation and Reason

One of the most important software packages in the proposed IMS is the DMSM. It is this software that provides the framework to record, search, retrieve, and organize the large variety and diversity of information required for its useful application by the user.

The DMSM is typically a data management tool that provides centralized control of design project data bases, providing for data integrity by pre-venting unauthorized access to files and providing drawing revision and release control. The intent of a DMSM is to accommodate large, complex projects, allowing users to integrate and manage the entire project process. Such software modules are typically designed for a generic project process not specifically for the NPP design, construction, and operation. In the current technology, this results in a considerable effort being required to include the entities, attributes, relationships, and special features for quality control, security, etc. required specifically for the NPP.

Search, retrieval, and linking is an important function of the DMSM. In the past, searches were performed utilizing "keywords", a method that simply finds a user specified word or combination of words within a text. If the text is very large or the subject is complex, this method is very inefficient and time-consuming for the user. A much better method is a rule-based system with inductive reasoning capability. A rule-based program or system is one that uses a set of rules to draw conclusions, make decisions, and solve problems. In Artificial Intelligence (AI), it is a two-part direction consisting of a condition and a consequent action. For example, an IF-THEN rule states that if a given condition is true, then a specification should be taken. Also utilized in AI is an inductive shell which allows the building of an expert system by entering knowledge as examples in a matrix. The shell induces rules that are used in reasoning. Programs applying these principals have been applied with considerable success.

Currently there is no software module, or combination of modules, that satisfies the full intent of all provisions in this document. However, some software packages provide the basic framework for most of the required features. A generic outline of what may be expected from a typical software package is outlined in Exhibit A.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

4.2 ENGINEERING AND DESIGN FUNCTIONS

The requirements specified for the engineering and design functions of the IMS are organized in two parts. The basic general requirements are characterized as either non-dimensional or dimensional with requirements for special purpose discipline related functions provided separately. The requirements are outlined in greater detail in Exhibit A.

4.2.1 General Requirements

The IMS software shall include the capability to produce documentation as well as standard non-dimensional drawings such as Piping and Instrument Diagrams, Electrical Elementaries, etc. A complete symbol library shall be included. This type of design activity shall be automatically linked to all other information sets in the IMS including the 2-D and 3-D design models.

- 4.2.1.2 A thoroughly tested 2-D-CAD package shall be provided as part of the IMS. The package shall include, as a minimum, provisions for the interactive production of orthographic projections. The system shall provide for automatic transfer and update of information entered in 2-D models to all other information sets in the IMS including 3-D models. The system shall be capable of maintaining a complete library of equipment outline drawings with associated attributes and relationships.
- 4.2.1.3 A family of thoroughly tested 3-D-CAD packages shall be provided as part of the IMS. The packages shall include provisions for the interactive production of three-dimensional designs, as a minimum, in the engineering disciplines described in Section 4.2.2. This includes complete unambiguous 3-D solid modeling capability.
- 4.2.1.4 The full text of the basis for each design information set, together with detail engineering analysis, shall be included in the IMS with appropriate coding to permit document search, retrieval and linking. Only thoroughly proven and verified computer software may be included in the IMS. The IMS is a production tool and shall not be used for computer code development or experimentation. Software that performs analysis by automatically obtaining input information from the IMS and automatically transferring output to the IMS may only be applied if fully developed and tested outside the environment of the IMS and prior approval is obtained from the Utility. In addition, the output of such programs must undergo the same review approval process as computer-aided engineering utilizing manual input.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

The system shall provide for automatic transfer and update of information entered in the 3-D-model to all other information sets in the IMS including the 2-D-CAD model. The system shall be capable of maintaining a complete library of purchased equipment outline drawings with associated attributes and relationships and a complete library of standard components utilized by that discipline.

- 4.2.1.5** The system shall be capable of automatic generation of separate (within a discipline) or composite (one or more disciplines) multi-color CRT display or multi-color hard copy drawings of the following engineering discipline activities. Automatic interference checking shall be provided as part of each package. CAD-CAE Graphics shall include tools for manipulating graphics such as copying, mirroring, trimming, stretching, dynamic translation, and rotation; comprehensive text and line fonts; use-definable parameters for tasks such as Inserting basic geometry ; entity and layer discrimination; intelligent graphics figure files for geometry construction; and tools for user-definable tablet and dynamic menus. The software shall also include provisions to format CAD-CAE data to Initial Graphics Exchange Specification (IGES) standards and to accept non-CAD-CAE databases presented in IGES formats.
- 4.2.1.6** All Engineering packages shall include provisions that permit designs to be entered initially as wire-frame models or as 3-D solid models. Double line representations shall be automatically generated from wire frame or 3-D solid information. The 3-D representation shall provide the users with the ability to visualize the work in each discipline in relation to other disciplines. For example, HVAC ducting relative to structural, electrical, piping, and architectural. In addition, an interference Checking package shall automatically search for hard and soft interferences between the various disciplines.
- 4.2.1.7** Each Engineering package must be capable of utilization by operations for plant walkdowns, by construction specialists to optimize construction sequence, and by operations for evaluation of operation and maintenance.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

4.2.2 Engineering Packages

The following sections provide brief descriptions of the function of each Engineering package. Each package shall be linked to a single database that includes entities, attributes and relationships defined in the PIN. (See Section 3.)

A more complete description of each package is given in Exhibit A.

The requirement (Section 4.2.1) for including the basis of each design together with the corresponding analysis in the IMS is a necessary element in maintaining control of the configuration throughout the life of the project.

4.2.2.1 The Site Engineering Package

The Site Engineering package shall provide the civil engineer, geologist, and cartographer with tools to integrate the modeling, visualization, calculations, and drawings associated with site-work. It shall automate multiple applications including: site-work, roads, utilities, grading, and embankments.

The package shall support collection and processing of survey data for the creation of three-dimensional Digital Terrain Models (DTM). The DTM shall enable automatic generation of contour maps, profiles, and cross sections, as well as output of area, tabulated earthwork volumes, and related calculations. The package shall enable the user to simultaneously view several portions or layers of a map at different scales, perspectives, and from user-defined locations.

4.2.2.2 The Architectural Package

The package shall include provisions for Architectural design and documentation, including 2-D architectural layout, 3-D modeling, and detailing. The package shall include the capability to produce plan drawings in all formats and detail required, at any scale, throughout the design process. The database structure shall include automatic generation of door and room finish schedules. The Architecture package shall be integrated with all other application packages.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

4.2.2.3 The Structural Engineering Package

The Structural Engineering package shall enable the user to assemble structural elements to build frames, trusses, platforms, etc. The module shall also include specification tables, parts libraries, and parameter files of standard and non-standard structural shapes. The user shall be able to create all types of structural drawings including concrete reinforcing drawings, framing plans and erection drawings. In addition, the package shall enable the user to generate material take-off reports automatically.

The Structural Engineering package shall be fully integrated with CAD- CAE design, drafting, and modeling packages. The user shall be able to interrelate various disciplines on the same model with automatic interference detection among all components.

4.2.2.4 The Mechanical Engineering Package

The Mechanical Engineering package shall include, as a minimum, CAD- CAE software that automates the design and analysis of mechanical equipment, plumbing, and Heating Ventilating, and Air Conditioning (HVAC) systems. The package shall provide engineers and designers with tools to create, modify, and analyze mechanical systems and to generate related documentation.

The HVAC module shall provide the tools for determining the thermal profile of a building. From this information, the module shall enable the user to select, size, and route ductwork and insert fittings. A library of commonly used components shall also be included.

The package shall permit designs to be initially entered as wire-frame models or as 3-D solid models. Double line representations shall be automatically generated from wire frame or 3-D solid model information. The 3-D representation shall provide the user with the capability to visualize HVAC designs in relation to all other systems. Examples are, structural, electrical, piping, and architectural. In addition, interference checking shall be automatic with provision for searches to locate hard and soft interferences between various construction disciplines.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

4.2.2.5 The Piping Design Package

The package shall enable piping engineers to create 3-D piping and equipment models that conform automatically to predefined project specifications. Information from the model shall be linked to all production documentation. Insulation requirements, isometric drawings, support restraints and welding details along with welding program information shall be included in the package.

The package shall include a complete collection of symbol libraries, master catalogs of standard components, etc., organized to produce customized piping specification files that, once established, require minimal input from the user. The specification files shall serve as "built-in" design rules during the modeling process. They shall enable automatic component selection and design rules checking to assist in ensuring that the users completed model includes only project-acceptable components.

The package shall enable the user to merge piping and equipment models with designs from all other engineering disciplines, including civil, electrical, and mechanical. This provision shall enable project-wide interference checking to be performed.

4.2.2.6 The Electrical and Instrumentation Engineering Package

The Electrical Engineering package shall include software modules to enable the user to automatically create loop diagrams, one- and three-line Motor Control Center (MCC) diagrams, and Control Wiring Diagrams (CWD) from Piping and Instrument Diagrams (P & ID's) data files created manually or with the Piping package described above. The Electrical Engineering package shall provide, as a minimum, applications modules that permit the user to: produce one- and three-line diagrams automatically based on minimum interactive input by the user, enable the user to generate loop diagrams automatically from a P & ID data file, and provisions for the user to generate drafts, append annotations, cross-reference CWDs and generate wire list reports.

Standard libraries of electrical component and motor control center symbols shall be provided.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

Explanation and Reason:

The CAE packages described above have been limited to currently available computer programs that include the most expensive and human resource intensive elements of the design and construction process. Generally these areas are, civil structural design, piping design, electrical wiring design, HVAC ducting and the related space allocation and configuration control.

It is certain that new, very useful software packages will become available as the NPP is designed and constructed. The ease or difficulty associated with integrating new software as it becomes available will be, to a large extent, dependent on the flexibility of the DMSM, the selection of the operation system and other factors. For this reason, a "flexibility requirement" cannot be precisely defined with a functional definition. (See Section 5.3.)

In addition, there are already many very useful computer codes available for micro-computers that may be desirable for increasing individual productivity. However, it is suggested that generally such programs should not be included in the IMS and should not be interactive with the IMS. Those that are selected will require rigorous verification prior to their application within the IMS.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

4.3 FUNCTIONAL AIDS

4.3.1 Project Control Functions

4.3.1.1 The following is a list of project control functions that, as a minimum, the IMS shall be designed to store, retrieve, manipulate and organize in the form and format required by the user.

- Project Design Documentation;
- Project Change Management;
- Project Material Management;
- Regulatory Requirements;
- Regulatory Documents (PSAR, FSAR and Regulatory Submittals and Responses);
- Equipment Purchase Specifications;
- Equipment Delivery Schedules;
- Equipment Receiving Inspection, Storage and Maintenance Records;
- Project Status Reports;
- Master Integrated Schedules (Engineering, Construction, Startup);
- Critical Path Analysis;
- Manpower Loading;
- Quality Assurance and Quality Inspection Plans and Records;
- Master Document Control File (Drawing, Specification, etc., Release Information);
- Cost and Schedule Analysis;
- Construction logistics and construction sequence;
- Boundary Interface Packages for System completion and startup;
- Documentation required for operation and maintenance;
- Vendor supplied information including maintenance manuals;
- Documents from sources external to the Plant Designers' IMS;
- Documents to sources external to the Plant Designer;
- Revision/Release Coding or Security Codes of employees; listing.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

4.3.1.2 Any application software may be used for the functions listed above, provided it meets the following criteria.

- The software is fully consistent with the functional requirements of the DMSM.
- The software file structure is such that it may be made fully interactive with all other software used on the project.
- The software is not duplicated. That is, only one package for one purpose may be used at any point in time.
- The software can be incorporated in the PIN plant data model.

Explanation and Reason:

As documents are generated, the DMSM provides the means to process and control the information as it is generated by the computer or entered in the computer. Specific software packages provide the organization and form of the information desired by the user. There are many software packages that will satisfy the overall needs of the project and the selection of a specific software package is largely subjective. For these reasons, the selection of software should be largely to the discretion of the user, provided it follows the stated requirements criteria.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

4.3.2 The Construction Functions

Early in the design phase of the NPP, the Plant Designer shall establish IMS files and access codes to permit Construction Specialists to optimize the construction sequence. For this purpose, the system shall be capable of producing and rotating a 3-D shaded plant model or wire frame model (with or without hidden lines) with any part of the structure displayed or any combination of equipment shown. It shall also be capable of displaying a user-selected construction step in a 3-D shaded model with clearances displayed. In addition, the system shall be capable of producing 3-D shaded or wire frame models of a sequence of operations that display user selected equipment placement routing or user-selected construction steps. This shall be a fully automated dynamic display. Bulk material quantities shall be automatically tabulated and displayed for each step in the construction sequence.

The IMS shall include work packages. The Plant Designer shall define and provide the contents of each work package as recommended by the Constructor. As a minimum, the work package shall include all information required to perform the task, all required inspections and tests, a schedule, a precise definition of completion, the mechanism for acceptance and turnover and the means for the Constructor to enter information in the IMS. When approved, the Constructor shall obtain all necessary information to perform the task from a "read only static" file contained in the IMS. As the work progresses, the Constructor shall enter in a "hold for approval file" all predefined information necessary to execute and track completion of the task. When all acceptance criteria are satisfied, the "hold for approval file" will be automatically transferred to a "read only static file" at the next IMS update. (See Section 14.)

Local work stations and peripheral equipment shall be provided to permit the Constructor to enter and retrieve information from CRT displays and to produce hard copy of documents. The Plant Designer shall update the IMS, as the plant is being built, to reflect the actual as-built condition. At the time of plant turnover, the Plant Designer shall assure the Utility that IMS is a complete as-built record set. All field installed equipment, such as small bore pipe and instrument lines, shall be included in the IMS by the Plant Designer.

The Plant designer shall enter in the IMS purchased equipment delivery schedules and all storage, installation and lay-up requirements from the manufacturer of the equipment prior to the receipt of the equipment. Receiving inspection, storage location and periodic inspections of the condition of the equipment shall be included in the IMS as the equipment is received on the site. For equipment important to safety, equipment qualification records and required maintenance shall be entered in the IMS as part of the receiving inspection process. Also, inspection records of bulk materials shall be entered in the IMS at the time the material is delivered to the site.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

Explanation and Reason:

The intent of the first paragraph is to furnish the means to integrate the Construction Specialist in the design process as early as possible. As the design progresses, the Construction Specialist can experiment with a variety of construction techniques and actually view the computer model of the building as it progresses through the various phases of construction. Where there are design options, the Construction Specialist can recommend to the Plant Designer the best option from the constructability standpoint. This process will result in design improvements that are more easily constructed and, as a result of the CAE-CAD system, can be readily incorporated in the design as it progresses, prior to start of construction. The provision for tabulating bulk material quantities permits an assessment of the logistics of the construction process as the design is developed.

The second paragraph deals with a major cost factor in past nuclear power plant projects, which has been design changes during construction. Since CAE-CAD systems permit relatively inexpensive exploratory designs that can be reviewed by construction experts as the design progresses, and since the process will support a much more complete design prior to start of construction, the number of revisions required during construction will be significantly reduced. An additional advantage of the IMS is, at the time of turnover, there should be very little additional work to assure the IMS describes the plant as it is actually constructed. As construction progresses and the computer models and related information are verified to be "AS-BUILT" the file is transferred to a static read only-record file (see Section 14). This provision is essential to minimize the cost of future changes to the plant, to provide information to operation and maintenance and for management to maintain configuration control.

The third paragraph deals with the logistics of materials and equipment and processing, storage and retrieving related records, which is a major cost and schedule factor in the construction and operation of the NPP.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

4.3.3 The Operations Function

Early in the design phase of the NPP, the Plant Designer shall establish IMS files and access codes to permit Utility Operations Specialists to review and comment on the plant design from the operational standpoint, as the design evolves. The system features for operation specialists shall be the same as those described in Section 6.1 for Construction Specialists.

The Plant Designer shall also establish IMS files and access codes to assist operations personnel in the operation of the NPP. For this purpose, the IMS shall include provisions to maintain dated information blocks for the operation of the NPP. The information blocks shall be under control of specified individuals and be linked to the design information. All documents shall be stored in full text mixed media mode and searchable in full text format.

The IMS shall include, as a minimum, the following information:

- Technical Specifications;
- In-service inspection requirements and schedules;
- PSAR, FSAR, SAR and reports and commitments to regulating agencies;
- Operating history (Trips, load rejection, etc);
- Outage plans and outage records;
- Refueling plans, operations and records;
- Plant operating procedures;
- Initial core configuration and subsequent core changes;
- Records of fuel location;
- Life cycle of safety related components.

Explanation and Reason

By involving the Operation Specialists early in the design process together with other provisions in this document, most of the information needed by operations will be in the IMS at the time the NPP is turned over to the utility for operation. The requirements above are intended to provide the special additional information needed for operations. This is primarily related to operational requirements and licensing records, reports and related documentation.

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4.3.4 The Maintenance Function

Early in the design phase of the NPP, the Plant Designer shall establish IMS files and access codes to permit Utility Maintenance Specialists to review and comment on the plant design from the maintenance standpoint, as the design evolves. The system features for Maintenance specialists shall be the same as those described in Section 6.1 for Construction Specialists.

The Plant Designer shall enter in the IMS all maintenance requirements together with the recommended maintenance and/or replacement schedules for each piece of equipment for pre-operation storage as well as operation. Maintenance requirements shall include step by step instructions utilizing 3-D shaded graphics with provisions for records of maintenance, inspections and verification testing.

The Plant Designer shall include provisions in the IMS for the following records:

- Maintenance test requirements and defined measurements together with the provision for automatic production of test reports in a standard format;
- Maintenance history of all equipment;
- Complete maintenance instructions for all equipment including 3-D displays where appropriate;
- Equipment environmental qualification records and records of the actual environment of equipment throughout the life of the NPP;
- Radiation status throughout the facility;
- Radiation exposure records of personnel;
- The design basis and design requirements for all equipment and systems in the NPP;
- Training records;
- Spare part requirements, spares inventory, critical item lead time.

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Explanation and Reason:

Most of the information needed for NPP maintenance is closely related to information generated during design and construction. This information will be in the IMS at the time the NPP is turned over to the utility for operation. As an example the same 3-D graphic work station that is applied to design should be used to assist the Utility in maintaining the plant. However, in a few special cases, additional information would be extremely valuable to maintenance personnel. One such case is in provision for detailed equipment maintenance procedures. In this case, the Plant Designer is in the best position to either create, supplement or convert maintenance information from suppliers to 3-D graphic form for later use by the Utility. This paragraph is intended to make provisions for additional information needed by maintenance personnel.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

5 GENERAL IMS REQUIREMENTS

This section contains additional requirements important to the plant owner to be followed in generating of data and features for operation of the IMS.

5.1 GENERATING INFORMATION

Information management, distribution and control is the responsibility of the Plant Designer until the NPP with the IMS is turned over to the Utility Owner. It shall be the responsibility of the Plant Designer to input, in a timely manner, all information necessary to design, construct and operate the NPP. Information, when it is entered in the IMS, shall include all entities, attributes and relationships necessary to search and link information from any location in the IMS and to maintain a single verified official traceable source of the information.

A "bar-coding" system shall be used for identification of documents and hardware. The system shall be compatible with the PIN (see Section 1.3.4).

Explanation and Reason:

One of the most important applications of an IMS is to record and recover diverse (by location, application or initiator) but associative (by content) information for a very large number of different specialized applications. Since a large amount of information is generated during the design phase of the NPP, it is essential to maintain the association of entities and attributes as the information is generated. (See Reference 1 for generic nuclear power plant information relationships.) This requirement is more costly at the beginning of the project but at some point the information generated is so great, retrofit coding is not feasible. At the end of the construction the IMS may contain the equivalent of ten million ten page documents. Entity is intended to mean a group of like information items and attribute is intended to mean ties or facts about the entities in an entity set.

"Bar-coding" is used successfully in many applications for entry of data into a computer system.

5.2 COMPATIBILITY OF INFORMATION GENERATED

It shall be the responsibility of the Plant Designer to provide the service of assuring compatibility of information in the IMS. Accordingly, the Plant Designer shall enter, in a timely manner, all information received from any source that is necessary to design, construct and operate the NPP. Information, when it is entered in the IMS, shall include all entities and attributes necessary to search and link information from any location in the IMS and to maintain a single verified official traceable source of the information.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

The Plant Designer with the advice and consent of the Utility, shall require that all major suppliers provide drawings and text files on magnetic media that is formatted as defined by the Plant Designer. Any translator(s) required for software compatibility with the Plant Designers system, shall be the responsibility of the supplier. In addition, all information transmitted shall include all entities, attributes and relationships as defined by the Plant Designer.

A method that may be considered to satisfy these provisions is the application of Rule-Based, Inductive, Expert System software that can read any text file and assign entities and attributes to information contained in the file.

Explanation and Reason:

All major contributors to an NPP are currently applying computer-aided engineering/design and each has developed an associated document numbering system. There is very little hardware or software compatibility between these systems and currently there is no fully satisfactory method to automatically convert such diversity into a single predefined IMS that operates in a specific hardware environment. One element in solving the problem is to assign the responsibility for hardware and software compatibility to the Plant Designer, as stated in the requirement. However, the Plant Designer will need the support of the Utility to place the responsibility for IMS compatibility on major contributors such as NSSS and Turbine Generator suppliers.

Major contributors should be willing to assist the Plant Designer to achieve the highest possible productivity in the design and construction process. However, it may not be in the interest of minor contributors to conform to the needs of the Plant Designer. To illustrate this situation, consider the following example. A report containing information that supports or supplements design information related to a piece of hardware is submitted to the Plant Designer. Assume the report was written on a word processor and submitted only on hard copy. The report can be converted to magnetic media in a standard format by an optical reader but the information contained in the report cannot be automatically linked to the single verified official traceable information source. To accomplish this essential element of the IMS, either the relevant information with appropriate entities, attributes and relationships must be added to the IMS by an operator, or a software package must be developed to automatically scan the text, select relevant information and append entities and attributes in their proper relationship. This type of Smart System software is beginning to emerge in some specialized applications. The development of such software would be extremely useful for the IMS concept.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

5.3 FLEXIBILITY AND ADAPTABILITY

A means shall be provided to incorporate in the IMS, computer application programs currently utilized by Utilities and major contributors to the NPP project.

Provisions shall also be made for the simple straightforward addition of new modules such as commercially available computer design application programs, cost control application programs, project scheduling application programs, etc., without affecting the database structure. The flexibility and adaptability of new modules should be considered in their selection.

Explanation and Reason:

Utilities and major suppliers currently utilize many computer application programs. Some of these programs, carefully selected, should be incorporated in the IMS at the beginning of the NPP project.

Maximum use should be made of standard commercially available computer codes because they are much less expensive, have been tested much more extensively, and generally have fewer errors than custom computer codes. Writing and maintaining custom computer codes should not be a function of the Plant Designer or the Utility. Competition forces software speciality houses to produce cost-effective products. Of course, in some cases, special purpose software will be needed. In these cases it is likely to be more cost-effective to utilize companies that specialize in special purpose software development. However, a precise definition of a "flexibility requirement" cannot be provided as a functional requirement.

5.4 HARDWARE COMPATIBILITY

It shall be the responsibility of the Plant Designer to develop a plan, approved by the Utility, that will assure and demonstrate computer hardware and software compatibility throughout the NPP project, including turnover.

Explanation and Reason:

Since the size and needs of the IMS will expand as the project progresses, and since the technology will change during the course of the project, the Plant Designer will require a plan, approved by the Utility, that assures hardware and software compatibility as the project unfolds.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

5.5 DESIGN VERIFICATION

The IMS shall be used to define and record the design review and design verification requirements with acceptance criteria for each information set. Individuals assigned responsibility for review and approval shall be identified by passwords and access codes maintained in the IMS. The IMS shall automatically record the review and approval process and record verified designs electronically, applying the principles described in Section 5.7.

Explanation and Reason:

This provision will assure that complete up to date records of the design process are available for audit at all times, including work in progress.

5.6 REQUESTS FOR DESIGN CHANGES

Provisions shall be made in the IMS for designated individuals with appropriate access codes to read any files. These individuals review and approve designs for adequacy relative to construction, operation and maintenance. Proposed changes intended to improve construction, operation or maintenance are submitted to engineering in the same manner, with the same review procedure and with the same approval criteria as described in Section 5.7

5.7 CONTROLS AND PROCEDURES FOR MAINTAINING THE VALIDITY AND INTEGRITY OF INFORMATION IN THE IMS

The IMS shall include a reliable method for electronic change control and regular systematic IMS backups.

Specific individuals shall be assigned the responsibility for obtaining and entering blocks of information. Also, specific individuals shall be assigned review and approval obligations. This information together with review and approval requirements for each information set shall be recorded in the IMS in conjunction with passwords and level code assignments.

A minimum of three levels of current files shall be maintained as well as weekly archive files. The first level is a Read Only Static (ROS) file, the second level is a file with Changes Requiring Approval (CRA) prior to implementation and the third is a file for holding approved changes (HAC) prior to transfer to the read only static file. The IMS shall automatically verify that all approval requirements have been satisfied, log the information and transfer the approved changes in the information set to the third level (HAC) file. The IMS technical management group will each day update the first level (ROS) file with approved changes in the third level (HAC) file. All changes from each version shall be recorded in a transaction log.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

Access to the IMS shall require the user to have an individually assigned password and an access level code. An information set may be transferred from the read only static (ROS) file to the change requiring approval (CRA) file and changed only by a user that has the assigned information set password together with the level appropriate for the files being changed. Any individual with a valid password and access level code shall be permitted read only access to any of the files and transaction logs but only specifically designated individuals may make changes as described above.

An automatic messaging system shall be provided to inform individuals that may be affected by the change, that a change is pending and to inform individuals assigned review and approval responsibility that a proposed change is on hold for their approval. An automatic transaction log shall contain, as a minimum, the name of the individual performing the transaction with comments and the time and date of the transaction. If the proposed change is rejected by an individual assigned review responsibility, the initiator of the proposed change shall be automatically notified by the IMS. Any conditional approvals shall be recorded in the IMS transaction log as a rejection, until unqualified acceptance is recorded in the log. The transaction log shall be retained as part of the record of the design evolution process.

Provisions shall be made in the IMS changes control process such that, after start of construction, design changes may require at least one additional engineering approval level as well as additional approvals by project and construction management.

Provisions shall be included for complete IMS backup on a weekly basis, for daily incremental backup and for IMS transaction logging.

Explanation and Reason:

The main theme throughout this document is to provide a single source of authoritative information for predefined information sets with a pre-defined approval process and criteria for all information within the IMS. This concept clearly defines responsibility and accountability to a specific individual, it provides for a uniform pre-established approval process, it permits automatic distribution of information, it provides automatic records of each step in the change process, and it provides for integrity of information in the IMS. By this means, configuration control becomes an integral part of the development of the IMS. It is clear that if multiple sources of the same information are permitted, management control of the configuration will be lost.

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An example of this approach is as follows. An engineer is designated as responsible for the Liquid Poison System (LPS), which is defined as an information set assignment. An information set password and level two access code is issued to the individual by the TMS technical management group. A proposed change is implemented by the engineer by transferring the Liquid Poison System information set from the read only static (ROS) file to the change requiring approval (CRA) file. The change is made in this file and when the work is completed, the automatic notification and approval process is initiated by the IMS. The IMS automatically notifies affected individuals and records notifications and responses in the transaction log. When the review and approval criteria has been met, the file is automatically transferred to the holding file (HAC). This file is automatically transferred to the read only static (ROS) file at the next update.

There is an important reason for an artificial time delay in the "static file" change process. The selection of one day is intended to assure stability in the dynamic change process. Assuming most design work is interactive at a work station during most of the design phase of the project, a large number of changes will be in process most of the time. Although some high speed systems can make changes appear sequential to the operator, there is the risk of system instability or very long delays in access. Experience with a specific system (hardware and software) together with a measure of the rate of changes occurring will be required to establish the optimum time delay needed, perhaps longer at the beginning of a project and shorter toward the end.

A separate consideration is assuring IMS integrity which is achieved by regular backups. Optical disk storage appears to be a good candidate for this requirement as well as the "read only" file. In fact, if optical disk storage is as reliable as promised, the "read only" file could be used to satisfy record retention requirements. This approach has the potential for significant cost saving.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

5.8 QUALITY ASSURANCE

The IMS shall be capable of automatically maintaining complete records of the design as it evolves. The method utilized to achieve this provision is described in Section 5.7.

Explanation and Reason:

Since design verification is achieved by peer design reviews which are recorded in the IMS, and the IMS is constructed to provide a single verified official traceable information source, the quality of the design is assured and can be demonstrated by appropriate IMS queries at any work station at any time.

5.9 COMPUTER AND NETWORK SECURITY

An IMS security level, together with the methods utilized to achieve the desired risk level, shall be proposed by the Plant Designer for review and approval by the Utility. The Plant Designer shall certify the IMS security system in accordance with Guidelines for Computer Security and Accreditation (GUIDE 83). The Plant Designer shall be responsible to maintain the security of the IMS at the approved and certified level.

Explanation and Reason:

There are a number of commercially applied methods to minimize computer system vulnerability to data loss or contamination. Since no system is absolutely safe, risk management involves analysis of risks, cost of recovery, cost of risk reduction, and acceptance of residual risk. Factors to be considered in a risk analysis are; the necessity of the system to function at a given level of performance, maintaining data accuracy and preserving continuity of operation. Utility management must decide what performance level is required relative to what level of residual risk is acceptable. The Plant Designer is responsible to demonstrate that the proposed methods achieve the acceptable security level. Reference 2 provides more information on the subject of computer and network security.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

6 TURNOVER TO THE PLANT OWNER

6.1 SCOPE

The Plant Designer shall provide the plant owner a complete IMS, including hardware and software, to carry out the functions as described in this document. The software will include the computerized technical data base as described in Section 6.2. The hardware will include a sufficient number of work stations, adequate memory and computing capability to carry out the desired objectives of the owner to make optimum use of a computerized technical data base in the activities of the constructor and the operator. It will also include systems and equipment necessary for communication within the system and between users.

6.2 CONTENT OF THE TECHNICAL DATA BASE

The technical data base shall include all the information generated in the course of the design which is required by the owner to construct and operate the plant. It shall also include information supplied by the owner which may be outside the scope of the plant design but required for construction or operation. (This may include, for example, site selection and preparation and owner-supplied equipment and services.) All of the technical data shall be in accordance with the plant data model described in Section 3.2. The owner shall provide information to the Plant Designer in that format.

6.3 HARDWARE COMPATIBILITY

As an objective, the IMS hardware should be compatible with the owner's in-house computerized information system; however, it must be fully compatible with the computer provided in the ALWR plant for non-signal processing and non-control functions (that is, compatible with the computer used for operator aids, maintenance, performance calculations, etc.).

6.4 APPLICATION TRAINING

The Plant Designer shall provide for training and end-user documentation for operation and maintenance of the IMS for all owner-designated personnel involved in construction and operation activities.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

6.5 TIMING

The Plant Designer shall arrange for review of the IMS development with the utility construction and operations personnel. Input will be solicited and utilized in preparation of the PIN and specific construction and operation needs will be incorporated.

At the time of plant purchase, the Plant Designer shall provide to the owner, as part of the proposal, a full description of the IMS he intends to supply, including a description of the PIN, the software packages to be included in the IMS, and the hardware to be provided at the construction site, in the owner's offices, and at the operating plant. The scope of the technical data base to be included in computerized form and in interactive-capability form shall also be defined.

The Plant Designer shall deliver to the plant site a completely functional IMS system (hardware and software) at the time of the start of construction. At that time, the system shall have recorded on machine readable media all completed design information which makes up the technical data base and information for the technical data base provided by the owner.

During the period of construction until turnover to the owner, the Plant Designer shall be responsible for updating and control of the technical data base and maintenance of the IMS. Procedures shall be established by the Plant Designer, with approval by the owner, which will permit assigned constructor and operations personnel to utilize the IMS. This will include access to data, retrieval, generation of hard copies, and selected interactive capabilities. The latter will include capabilities to perform studies utilizing CAD, generation of reports, and development of owner-specific information.

As the ALWR nears completion and systems are turned over to the operator, the Plant Designer shall, as part of the turnover process, assure that the corresponding information set is completely consistent with the ALWR as it is actually constructed. Computer model walkdowns shall be performed concurrently with actual plant walkdowns. Information sets shall contain all the data necessary for operation and maintenance of the equipment in the system under consideration for turnover.

FUNCTIONAL REQUIREMENTS FOR AN INFORMATION MANAGEMENT SYSTEM

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EXHIBIT A

TYPICAL SOFTWARE PACKAGES

The following is an outline of a set of typical software packages currently available in the industry. Generally these packages function most efficiently on hardware that utilizes a specific operating system and are usually not easily transported to hardware that utilizes a different operating system for which the software was not specifically designed. If a combination of software and hardware is selected that performs the desired functions then application problems are minimized. However, problems arise when the attempt is made to cause dissimilar systems, i.e. different operating systems or different software, to communicate. Here it has been assumed that the hardware and software is completely compatible. In Exhibit B some considerations concerning a practical approach to dealing with the unavoidable problem of communication are outlined.

A.1 THE DATA MANAGEMENT SOFTWARE MODULE

A.1.1 Overview of Primary Functions

The Data Management Software Module (DMSM), described below, is a typical data management software package that provides centralized control of design project databases. It includes provisions for data integrity by preventing unauthorized access to files, drawing revision, document release control and several other functions. The intent of a DMSM is to accommodate large, complex projects allowing users to integrate and manage the entire product process. Such computer software utilities are designed for a generic product process not specifically for NPP design, construction and operation. In the current technology, this results in a considerable effort being required to include the entities, attributes, relationships and special features for quality control, security, etc. required specifically for the NPP.

The EPRI document (Reference 1) contains a definition of a network of Nuclear Power Plant (NPP) information called "Plant Information Network" (PIN). The PIN combines the data requirements for design, construction, and operation activities to provide a thorough understanding of the flow of information throughout the entire power plant life cycle. As illustrated below, much of the framework for applying PIN in the development of an Information Management System (IMS) for an NPP is available in today's hardware and software.

The typical DMSM centralizes, manages, and secures design project data within a mainframe environment. Of course, the DMSM must include the ability to store and retrieve a large number of files and drawings, authorize data access, ensure project security, issue project status messages, and manage databases. The DMSM software must also provide comprehensive revision and release control, change-ordering, definition of user tables, and the ability to view CAE-CAD graphics on mainframe terminals or work stations.

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TYPICAL SOFTWARE PACKAGES

Using the DMSM, CAE-CAD operators can transfer parts and drawings to and from the mainframe environment. By closely coupling the DMSM to CAE-CAD software, data may be transferred automatically. The DMSM also manages information other than CAE-CAD data such as information important to project management functions.

A.1.2 Main Features of a Typical Data Management Software Module

- Access to large mass storage devices for data centralization, consolidation, and data integrity;
- Management of part and drawing databases;
- Automation and monitoring of the product design development process;
- A system administrator's menu to access, set up, and control the DMSM software module functions;
- User configurable file access mechanism to ensure data integrity and project security;
- Data base maintenance tools for archive/restore and backup/recovery functions;
- Revision and Release Control software to monitor the design process;
- Engineering Change tracking software to automate and validate the approval cycle for change requests.

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TYPICAL SOFTWARE PACKAGES

A.1.3 Data Access and Control

Within a typical DMSM, projects (or segments of projects) may be defined in terms of project members, user authority levels, and design components. A different authority scheme can be used for each project, and users may be assigned different authority levels for each project.

All users receive a read or write authorization code based on an Owner-Management defined authority scheme. By controlling access to design project data, the DMSM not only protects data integrity, but also ensures that only the latest and most accurate product and design information is distributed.

Access control is a necessary element of the broader and more complex topic of Security for the entire Information Management System. The Security topic is treated in Section 5.9 of Attachment 1.

Utilizing the Data Management Software Module for Messaging as the product design progresses, the DMSM can automatically distribute messages to inform users that a specific action must take place. For example, the DMSM can notify the appropriate supervisor that a drawing is ready for his approval. A Message and User List software module is provided with the DMSM to allow customized distribution lists to accommodate each project's unique requirements and staff structure.

A.1.4 Backup & Recovery - Archiving & Restoring Files

The DMSM provides data integrity tools that help protect databases. Using the DMSM, both incremental and universal back-ups of stored data may be executed. The incremental backup function copies only those files that have been updated since the last incremental backup, while the universal backup function copies all data under the DMSM. Additionally, the DMSM includes the ability to recover specific versions of a part or entity. Every time a part or entity is retrieved from a DMSM data base, a new version is created. If the current version gets lost or damaged, DMSM can recover an earlier version.

The DMSM permits designation of both released and in-process files for off-line, archival storage. When the archive operation is executed on the mainframe system, the DMSM automatically associates archived files with the physical storage medium and retains this data on-line to simplify future access to archived information.

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TYPICAL SOFTWARE PACKAGES

Similarly, files can be designated for restoration on an individual basis. When a restore request is encountered, the DMSM prompts the user with the identification number of the tape or other machine readable media to be made accessible.

Backup, recovery, archiving and restoring files are all important aspects of the broader and more complex topic of Security for the entire Information Management System. The Security of the IMS is treated in Section 5.9 of Attachment 1.

A.1.5 System Administration

- Full-screen menus provide users and system administrators with access to the following computer utilities:
- Maintenance commands to associate data integrity and authorization levels with users and projects;
- File access commands to create, read, and revise files in the DMSM data base;
- File maintenance commands to modify information associated with a particular file;
- System maintenance commands to delete, archive, and restore files on the host processor;
- Data base maintenance commands to back up and restore the DMSM Data base, a minidisk, or a single file;
- User table commands to allow creation and use of custom tables within the DMSM;
- Release control commands to track the progress of files and parts from inception through release;
- Engineering Change Notice (ECN) commands to manage the process of defining, reviewing, and approving ECN specifications;
- Message and use list commands to distribute and access messages generated by DMSM Release Control and ECN Tracking options;
- The DMSM view commands enable viewing of CAE-CAD drawings stored in the DMSM on mainframe graphics terminals or work stations.

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A.1.6 Revision/Release Control

With Revision/Release Control module, the DMSM's coding system can monitor the status of design work as it moves through the organization. Lower codes may be used to identify work in progress; higher codes for designs that are ready for application. Revision/Release Control allows management to define a set of events that must take place before the status of any file can be changed.

For example, before a draftsman is authorized to raise the status of a completed drawing, Revision/Release Control may require a supervisor to review the drawing. The DMSM's messaging capability can be used to notify the supervisor that a drawing is ready for approval. The supervisor can then review the drawing and either approve it for release to the next level of operations or return it to the draftsman for correction or enhancement. See Section 5.7 of Attachment 1 for more information on how the module may be applied to the IMS.

The Revision/Release Control module also protects the integrity of information by preventing file editing without proper access codes.

A.1.7 Engineering Change Notice (ECN) Tracking

The ECN Tracking module is utilized when a design that has been released requires modification. To initiate an ECN, an authorized DMSM user creates a list of people who must approve the change order before it can go into effect.

The DMSM's Messaging facility then notifies each individual of the proposed change. Only when all responsible parties have approved the change will the DMSM release the data for revision and re-release.

A.1.8 User Controlled Modules

The DMSM User Tools allow the user to specify, define, and create custom tables within the DMSM and relate custom tables to existing DMSM tables or user applications. For example, a table may be defined to associate data integrity related attributes with specific geometry stored under the DMSM.

A.1.9 Visualization

The DMSM provides view-only access to CAE-CAD graphics directly from a mainframe graphics terminal or work station. Using a DMSM view module, the user can call up files, pan and zoom images, and produce hard-copy output.

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A.1.10 CAD-CAE Graphics

CAD-CAE Graphics includes tools for manipulating graphics such as copying, mirroring, trimming, stretching, dynamic translation, and rotation; comprehensive text and line fonts; use-definable parameters for tasks such as inserting basic geometry; entity and layer discrimination; intelligent graphics figure files for geometry construction; and tools for user-definable tablet and dynamic menus. The IGES module provides the ability to format CAD-CAE data to IGES standards and to accept non-CAD-CAE data bases presented in IGES formats.

A.2 THE SITE ENGINEERING PACKAGE

A.2.1 Overview of Primary Functions

The Site Engineering package provides the civil engineer, geologist, and cartographer with tools to integrate the modeling, visualization, calculations, and drawings associated with site work. It automates multiple applications including: site work, roads, utilities, grading, and embankments.

The package supports collection and processing of survey data for the creation of three-dimensional Digital Terrain Models (DTM). The DTM may then be utilized for automatic generation of contour maps, profiles, and cross sections, as well as output of area, tabulated earthwork volumes, and other vital calculations. For visualization purposes, several portions or layers of a map may be viewed simultaneously at different scales, perspectives, and from user-defined locations.

A.2.2 Minimum Basic Features

- Terrain or sub-terrain models digitally created, enabling elevations to be reported with large-scale map accuracy;
- Automatic contour generation;
- Interactive contour editing and annotation with full control over smoothing and text placement;
- Automatic profile generation of any existing alignment or arbitrary strike line, with independent vertical and horizontal scaling;
- Cross section design and generation along any specific alignment and at any station interval;
- Full control over template design, including cut and fill slopes, scaling, etc.;
- Interactive design in plan, profile, and cross sectional views to allow rapid earthwork calculations;

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- 2-D and 3-D presentations of the terrain at any phase, including planimetric, perspective diagram, views, and line of sight profiles;
- Alignment design facilities maximized for boundary surveys, foundation footprint, embankment, road and route planning/design;
- Finished document annotations for alignment stationing, boundary notation/dimension, and inset contour labeling.

A.2.3 Volumetric Analysis and Report Generation

Digital terrain modeling techniques provide elevation grid matrix, elevation reporting and editing, elevation interpolation, and regional volumetric calculations for inter-surface analysis. Statistical analysis of multiple DTMs, permitting generation of new DTMs by addition, subtraction, multiplication, and division of existing DTMs.

A.2.4 Survey Data Capture

With the Site Engineering package, the user can enter both graphic and non-graphic information from many sources including: survey and field notes, existing contour maps, United States Geological Survey digital data, and external data collection devices, including survey data memory devices and stereo digitizers. This data is displayed on the screen as it is entered, providing the user with the opportunity to continually check, change, or delete information.

A.2.5 Contour Maps

The initial data input is the basis for automatic contour map production.

A.2.6 Profiles

The Site Engineering package may be utilized to automatically create a profile based on the DTM.

A.2.7 Cross Sections

The Site Engineering package provides tools for automatic generation of cross sections of a specific alignment. The user controls such parameters as template design, size, and positioning of cross section details. Data, station, value, and horizontal and vertical scaling may be associated with the cross section.

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A.2.8 Alignment

With Site Engineering tools, the user may work in plan, profile, and 3-D representation of the site, with full associativity among views. The package also offers interactive capabilities for storing, updating, and dimensioning site alignments. Alignment reports giving coordinates at selected points can be generated. The alignments can be automatically annotated using bearings and distances, or using stations and station terminology.

A.2.9 Calculations

The Site Engineering package provides methods for calculating, either interactively, for use during design, or automatically, for output in reports. For example, all cross sections carry with them as attributes their cross sectional area. Based on these, the engineer can tabulate earthworks volumes between any cross sections or for an entire set of cross sections. In addition, the package provides distances along alignments, offset distances, and lengths of curves. Computations may be made comparing information that describes different surfaces of the same area, for example between two specified DTMs or between a DTM and a design plane for a foundation footprint. The designer has the tools to interactively perform calculations of volume for entire sites, before and after construction, and for selection of optimum construction site.

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A.3 THE ARCHITECTURAL PACKAGE

A.3.1 Overview of Primary Functions

Architectural design and documentation, including 2-D architectural layout, 3-D modeling, and detailing. The package includes the capability to produce plan drawings in all formats and detail required, at any scale, throughout the design process. The data base structure permits automatic generation of bills of materials and room finish schedules. The Architecture package must be fully integrated with other application packages.

A.3.2 Minimum Basic Features

- Interface featuring icons, menus, and libraries;
- Automatic production of user-tailored plan graphics that can be detailed or edited;
- Automatic creation of a 3-D model from a 2-D plan;
- Three-dimensional representation of one-, two-, or three-point perspectives;
- Associative dimensioning for monitoring design changes;
- Single common data base for monitoring design changes;
- Data base allowing automatic generation of bills of materials and finish schedules.

A.3.3 Layout Features

With the Architecture package the user has the ability to automatically create and manipulate double-line wall geometry. Walls, their logical connections, and associated attributes are maintained in a Data base. Walls may be placed using center, right, or left justification to accommodate different input requirements.

A.3.4 Editing Features

Once placed, walls can be edited, altered, or trimmed; new intersections can be created. The user may layout symmetric or repetitive floor plans by copying, mirroring, or rotating walls, rooms, or groups of rooms previously placed in the data base.

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A.3.5 Determining Areas, Perimeters, and Volumes

The topology of the architectural model Data base permits the user to automatically identify buildings and rooms. Therefore, after or during the layout of a total floor plan, the user can obtain area, perimeter, and volumetric information. By identifying a wall segment, the system will respond with the corresponding data. Room areas reflect the current plan layout regardless of the number of changes made. Associative dimensioning provides the user with the ability to maintain accurate dimensions automatically as the floor plan changes. Non-associative dimensioning and the ability to dimension in English or Metric units is also provided. In addition, the system distinguishes between interior and exterior walls so the user can calculate heating and cooling requirements for the room or building.

A.3.6 Three-Dimensional Features

Once the floor plan is complete, a user command can create a 3-D representation of the layout. The Architecture package allows the user to slide a plane through any wall or group of walls to create subdivisions or floors within the building.

After the walls have been projected to the appropriate height, hidden-line removal or perspective generation can be employed for visualization. The visualization capability provides the user with control over vantage point, picture plane, and cone-of-vision to enable the user to construct views in one, two, or three point perspectives. This capability may be used as the basis for establishing any wire-frame or surface-rendered view.

The walls may also be used as the basis to layout the building mechanical, electrical, and plumbing plans in conjunction with various menus and library symbols representing these building systems.

The package includes the capability to produce 3-D shaded construction sequence displays with or without hidden lines or a combination of shaded views with wire frame extension to the buildings. Dynamic motion of an object moving through a building is also a feature of the package.

A.3.7 Detailing Drawings

Detailing architectural drawings are automated through the use of supplied libraries. A wide selection of patterns is provided. In addition, the user is able to create and store user defined patterns. A wide selection of line fonts and layering capabilities is provided to aid the user in detailing drawings. Automatic dimensioning is provided.

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A.3.8 Required Dimensioning Capability

The user is able to create working drawings from any computer model with appropriate architectural annotations.

Dimensions are displayed in standard architectural format. As a minimum, four types of dimensions are available: linear (which measures the distance between entities), angular (the angle between two lines), radial (the radii of circles, arcs, and fillets), and point (labels the coordinates of a point). The user controls the placement of the dimension lines as well as dimension text, arrowhead type, the precision of the dimension value, and the use of leader lines.

A.3.9 Required Libraries

Template and symbol libraries provide an initial set of graphic symbols that may be added to or replaced, depending on the users requirements. The template libraries include all symbols commonly used for architecture, interior design, HVAC, electrical, and plumbing layout.

The user may add to symbol libraries by creating the users own symbols or modifying existing symbols. The user may also associate non-graphic information to these symbols, such as manufacturer and size, for generation of bills of materials.

The Architecture package provides the ability to define different wall types. The wall type data, non-graphic in nature, serves to inform the system of the type of wall the user is inputting. When the user creates a floor plan, the user may call from the library the appropriate wall type. Additionally, the user may break walls into appropriate cavities for detailing and dimensioning.

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A.4 THE STRUCTURAL ENGINEERING PACKAGE

A.4.1 Overview of Primary Functions

With the Structural Engineering package, structural elements can be assembled to build frames, trusses, platforms, etc. The module also includes specification tables, parts libraries, and parameter files of standard and non-standard structural shapes. The user can create all types of structural drawings including framing plans and erection drawings plus generate material take-off reports automatically.

A.4.2 Features

- A user interface that includes icons, windows, pull-down/pop-up menus, mouse, and features to increase productivity and ease of use;
- Simple creation of beam, columns, and structural networks;
- Commands for placing, connecting, modifying, deleting, moving, and displaying steel members;
- A library of sections including W-shapes, channels, tees, angles, rectangular tubes, round pipes, and flat bar cross-sections. The user can create other shapes by defining a library symbol and a supporting procedure file;
- Complete control over the three-dimensional location and orientation of the piece as well as the position of a steel beam with respect to its centroid;
- Representation of members from any perspective—front, top, isometric, cross-section, or three-point perspective;
- Choice of representations—single line for framing plans, or complete representation of all surfaces for detailing;
- Parameter files for American, Canadian, Australian, European, and British standard specifications;
- A full range of graphic output functions;
- Material take-off macro programs and user aids to increase productivity and assist in estimating.

The Structural Engineering must be fully integrated with CAD-CAE design, drafting, and modeling packages. The Structural Engineering package must also be fully compatible with all other engineering packages such as Piping, HVAC, General Building Design. With a visualization module in conjunction with the Structural Engineering package, the user can interrelate various disciplines on the same model with automatic interference detection among all elements.

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A.4.3 Structural Steel Modeling

A.4.3.1 Placing Members

Prior to placing members, the user establishes modeling defaults. Next, steel members can be inserted in the three-dimensional model using multiple construction plane, views, and layering schemes for center line and section graphics. The user can select standard cross-sections (e.g., W21X147) or input the flange and web dimensional data for non-standard or built-up sections. The standard library parts give a simplified wire-frame representation, accurate in size, and scaled to correct length, width, and depth. For example, a steel angle is represented by one line at the tip of each leg and one line at the heel; and L connects them at each end.

The user specifies non-standard member length either explicitly or by digitizing bounding members and orientation. These can be vertical, horizontal, parallel to members and lines, or at any angle in the construction space. Center line locations, i.e., top, bottom, or center of steel, can be moved to override the selection file default location. The user can also specify fillet parameters, weld gap, offsets, and units of measurement during this design phase.

The user can divide, move, and copy members to expedite the design and replication process. Members can be subdivided at their intersections with other members. Columns, beams, trusses, floor levels, stairs, etc. can be made easily by copying existing modeled members.

The user may rotate and orient members, bound a member by other members, specify a fixed length, move the center line, override the selection file, and specify a fillet parameter, units of measurement, weld gap, or setbacks.

A.4.3.2 Editing Steel Members

The Structural Engineering package contains editing, deletion, disconnection, and listing commands to facilitate design changes. The user can edit members in place, without deleting and reinserting, to change any of the parameters used during member placement. The structural shape type and designations, orientation, length, centerline locations, clearance, etc., can all be changed for existing members. The user can disconnect members from others to allow certain translations and to insert adjoining members between them. The user can also list member parameters such as structural shape type and designation, centerline length, graphic state, and command history.

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To change the cross-section of a member the user simply edits the cross-sectional name; the graphics will change automatically. Often, designers work with centerlines which may not be located at member centroids; for example, most beams are located at the top of steel but bracing is located at its centroidal centerline. They can change the location of the center line relative to the cross-section during or after initial insertion.

A.4.3.3 Connecting Steel Members

To further simplify the design process there are commands for connecting steel member ends to other members. These connections make it possible to translate one girder and appropriately stretch (or shrink) all supported beams in the same step. A connection library part, provided with the package, schematically represents the connection. These parts can be replaced with user-specified connections such as clip angles, splices, welds symbols, and plates. A Finite Element Modelling (FEM) interface can utilize the connectivity established in the model data base so an analysis of the structure can be generated.

A.4.3.4 Visualizing Steel Members

A Visualization package contains extensive commands that enhance detailed graphic representation, section views, and hidden line removal of structural members.

Using Visualization, the user can generate a detailed representation of structural members to show clearly the flange, web, and intersection surface edges, in addition to the wire-frame representation. The detailing software performs automatic end coping at intersecting connected members. A command for cutting and displaying sections through a structure is included and cross-sectional views in any viewing plane can be displayed with cross-hatching options.

Framing plans can be generated by displaying the centerlines of beams and the footprints of columns. The user can switch the display from detail to wire frame at any time during the design session. When the detailed representation is generated, the schematic symbol is automatically blanked.

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A.4.4 Symbol Library

A structural shape library, supplied with the Structural Engineering package, contains wire-frame representations of seven shapes, each prepared in inch, millimeter, and meter units. The seven shapes—W-shape, channel, tee, angle, structural tubes, steel pipes, and flat bar—all have unit length, width, and depth. They are automatically scaled on insertion by length, web depth, and flange width. Flanges and webs have no thickness until the user creates the detailed representation. Library figures, noted above, schematically represent connections.

A.4.5 Associated Files

Structural Engineering supplies standard tables as defined in American, British, Australian, Canadian, and European code specifications. These tables list each cross-section by name and describe its dimensions (depth, flange width, web thickness and flange thickness, etc.).

A.4.6 Non-graphic Properties

After the user inserts members, descriptive properties are automatically added to the data base. These properties describe centerline displacement at each end, cross section dimensions, stock number, and material specification. Other properties describe the beams end point coordinates, centroidal center line length, actual cut length, connecting members (supporting and supported), layering and drafting status (whether it has been dimensioned, detailed, or sectioned). These properties and attributes are sufficient to drive most commercially available FEM and connection design analysis programs.

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A.5 THE MECHANICAL ENGINEERING PACKAGE

A.5.1 Overview of Primary Functions

The Mechanical Engineering package is a CAD-CAE software package that automates the design and analysis of mechanical equipment, plumbing, and Heating Ventilating, and Air Conditioning (HVAC) systems. The package provides engineers and designers with tools to create, modify, and analyze mechanical systems, and to generate related documentation.

The HVAC module provides the tools for determining the thermal profile of a building. From this information, the user may select, size, and route ductwork and insert components. Also included is a library of commonly used components.

Designs may be entered initially as wire-frame models or as 3-D solid models. Double line representations may be automatically generated from wire frame or 3-D solid information. The 3-D representation enhances the user's ability to comprehend HVAC work in relation to other systems, for example, structural, electrical, piping, and architectural. In addition, interference Checking package will automatically search for hard and soft interferences between various construction disciplines.

A.5.2 Features

- A extensive fitting and component library representing most commonly-used equipment. User-defined entries are easily created and entered in the library as well.
- Building envelope analysis to calculate heating and cooling loads for building areas.
- Three different methods of fittings and component insertion. These methods may be used independently, or in combination with one another, providing flexibility in fittings insertion.
- Duct design calculator to compute duct cross sections based on duct length, air volume, elevation, dry/wet bulb temperatures, friction, and other parameters.
- Automatic clearance checking between ductwork and other building disciplines such as architectural, piping, structural, and electrical.
- Automatic double line graphics generation to produce 3-D ductwork representations from wire-frame models. 3-D models may be viewed and checked from multiple vantage points.

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A.5.3 Modeling Duct Runs

The Mechanical package provides two programs to assist in determining the thermal profile of the structure in which the HVAC will be run. These programs allow evaluation of an entire structure on an area-by-area basis, for example room-by-room, to determine both heating and cooling loads.

After the airflow requirements have been determined, the ductwork for the air distribution system is sized, using the duct design calculator. This program evaluates parameters such as elevation, dry/wet bulb temperatures, and duct roughness in computing the size of the duct. Governing criteria such as equivalent duct diameter, air velocity, maximum duct length, pressure drop, and the duct friction factor are input to specify parameters required by the designer.

To route ductwork, the user may initially create a single line model representing a duct run. The only information required for routing ductwork is size of the duct and end points of the run. The specified ducts are inserted and duct dimensions recorded automatically. After a duct is routed, fittings are inserted in one of three ways. These include the following; automatic selection from the extensive fittings library; selection from a set of primitive shapes; or creation of an entire set of fittings to be defined parametrically by the user.

All three methods of fittings insertion may be used during the modeling process, either separately, or in combination with one another. When fittings are inserted, the original ductwork is split and the downstream portions of the duct are updated appropriately, reflecting changes in duct size due to reduced fittings and modification of duct centerline due to eccentric fittings.

After the ductwork has been established in a wire-frame model, the user may generate double line representations by the use of a single command. This feature shows an actual representation of the ductwork that may be viewed from any vantage point in plan, elevation, or section.

The user may also generate reports automatically. These contain overall ductline descriptions and fitting or component descriptions. Ductline information includes label, size, insulation, sources, and destinations, excluding branches. Material descriptions consist of the items that make up ductlines. Automatically produced duct reports will also point out such inconsistencies as regards duct size, flow, material, etc. From the duct model, bills-of-materials, notes, dimensions, and drawings are also taken.

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A.6 THE PIPING DESIGN PACKAGE

A.6.1 Overview of Primary Features

The Piping Design Package enables piping engineers to create 3-D piping and equipment models that conform automatically to predefined project specifications. Information from the completed model then drives all production documentation. The final result is an accurate and consistent set of drawings and reports.

The package includes a collection of tools—symbol libraries, master catalogs of standard components and special commands—for producing customized piping specification files which requires minimal operator input.

These specification files then serve as “built-in” design rules during the modeling process. They govern automatic component selection and design rules checking, ensuring that the user’s completed model includes only project-acceptable components and requirements.

Each graphic element in the model the user creates is tied to dimensional and other descriptive data stored in the model data base. This allows the user to produce a full line of drawings and reports as by-products of the users model.

This means the user can merge piping and equipment models with designs from other engineering disciplines, including civil, electrical, and mechanical. Project-wide interference checking can then be performed using the software.

A.6.2 Features

- User-interface that feature easy-to-master icons, screen menus, and on-line documentation;
- An “Intelligent” 3-D model data base that serves as the basis of all drawing and report production;
- Automatic fitting insertion based on predefined piping specification files;
- Automatic design rules checking for flagging errors in user selection of end type, flow direction, spool lengths, elbow room, fitting orientation, etc.;
- Master catalogs containing specifications and dimensional data for a large number of standard manufacturers’ components, designed to speed the production of customized piping specification files;

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- 2-D and 3-D symbol libraries containing graphic representations and clearance shapes for all components in the master catalogs;
- Multi-disciplinary clearance checking software for reporting all hard and soft interferences;
- Project linkage software for checking design consistency across piping and instrumentation diagrams (P&IDs), computer design models, and final production drawings.

A.6.3 Schematic Design

The Piping package includes tools for generating piping and instrumentation diagrams and related reports, much more efficiently than is required by manual methods.

Using keyboard commands, the user may generate schematics and simultaneously build a data base of associated information. From these commands alone, the system "knows" a given line represents a pipeline with a set origin, destination, and flow direction. It also "recognizes" the graphic symbol as a particular component and links it in the P&ID data base to the pipeline.

Taking advantage of the software's layering capabilities, the user can associate other information, including labels, stock numbers, P&IDs, and specifications to elements in the user's diagram. This information can then be extracted from the data base automatically to generate line lists.

To minimize manual input, the package includes the following drafting and reporting aids:

- Symbol libraries – which are easily customized – containing 2-D graphic representations and associated property data for components, including piping equipment, instrumentation, and standard assemblies;
- Commands for inserting, labeling, and aligning equipment, process lines, instrumentation, valves, and assemblies. The user invokes a command and indicates the location of the component. The software will add the appropriate lines or symbols to the user's drawing and transfer property values to the user's data base.
- Automatic annotation of diagrams with conventional P&ID symbols, including squared-off piping segments, bold lines for major piping, direction of flow arrows, and interval banking at major piping intersections.

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A.6.4 Equipment Modeling

The user initiates equipment and nozzle layout by parametrically constructing the outline of unique pieces of equipment from basic geometric shapes, such as cylinders, cones, and spheres. These shapes can be called up individually using CAD-CAE commands. The package provides tools for defining clearance shapes in addition to the actual appearance outline of any piece of equipment.

The software includes a series of library figures, for representing equipment such as pumps and exchangers. Like all software-supplied symbol libraries, these graphic representations can be easily and quickly altered to conform to job-specific needs.

The nozzle figure library includes the size and pressure rating for each nozzle. This data helps size and orient nozzles correctly. It also provides the basis for size and end-type compatibility checks between pipes and nozzles during pipeline modeling.

Once constructed, entire equipment assemblies can be inserted into a model with a single command. Dynamic control of graphics makes it easy to test out different equipment layouts. Drag mode, for example, allows the user to shift components around, visually gauging their optimum location. Once the layout is complete, the user can generate equipment arrangement drawings.

A.6.5 Piping Specifications

Piping specification files are the key to efficient pipeline modeling and accurate documentation. Customized specifications define project-acceptable components and record vital design and dimensional data about these components. They also automatically establish design dependencies among pipes, fittings, assemblies, and branch reinforcements. During the modeling process, this information is used to verify the design consistency of all selected components and to execute automatic fitting insertion.

Each time the user inserts a component, supporting data included in these files is copied into the user's model data base. This ensures the user's completed model includes all the data that is required to produce standard drawings and reports. Because specification data is entered only once, design consistency is preserved.

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A.6.6 Creating Specification Files

The Piping package includes a set of master catalogs and 3-D symbol libraries which assist in the production of project-specific piping specification files.

The master catalogs list relevant design and dimensional data for a large number of standard components. They encompass commonly-used items from ANSI, DIN/ISO, MIL-STD 777, and standard plumbing manufacturers' catalogs. Stored information for each item includes its true size, nominal size, end type, pressure rating, eccentricity, and its reference symbol figure name.

Customized piping specification files are re-built by selectively copying this data into special files. Organized by header size, each specification lists all necessary design and dimensional data for a class of pipe and all corresponding fittings.

The user can also use these files to predefined standard assemblies, such as vents and drains, and set up branch reinforcement tables.

The supplied 3-D symbol libraries contain a single graphic representation of each general type of component listed in the master catalogs. Whenever the user inserts a component, the software "looks up" its dimensions in the specification files and adds a correctly scaled version of that figure into the users model – automatically.

Clearance or access volumes are also built into each symbol. Based on this geometry, interference checking software will highlight all hard and soft interferences.

Because standards and methods vary from company to company, these tools – master catalogs, symbol libraries, and specification files – can be easily added to or customized.

The range of component sizes accommodated is virtually limitless. All entries can be modified and expanded. For example, the piping specification files can accommodate unique stock members based on internal classification schemes, special mounting instructions, or any other data the user wishes to track and report.

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A.6.7 Pipeline Modeling

Once project specifications are established, the user can begin modeling pipelines utilizing semi-automatic pipe routing. A keyboard command inserts, aligns, and labels the center line of the users pipeline in 3-D space. The user indicates its size and specification, origin, destination, and installation path, using x, y, and z coordinates or directions. The software then inserts the pipeline into the users model. It also checks the inserted component against the piping specification files. If it matches, all the recorded information about the pipe will be copied into the model data base, so the system "knows", for example, the pipe's true size, nominal size, end type, and rating.

An error message flags all inserted pipelines that do not conform to specifications.

The software also includes the following special features:

- Automatic offsetting lets the user orient a pipeline by specifying the location of its top or bottom edge. The software properly positions the pipe center line, automatically offsetting it by one half the diameter of the pipe and insulation.
- Automatic alignment correctly joins end points of pipelines at origins and destinations.
- Automatic elbow room checking ensures the user have sufficient space for proper elbow or bends.
- Minimum pipe length checking flags pipe spools which are too short, given their size and specification, for proper welding.
- Special editing commands let the user quickly modify his design at any time. A single command simultaneously updates screen graphics and the model data base.

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A.6.8 Automatic Fitting Insertion

With the Piping package, fittings are inserted into the users piping model automatically. The user simply indicate the type of fitting he wishes to insert and specify its location.

Based on information in the specification files, the software selects the right fitting, scales it parametrically, and correctly positions it in the users piping model.

Line attachments and connecting material associated with each fitting are added to the model as well. All related components such as flanges, gaskets, and bolting are transferred to the model data base.

Fittings can be inserted singly or in series. When inserting reducing fittings, the software not only selects and positions the correct fitting, it also re-sizes the adjacent pipe section automatically.

With a keyboard command, the user can quickly remove any fitting from his model and restore the screen graphics and data base to its former state. For example, deleting a reducing fitting from the user's model eliminates the fitting from this model and re-sizes the pipeline.

The flexibility of the software allows the user to override predefined specifications on a case by case basis. For example, the user can modify the prescribed orientation of individual fittings for clearance or access reasons. The user simply specifies a new angle or direction of rotation; the system will make the adjustment automatically.

A.6.9 Design Rules Checking

An auto-selection file provide engineers with on-line design rules checking. By matching inserted components against data in these files, the software flags all inconsistencies in size and end type, flow specification, alignment, etc.

A.6.10 Interference Checking

Interference checking software detects and reports all hard and soft interferences—components that violate each other's space or clearance volumes. This software operates in conjunction with plant design software. Accordingly, the user can merge piping and equipment models with designs from other disciplines and perform project-wide interference checking. The user can run this checking routine at any time during the modeling process, safeguarding design integrity at every step.

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A.6.11 Analysis

To help the user validate a design for its intended use, the Piping package includes a generalized stress interface. With a keyboard command, the software will extract all relevant data—anchor and grid point coordinates, piping element connectivity, fitting types and locations, and the cross-sectional properties of pipelines—directly from the model data base in a neutral format. This file can then be edited and reformatted for input into a number of commercially available stress analysis programs. Based on the results of stress analysis, the user can modify the computer model using the package's editing commands. Commands delete, insert, reorient, and resize components, enabling the user to rework, reanalyze, and optimize the design.

A.6.12 Detailing/Documentation

Information embedded in the users model data base drives all drawing production; each drawing constitutes a view of the model from a defined angle and elevation.

With the Piping package, the user can graphically document the user's design at any time during the modeling process. Once the computer model is perfected, the user can generate a complete range of accurate and consistent orthographic and isometric drawings.

Since stored drawings are tied to the model, any modifications to the model are automatically reflected in related drawings.

A.6.13 Fabrication Drawings

The Piping package provides a set of tools for generating fabrication isometrics, directly from the completed 3-D model.

The software selectively extracts data from the model and properly formats and annotates the drawing. Pipelines are rescaled proportional to minimum and maximum assigned lengths along designated design axes. Fittings are given a constant, user-definable length. Flow arrows are placed at all junctions. Shop and field weld dots are inserted automatically.

On the final drawing, diagonals are indicated with angle notation. Segments offset in 3-D space are dimensioned clearly with box outlines, providing fabricators with all necessary information.

EXHIBIT A

TYPICAL SOFTWARE PACKAGES

A keyboard command places all necessary dimensions on the drawing, based on true 3-D geometry from the model. No manual input is required. Reference coordinates can also be calculated and inserted automatically. Dimension precision and format are user-definable. Another command inserts proper annotation for reducing fitting, bend angles, specification changes, and line attachments. CAD-CAE software provides a versatile selection of text sizes and fonts.

The software generates detailed blow-ups of any nonstandard fitting orientations automatically, clarifying their proper alignment. The rescaled pipeline is then centered on the drawing and scaled to fill the allotted drawing space.

A.6.14 Production Drawings

The Piping package includes special tools that facilitate the production of orthographic drawings including piping arrangements, plans, elevations, and front views. Upon command, the software converts wire-frame piping and equipment models into double-line representations, conveying the actual size and shape of each component. This feature can be conditionally invoked, allowing the user to represent pipelines with small diameters with single lines and pipelines with larger diameters with double lines. The user can also use this command to create solid representations of items in an arrangement drawings.

Using the Piping package in conjunction with Hidden Line Removal software, the user can automatically mask all lines in a drawing that would not be visible from the given viewing angle. This feature allows the user to render orthographic and double line isometric drawings quickly and accurately. Another command inserts breaks in pipeline graphics to reveal previously hidden design elements.

Pipelines can be annotated with a keyboard command. The user indicates where he wishes the text located. The software automatically extracts the pipeline's label from the data base and centers the text accordingly.

The user can add elevations, and orientation to any pipeline or piece of equipment in the user drawing. The software will compute the reference coordinates automatically and insert the datum as indicated.

The package provides editing commands for adding custom detail and clarity to the users production documentation. Using these tools, the user can "erase" parts of components that overlap annotation, remove hidden lines from small sections of a drawing, and produce "cut away views" within any drawing.

EXHIBIT A

TYPICAL SOFTWARE PACKAGES

The user can selectively add text files, such as bills of materials. Using the text editing features of CAD-CAE, the user can change the font, size, and angle of his text.

The software calculates and inserts dimensions between two specified points with one keyboard command. The user indicates the two items he wishes to dimension and establish a witness line.

A.6.15 Reporting

At any step during the design, modeling, and detailing process, the user can extract information from the data base and produce user defined reports. Complete from-to reports can be generated automatically. In addition to a pipeline's origin and estimation, these reports tabulate other requested information, including stock number, length, quantity, and cut lengths. This capability not only accommodates multiple sources and destinations, but also checks the pipeline for missing gaskets, flanges, and elbows, misaligned pipes, and pipelines that are shorter than specified minimum spool length.

Instrument lists contain the functional and loop identification of each instrument, listed alphabetically. They include the label, size, and specification of the appropriate pipeline and mounting instructions.

Bills of materials can include all pipeline components: valves, fittings, assemblies, and even bolting, which is not represented graphically in the users model. Identical items can also be tallied.

The user can integrate descriptive files with the computer model data base. This means the user can add data such as cost, weight, manufacturer, and order lead time for each stock number to the user's data base to produce accurate cost estimates and facilitate material ordering.

A.6.16 Project Linkage

The user can create a single project data base for large design projects that have to be modeled using multiple databases. By cross-referencing these model data bases with the original P&IDS, the user can produce project wide reports and conduct consistency checking across and between models and P&IDS.

EXHIBIT A

TYPICAL SOFTWARE PACKAGES

A.7 THE ELECTRICAL ENGINEERING PACKAGE

A.7.1 Overview of Primary Features

The Electrical Engineering package includes software modules to enable the user to automatically create loop diagrams, one- and three-line Motor Control Center (MCC) diagrams, and Control Wiring Diagrams (CWD) from Piping and Instrument Diagrams (P&ID's) data files created manually or with the Piping package described above. The Electrical Engineering package provides applications modules that permit the user to; produce one- and three-line diagrams automatically based on minimum interactive input by the user, enables the user to generate loop diagrams automatically from a P&ID data file, and permits the user to generate drafts, append annotations, cross-reference CWDs and generate wire list reports.

Provisions are made for the production of MCC one-line diagrams automatically from minimal input and automatic generation of three-line MCC diagrams from one-line diagrams and with commands to annotate and cross-reference control wiring diagrams and MCC three-line diagrams. The software also provides for the generation of signal and wire list reports from control wiring diagrams and MCC three-line diagrams and the automatic production of loop diagrams from Piping and Instrumentation Diagrams or P&ID data files. Libraries of electrical components and symbols are provided.

The software features a user interface that includes icons, windows, pop-up/pull-down screen menus, and mouse. These menus and icons can be activated by mouse, pen, or puck. User-programmable menus and keyboard functions can be tailored to specific design needs. Fixed menus can contain standard editor commands, user-created macro commands, and graphic symbols. For example, the user can insert "sheets" of commonly used library symbols and then flip through the sheets to choose the desired symbols.

Using the MCC Wiring Diagram module the user may input minimal data MCC one-line diagrams. The data associated with each drawing in the data base provides the information necessary to automatically produce the corresponding three-line diagrams. In turn, the information in three-line diagrams is used for automatic wire numbering, component tagging, and contact cross-referencing. From these diagrams the user can produce reports, such as bills of materials and total MCC power requirements.

EXHIBIT A

TYPICAL SOFTWARE PACKAGES

The MCC Diagram module consists of the following capabilities:

- User defined input format for building MCC data files;
- System facilities that transfer industry-standard or user-defined electrical ratings, values, and symbols from supplied libraries to one-line diagrams;
- Creation of three-line diagrams automatically from one-line diagrams;
- User guide with explicit instructions for using and customizing the module to individual requirements;
- User-definable default parameters for motor protection, disconnect means, drawing format, etc.;
- Report generation directly from intelligent drawings.

Once the user enters the required data, the MCC module generates the actual one-line diagram automatically. All diagrams are linked in the data base to their relevant data. This is updated each time the user finishes editing. From the one-line data file, the system automatically extracts the data to produce the three-line diagram(s). The user may then enhance the drawings with additional text annotation or titles in a variety of type sizes and styles. The user may also alter diagrams utilizing part libraries. The user can input data for a number of MCCs in one session and generate the resulting one-line and three-line diagrams in batch mode.

The data base organization makes it possible to locate any drawing set, sheet, component, or wire, and all the contacts associated with a coil, or all the wires associated in a network. The user can also automatically place the map location of a split component, or entry and exit point of a split wire network and extract a status report from a drawing set. The report will list dates and descriptions of revisions. The data base also provides a relation between the attribute list and the physical device locations to facilitate wire routing.

Reports, such as wire and conduit bills of materials, can be generated and placed on the drawings with keyboard commands. The interconnecting list, especially important with multi-sheet diagrams containing cross-page connections, can be extracted as a wire list reporting from-to connections, or as a logical net list reporting an entire net of connections. The user may define the formats for these lists. Additional information, such as signal name and source, and wire size and color contained in a drawing set can be included. The user may extract information from multi-sheet diagrams and present it in a report format of the user's design, or automatically insert it into drawings. Standard information such as component name, type, and quantity can be tallied to the bill of materials, as well as related information, such as manufacturer's part number and cost.

EXHIBIT A

TYPICAL SOFTWARE PACKAGES

The CWD module of the Electrical Engineering package is used to annotate and cross-reference both CWDs and MCC three-line wiring diagrams produced with the MCC software module. The control wiring diagrams are based on a library of electrical component symbols and wiring diagram form parts that are fully compatible with the MCC module. This enables the user to integrate control wiring diagrams and MCC three-line diagrams into a single drawing set. Since MCC three-line library symbols are composed of figures taken from the electrical component library, the user can use CWD commands on control wiring diagrams as well as MCC wiring diagrams.

The CWD module features:

- Several methods of tagging line references, components, and wire numbers;
- Built-in error detection routines;
- Automatic tagging of primary and secondary elements of electrical components;
- Automatic cross-referencing of components and wire networks across multi-part CWDs and MCC three-line diagrams;
- Provision for on-page and off-page wire network connections;
- Automatic signal and wire list report generation;
- Detailed component termination data facilities.

The Electrical Engineering package formats control wiring diagrams and three-line diagrams into side-by-side vertical columns of standard symbols. To create a CWD the user inserts line reference numbers down each column of an active CWD or MCC three-line diagram. Then the user instructs the system to extract the relevant electrical data and reference numbers from all electrical component symbols and wires that make up the basic CWD or MCC three-line diagram.

EXHIBIT A

TYPICAL SOFTWARE PACKAGES

A.7.2 Wire Tagging

Additional capabilities allow the user to tag primary and secondary elements to identify component family, specific member, or line reference location. This CWD facility works on single components divided into multiple elements in different locations on the same diagram or on two different diagrams. After all components have been tagged, the module lets the user automatically assign unique wire number tags to wire networks on the basic wiring diagram. The user can pre-define prefixes, suffixes, or complete wire number tags for individual wire networks. Cross-referencing Commands permit the user to cross-reference each primary element in the wiring diagram with the line reference number and contact state of each of its associated elements and to annotate the primary element with this information.

A drawing control file, listing the names of all parts in a multi-part wiring diagram, automatically processes cross-references across all the parts of that diagram. It will also output a cross-reference report to the users terminal.

The package is able to detect a variety of errors, including unnamed contacts or coils, a coil with no contacts or a contact with no coil, and more than one coil with the same name. Report generation capabilities facilitate checking for information missing from drawings.

Wire lists are generated from the annotated, cross-referenced control wiring diagram automatically. These lists denote component location codes, network wire numbers, wire gauge codes, and wire color codes. The user can create reports for single diagrams or for series of related diagrams.

The Automatic Loop Diagram module allows the user to produce loop diagrams from P&IDs. This package and the Piping package described above are related in that the Piping Package supplies data for input files to drive loop production. This module permits automatic creation of loop diagrams from P&IDs and automatic insertion of job-specific and loop-specific title block data into diagrams.

The Automatic Loop Diagram module is based upon the inherent standardization in the monitoring, alarm, and control functions for a given project; i.e., most loops for a particular function appear graphically the same. Therefore, the module requires only a small library of standard loop configurations, or parts with data from other files, to create the loop diagram.

EXHIBIT A TYPICAL SOFTWARE PACKAGES

A starter library of loop-diagram symbols and standard loop configurations is provided. These loop-diagram symbols can be used as templates for creating a library complying with company or project requirements. Standard loops are constructed from the library of loop symbols and can be customized to the users standards. Additionally, an instrument reference file and a loop-diagram library annotation file are required. The module includes a drawing-title block and accompanying query file, a loop instrument index format, and a wire and termination scheme. These, too, can be used as templates for customizing.

EXHIBIT B

COMMUNICATION PROBLEMS AMONG SOFTWARE PACKAGES

Exhibit A is an outline of a set of typical software packages currently available in the industry. In order to concentrate on the performance objectives of the IMS it was assumed that the hardware and software were completely compatible. Here, in Exhibit B, some considerations concerning a practical approach to dealing with the unavoidable problem of communication is outlined.

In order to better define the problem, consider the following:

First, if all software was completely portable and independent of hardware and its operating system, it would not be difficult to assemble the software packages needed to perform the functions defined in this document. However, software is usually not entirely portable, is dependent on hardware, and is continuously being improved and updated. In addition, software that takes full advantage of new developments in hardware may not run on hardware of the previous generation.

Second, each Utility, AE, NSSS supplier, Turbine Generator supplier, as well as many hardware manufacturers have their own computer systems, including CAE/CAD. In most instances, the software will not be transportable between these systems without considerable expense.

Third, during the time of design, construction and operation of the plant, the computer industry will have evolved through several generations of products.

Fourth, the computer system functional requirements (a hardware and software consideration) and the source and distribution of information (a communications consideration) changes as the emphasis shifts from design, to construction, to operations.

Fifth, the computer system size (required data transfer rates, storage requirements, etc.) may be expected to expand during the design phase and level out and diminish as construction nears completion.

These observations suggest it may be an acceptable, cost-effective compromise to consider several separate computer systems, each of which satisfies the intent of an IMS within the system but not external to the system. The systems should be completely stand alone but not necessarily linked. For example, these separate systems may be: The Plant Designer/Utility Information Management System (IMS), The NSSS IMS (NS-IMS), and The Turbine Generator IMS (TG-IMS).

EXHIBIT B

COMMUNICATION PROBLEMS AMONG SOFTWARE PACKAGES

Clearly, the optimum IMS is a totally integrated single system. However, the relatively well defined nature of the three design activities that progress, in parallel, make this a natural separation. Also, much of the information from the NS-IMS and the TG-IMS may be transferred to the IMS as "read only" files, which would not be difficult.

Applying this concept does not require any changes to the IMS Functional Requirements because the interface information necessary for the IMS is already the responsibility of the Plant Designer. It does mean, however, that there will be more hand entry of information from the NS-IMS and TG-IMS to the IMS by the Plant Designer and, as stated above, some information would be "read only".

Of the three systems, the IMS is the only one that defines the complete plant and is turned over to the utility at the completion of the project. For this reason the IMS must provide all the features and information as defined in the functional requirements.

If the entire industry will adopt a standard Plant Information Network (PIN) data model, this transfer of information between dissimilar systems would be greatly simplified.



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Appendix B. Sample Work Package Procedure

1

2

3

4



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ADMINISTRATIVE SITE PROCEDURE
WORK PACKAGE DEVELOPMENT

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1.0 PURPOSE

1.1 The purpose of this procedure is to delineate the responsibilities and the steps required for the preparation and revision of Work Packages.

2.0 SCOPE

2.1 This procedure applies to the preparation and revision of Work Packages for all permanent plant work. Work Packages shall also be prepared for work of a temporary or support nature, at the direction of the Site Manager.

3.0 REFERENCES

- 3.1 ASP-1, "Organization Description".
- 3.2 ASP-29, "Construction Reports".
- 3.3 ASP-20, "Site Control Center Operations".

4.0 ATTACHMENTS

- 4.1 Work Package Development Schedule.
- 4.2 Work Package Control Sheet.
- 4.3 Section A - Work Package Open Engineering Summary
- 4.4 Section B - Work Package Open Material Summary.
- 4.5 Section C - Work Package Bill of Material
- 4.6 Section D - Work Package Work Plan.

5.0 DEFINITION OF TERMS

5.1 AREA: A subdivision of the plant site to establish boundaries for separate, identifiable work areas. Initial area designations for St. Lucie Unit #2 are:

- Area 1 - Reactor Containment Building
- Area 2 - Reactor Auxiliary Building
- Area 3 - Turbine Generator Building
- Area 4 - Outlying Facilities

5.2 CUBIC: A subdivision of an Area into separate volumes or work areas, the boundaries of which can be managed and readily identified as established by the Area Director.



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5.3 WORK PACKAGE: A document which identifies all work within a Cubic for a manageable and identifiable time frame as established by the Area Director. The Work Package contains Work Plan, Bill of Material, Open Engineering and Material Summaries and a Control Sheet.

5.4 Required Date: Is the required at site date, which is established from lead time of the early start date of the activity concerned.

RI

5.5 Schedule Date: The latest vendor promise date.

RI

6.0 PREREQUISITES

6.1 Prior to preparing Work Packages, a Level 2 Master Project Schedule integrating engineering, procurement, construction and start-up must be developed.

6.2 Work Package development begins as Level 3 logic is developed with the initiation of Work Plans.

6.3 As Level 2/3 is accepted, Work Package scoping begins by grouping work activities into a manageable time frame.

7.0 RESPONSIBILITY

7.1 The Site Manager has the overall responsibility for the implementation of this procedure.

7.2 The Construction Control Superintendent has the general responsibility for the implementation of this procedure.

7.3 The Area Director is responsible for the plan of action outlined in the Work Package, and he is responsible for indicating his approval of the plan by signing the Control Sheet. He is also responsible for coordinating the planning efforts of all subcontractors with work in his area and for securing their approval by their signature on the applicable Control Sheet. In addition, he is responsible for revising the Work Package as required.

7.4 The Area Director, through the Area Planning and Scheduling Engineer, is responsible for preparation of the following sections of the Work Package:

7.4.1 Section D - Work Plan - Fragnets which reflect the detailed logic or sequence of work and make up the work plan. The Work Plan, Attachment 4.6 also includes quantities, manhours, crew size, etc. to provide backup data for activity durations.



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7.4.2 Control Sheet, Attachment 4.2, - illustrating approval sign outs, revision sign outs, Work Package Number and Title, etc.

7.5 The Senior Resident Engineer has the responsibility for providing engineering documents and material requirements for the Work Package.

7.5.1 The Office Resident Engineer is responsible for the "take off" by engineering drawing.

7.5.2 The Field Resident Engineer, through the Area Engineers, is responsible for preparation of the following sections of the Work Package:

7.5.2.1 Section A - Open Engineering Summary - Attachment 4.3, A listing of all open engineering items, such as: a missing procedure, a late drawing or specification, etc.

7.5.2.2 Section B - Open Material Summary - Attachment 4.4, A listing of all open material items - items which have not been received, released, or for which the delivery date is questionable.

7.5.2.3 Section C - Bill of Material - Attachment 4.5, A bill of material for all work activities covered by the Work Package. The bill of material shall list all permanent, engineered items - items which can be identified on a drawing, a bill of material, or other engineered lists.

7.6 The Area Director, through the Area Engineer, is responsible for maintenance of the Work Package and the Work Package Development Schedule.

8.0 PROCEDURE

8.1 General

8.1.1 A Work Package shall be approved for construction by the Area Director and issued in accordance with the Work Package Development Schedule (a minimum of 3 months prior to the start of construction work included in that Work Package).

8.1.2 When all construction activities are completed in a Work Package, the Work Package shall be "closed out" in accordance with the "revision sign out" process of a Work Package.



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8.1.3 If one or more construction activities in a Work Package is delayed or rescheduled for a lengthy period of time, the activity or activities and related engineering information should be removed from the Work Package and placed in another Work Package.

8.2 Work Package Development Schedule (WPDS) (Attachment 4.1)

8.2.1 The Area Director is responsible to insure that the Work Package Development Schedule is properly illustrated and that a Work Package will be ready for approval 3 months prior to start of construction work included in the Work Package.

8.2.2 The Area Engineer (AE) is responsible for originating and maintaining the WPDS. The WPDS is generated after Level 3 logic has been scoped into a Work Package and an identification number assigned. The WPDS is expanded or reduced as new Work Package numbers are produced or Work Package development is completed.

8.2.3 The typical phases of Work Package development that should be illustrated are:

8.2.3.1 Receipt of the Work Package Control Sheet with Work Package number from the Area Planning and Scheduling Engineer (APSE).

8.2.3.2 Assembling work plans into the Work Package by the APSE.

8.2.3.3 Receipt of Work Plans and Control Sheet from the APSE.

8.2.3.4 Development of the Bill of Material by the AE.

8.2.3.5 Approval for construction "sign off" by the Area Director.

8.2.4 The WPDS should cover a manageable time frame (approximately 9 months) and have a rolling time window as Work Packages are added and completed.

8.2.5 The WPDS should illustrate:

8.2.5.1 The point in time construction starts in each Work Package.

8.2.5.2 A bar for scheduled development, reschedule, and actual progress of each Work Package.

8.2.5.3 The status of each Work Package (.e.g. under development, complete, approved for construction, delayed, etc.) in the status column provided.



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8.3 Work Package Control Sheet (WPCS) (Attachment 4.2)

8.3.1 The WPCS is originated by the APSE and maintained by the AE. The WPCS is generated after a Work Package has been scoped from level 3 Logic and a Work Package identification number has been assigned.

8.3.2 The Work Package identification number is initially entered on this form by the APSE. The Work Package number is in the format 999A where:

8.3.2.1 The first digit (0-9) is the Area involved (e.g., RCB, RAB, etc.)

8.3.2.2 The second digit (0-9) is the major cubic (e.g., elev., etc.)

8.3.2.3 The third digit (0-9) is the minor cubic (e.g., room, sub area, etc.)

8.3.2.4 The fourth digit (A-Z) is the time interval involved. (Ex: Work Package 999B would follow in time sequence the construction work of Work Package 999A).

8.3.3 The "approval sign out" block is used to control and document Work Package development.

8.3.3.1 The contractor or contractors involved shall "sign out" the Work Package when their input is complete as determined by the Area Director.

8.3.3.2 The APSE should "sign out" the Work Package as soon as he has assembled all the related work plans into the Work Package. He then transmits these forms with their Control Sheet to the AE.

8.3.3.3 The AE should "sign out" the Work Package as "ready for construction" after he has assured all the planning and engineering information required is complete.

8.3.3.4 The Area Director shall "sign out" the Work Package "approved for construction" after he has determined the construction work contained in the Work Package can be accomplished in an orderly manner with the information available. The Area Director "sign out" should occur a minimum of 3 months prior to start of construction work in the Work Package.



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8.3.4 The "Revision Sign Out" block is used to control and document the Work Package revision process.

8.3.4.1 The Work Package is revised by the Area Director based on recommendations from his Area personnel.

8.3.4.2 In general, revisions would reflect major engineering or material changes, logic changes, unit rate changes, etc.

8.3.4.3 As revisions are made, the information revised should be "bubbled" and once the revision has been issued, the bubble can be removed.

8.3.4.4 The sections of the Work Package revised shall be "signed off" by the responsible party (e.g., AE, APSE, etc.).

8.4 The Work Package Open Engineering Summary (WPOES) (Attachment 4.3)

8.4.1 The WPOES is originated and maintained by the AE. The WPOES is generated after the Work Package Bill of Material is developed and stasured.

8.4.2 The WPOES is maintained and updated on a weekly basis by the AE to track open engineering drawing status and provide a reporting mechanism to the weekly area construction meeting.

8.4.3 The criteria for determining which engineering is open are:

8.4.3.1 Any drawing covering work in the Work Package but which has not been approved.

8.4.3.2 Any drawing covering work in the Work Package which has been approved but which contains areas applicable to the Work Package marked "hold".

8.5 The Work Package Open Material Summary (WPOMS) (Attachment 4.4)

8.5.1 The WPOMS is originated and maintained by the AE. The WPOMS is generated after the Work Package Bill of Material is developed and stasured.

8.5.2 The WPOMS is maintained and updated on a weekly basis by the AE to track open material status and provide a reporting mechanism to the weekly area construction meeting.



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8.5.3 The criteria for determining which material is open are:

- 1) Material which has not been ordered
- 2) Material which has been ordered but is late or historically late
- 3) Material which has been received and is in "hold" status.

8.6 The Work Package Bill of Material (WPBM), Section C (Attachment 4.5) is a complete listing of all the engineered drawings, material and equipment required to perform the work detailed by the Work Package Plan (Section D).

8.6.1 The WPBM is originated and maintained by the AE.

8.6.2 The WPBM is developed utilizing the Work Package Work Plan; engineered drawings and sketches; and Material Takeoffs as supplied by the Office Engineering group.

8.6.2.1 The Work Package Work Plan defines the work to be performed and is utilized by the AE in determining which drawings and sketches are required.

8.6.2.2 The engineered drawings and sketches are listed on the WPBM along with the engineered material and equipment necessary to perform the work outlined on the Work Package Work Plan.

8.6.2.3 The Material Takeoff is referenced to check the accuracy of the WPBM as well as the takeoff itself.

8.6.3 Development

8.6.3.1 Upon receipt of the Work Package Work Plan from the APSE, the AE determines what detailed drawings and sketches are required to perform the work. He lists these as well as their latest revision number in the appropriate column of the form.

8.6.3.2 Once the drawings are known, a detailed material take-off is performed for the scheduled work associated with each drawing.

8.6.3.3 An arbitrary Bill of Material Number is assigned to each unique material item per drawing and is listed along with the material description, quantity, and unit of measure. (The B.M. number is also posted against the work item on the WPWP for reference).



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8.6.3.4 The Office Engineering material takeoff by drawing is referenced and the purchasing/receiving information is entered. The accuracy of the WPBM and Takeoff is also checked.

8.6.4 Revision

8.6.4.1 The revision of the WPBM is the responsibility of the AE.

8.6.4.2 The need for a revision is determined by the AE when material requirements have been revised.

8.6.4.3 The WPBM is to be kept statused at all times by the AE. Status information should not require a revision to the WPBM but should be incorporated into the next revision.

8.6.4.4 A revision to this section constitutes a revision to the Work Package but may be issued separately (i.e., the Work Plan and Open Item sheets do not have to accompany the revision if they are not revised.

8.7 Work Package Plan (WPWP) (Attachment 4.6)

8.7.1 The Work Plan is originated and maintained by the APSE. It is generated to produce Level 3 logic and be an integral part of the Work Package.

8.7.2 Development

8.7.2.1 The APSE creates detailed logic that summarizes level 3 activities. He assigns a description and node numbers to each level 3 activity. The logic (gragnet) should appear in the space provided under "logic". He also lists the level 3 node numbers and activity description in the columns provided above the logic area. This listing should reflect both level 3 activities and sub-activities.

8.7.2.2 The APSE assigns a number to the WPWP as he generates each document. The WPWP number is in the format 999-999 where:

8.7.2.2.1 The first digit (0-9) is the Area involved (e.g., RCB, RAB, etc.)



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- 8.7.2.2.2 The second digit (0-9) is the major cubic (e.g., elev. etc.)
- 8.7.2.2.3 The third digit (0-9) is the minor cubic e.g., room sub-area, etc.)
- 8.7.2.2.4 The fourth through the sixth digit (000-999) is the sequential numbering of the WPWP.
- 8.7.2.3 The AE performs a material "take off" to support the activities listed on the Work Plan. He inputs these quantities and units to the Work Plan.
- 8.7.2.4 The Area Cost Engineer (ACE) enters unit rate and manhour information for each work activity in the appropriate columns.
- 8.7.2.5 The APSE and area construction supervision develop, from the data that has been entered, appropriate crew sizes and activity durations. This information is entered in the columns provided. The activity duration is entered on the activities in the logic area and also sent to Office Planning for incorporation into the computerized construction schedule.
- 8.7.2.6 As the AE develops the Bill of Material for the Work Package, he lists each material item number from the Bill of Material in the "Material Items" column to the associated construction work activities.
- 8.7.3 The APSE is responsible for revising the WPWP when:
 - 8.7.3.1 Logic is revised due to schedule impacts.
 - 8.7.3.2 Revised WPWP's received from the ACE due to unit rate changes.
 - 8.7.3.3 Revised WPWP's received from the AE due to material/quantity changes.
- 8.7.4 The originator of a revision to a WPWP should "bubble" the change. Once the revised WPWP has been incorporated and issued by the APSE, the "bubble" can be removed.

9.0 INSPECTION

9.1 Not applicable.



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10.0 QUALITY ASSURANCE RECORDS:

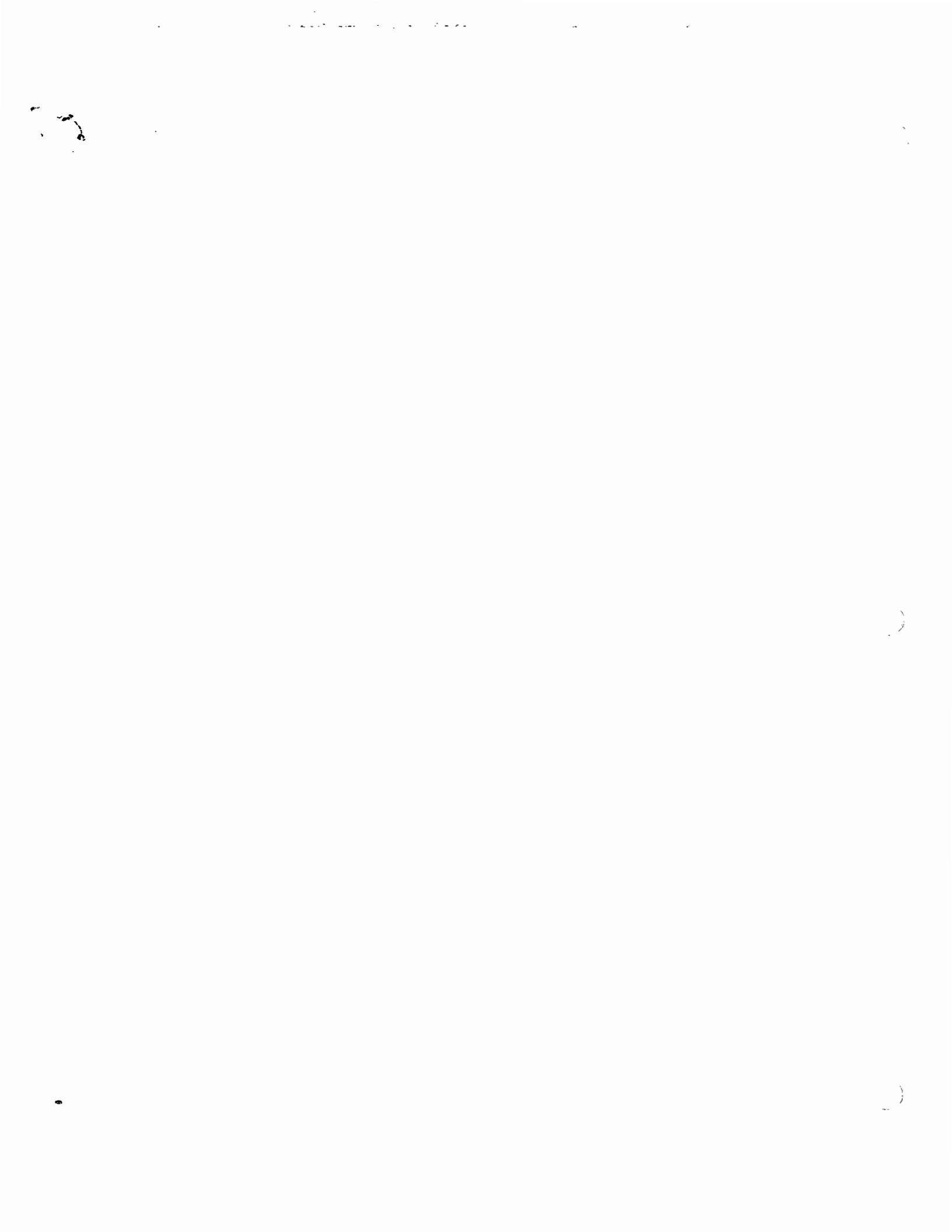
10.1 The following list of records designates the Quality Assurance Records generated per the requirements of this procedure. The records noted in this section shall be transmitted to the QA-Construction Records Vault upon completion of the record, by the individual/organization responsible for final sign-off.

10.2 Quality Assurance Record List

None

RI

Appendix C. Consortium Approach to Future Nuclear Plants



OVERVIEW

Introduction

The next generation of nuclear power plants will most likely not be a venture by a single company, but an owner consortium of several companies. Without the consortium approach, which many feel is the only approach to overcoming the risks involved in the next generation of nuclear plants, the success of future nuclear construction efforts looks dismal.

Consortium benefits

A consortium offers significant benefits:

- Each owner shares risks and obligations.
- Owners could phase in rate increases at a lower rate to minimize negative customer relations.
- The construction effort gains from a variety of personnel resources with different backgrounds and experience.

Consortium experience

Ownership and management of the following nuclear plants simulate the consortium approach:

- Standard Nuclear Unit Power Plant System (SNUPPS)
- Seabrook Station

The consortium of the future will probably be quite different from the SNUPPS and Seabrook examples.

SNUPPS

SNUPPS -- is the best example of a consortium experience thus far in the U.S. nuclear industry. This effort was established by 5 U.S. utilities planning to build 6 standardized nuclear units in 4 locations:

- 2 in Missouri
- 2 in Wisconsin

- 1 in New York
- 1 in Kansas

How SNUPPS was formed -- The utilities formed Nuclear Projects, Inc. (NPI), representing the utilities managing the design, licensing, procurement, and quality assurance activities. The NPI group, called "the SNUPPS staff," was assisted by engineering, licensing, and QA personnel from each utility.

Design -- SNUPPS selected an A/E to design the power block and make most procurement for each site. SNUPPS selected one vendor for each major equipment supplier (e.g., valves, cable, steel). Each utility had separate equipment contractors but had almost identical contracts. The SNUPPS staff managed these contracts. The utilities selected their own site A/Es.

Construction -- Only 2 plants were built - 1 in Missouri and 1 in Kansas. The other 4 were cancelled because of inability to obtain state licensing or because of slow load growth. Both plants were built by the same constructor; the plants power block are identical down to the knobs on bathroom doors.

SEABROOK

Initial management -- Seabrook began with 16 owners in 5 states. Public Service of New Hampshire (PSNH), the majority owner, was the licensee and managed the project on behalf of the owners.

Management under New Hampshire Yankee -- In 1984, New Hampshire Yankee (NHY) was formed as the managing agent for all the owners. For ease in administering benefits, payroll, policies, etc., NHY was a division of PSNH. NHY did the following:

- Named its own CEO and president
- Brought in its own employees who developed their own production control system (PCS)

- Reported as an Agent to the joint owners
- Presented a monthly presentation on cost and schedule

All 5 states' public utility commissions requested and reviewed all PCS material.

Executive committee -- The joint owners assembled, appointed, and endorsed an executive committee of the 3 majority owners: PSNH, Eastern Utility Associates, and United Illuminating. This executive committee was actively involved and participated in the critical decision-making issues.

Transfer of license to NHY -- Today 12 owners in 3 states remain involved. NHY will disengage from PSNH, incorporate, and accept the transferred license. The owners fund the project as dictated by this agent, NHY.

In this appendix

This appendix addresses the aspects of a consortium approach to solving the problems of future nuclear construction projects.

CONSORTIUM CONSIDERATIONS

Introduction

Discussions of the consortium approach produced the following considerations which would impact management of the construction effort:

- Operating organization
- Coordinating organization
- The contract
- Management group
- Flexibility
- Arbitration

Operating Organization

The NRC will license only one operating organization. Clearly established and identified up front, this organization must be able to attract and retain top quality individuals. The operating organization, which works for the owners, may or may not be one of the owning organizations.

Coordinating Organization

Multiple decision makers or committee decision groups are extremely difficult to manage, but they have value which should not be overlooked. With a strong, competent coordinating organization, committees with members from multiple owner organizations and varied backgrounds can function effectively. The coordinating organization must be responsive to the needs of the schedule and work force.

The Contract

A good, clear agreement (contract) between owners is crucial. Such a contract should:

- Provide owner influence on the project proportional to ownership share.

- Thoroughly define the types of cost to be monitored and reported, but not tie directly to specific dates, schedules, or quantities.
- Address and provide for an up-front project control system.

Management Group

Management of the various interfaces will be key to the success of the consortium approach and will influence the management and flow of information to and from the construction effort. To manage the consortium contract, a separate group should be set aside with the following responsibilities:

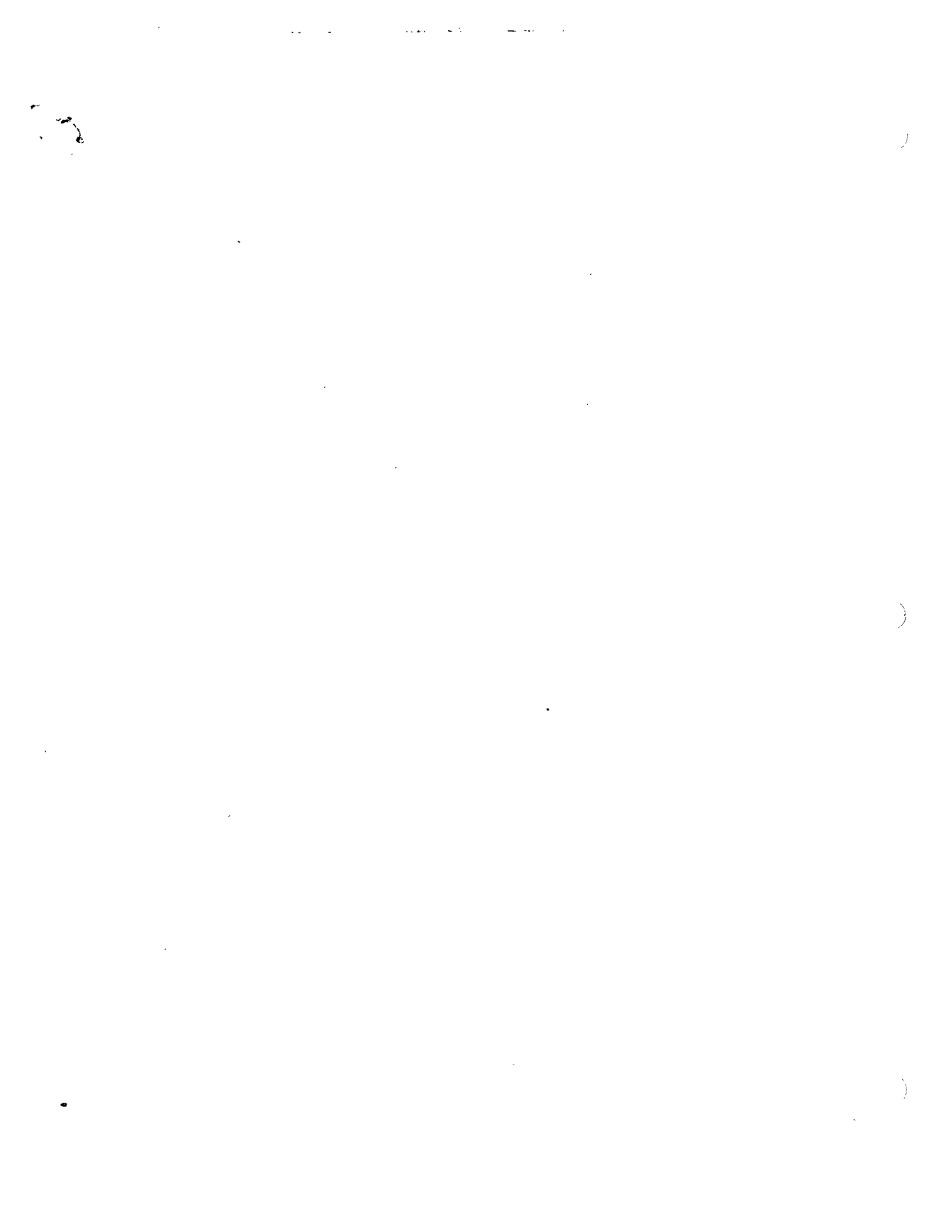
- To minimize adversarial relationships by:
 - Effective communication with all parties
 - Answering all questions promptly
 - Trying to see the other point of view
- To provide sufficient consortium involvement to balance prudence without meddling in every site decision.

Flexibility

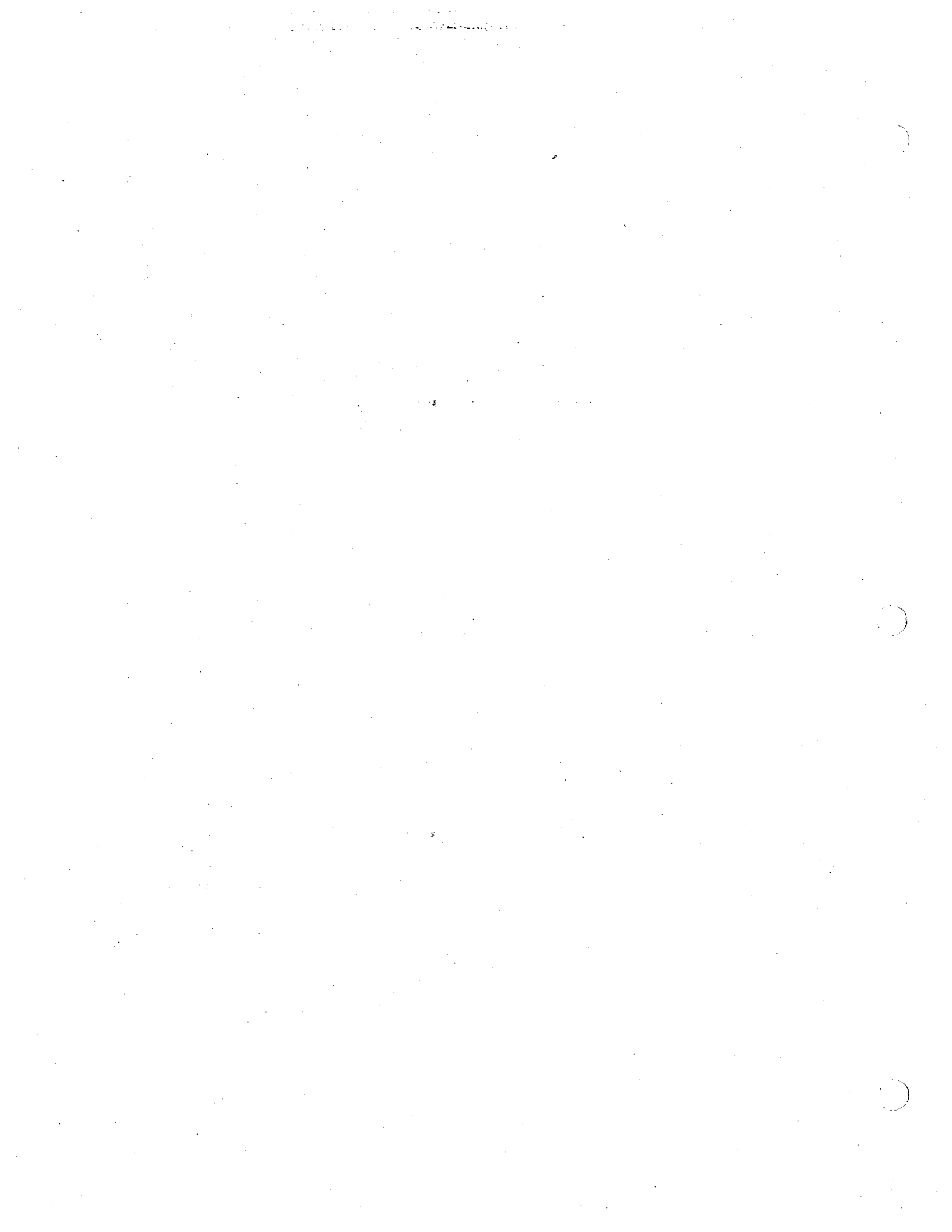
Because of the history of change associated with projects of this magnitude, consortiums must be flexibly structured. Provisions for dropping and adding participants should be agreed to in advance. Efforts should assure changes in participants, procedures, and approaches have minimal impact on the construction effort.

Arbitration

Good arbitration/dispute resolution procedures must be established. These procedures should consider that the owners are not only partners, but may also be competitors in other areas. Each consortium member may have different ultimate objectives in the partnership.



Appendix D. Modular Approach to Plant Construction



OVERVIEW

Introduction

Modularization has been a recurring topic discussed by industry representatives participating in this program. For nuclear to be a viable option for future additions of capacity, a significant reduction in costs and shortened construction schedules must be achieved. Many look to the success of modularization in the shipbuilding, petro-chemical, and other industries as enhancing the possibilities for these needed changes.

Past Prefabrication Efforts

Prefabrication efforts within specific disciplines in the past have included:

- ◆ Piping subassemblies
- ◆ Instrument panels
- ◆ Light manufacturing of steel shapes
- ◆ Equipment skids

Limited Experience of Modularization on Nuclear Projects

Nothing of the scale anticipated with modularization described in this program (reference WS VIII) has been tried on an entire nuclear project. The limited experience with modularization on nuclear projects did not warrant discussing its effects in the development of this report.

In This Appendix

The appendix addresses the perceived concerns and considerations of the owner and/or construction manager in applying the modular approach to plant construction, testing, and subsequent operation. These considerations should help in the future when the recommendations from the report text are applied to whichever approach(s) is chosen.

MODULARIZATION CONCERNS

Introduction

The following considerations related to the modular approach to plant construction were identified:

- ◆ Up-front commitment to modularization
- ◆ Modified plant layout
- ◆ Earlier design completion
- ◆ Component standardization and vendor preselection
- ◆ Management of off-site activities
- ◆ Other material issues
- ◆ Standard QA program
- ◆ Standard vendor/owner programs
- ◆ Code reevaluation
- ◆ Project labor agreement

- ◆ Cash flow analysis
- ◆ Risk analysis

Up-front Commitment to Modularization

The up-front commitment of all involved parties to the modularization approach is key to the success of that approach. From conceptual through detailed design, modularization should be incorporated in all of those areas where it is determined to be the economical choice. This commitment will impact the approach to the construction effort (e.g., plans for placing modules instead of stick building, control of field changes).

Modified Plant Layout

A whole new approach to plant layout may be appropriate. Flattening the layout of buildings instead of using the customary vertical layout may provide benefits and reduce risks with the modular approach. A modified plant layout would impact material and personnel accessibility, crane utilization, and other construction management issues.

Earlier Design Completion

An earlier, essentially complete design is necessary. Sufficient time (possibly 18 months) before beginning construction must be provided for material and component procurement, fabrication, and assembly of modules. A more stable plant design and fewer field changes will result.

Component Standardization and Vendor Preselection

The degree of standardization necessary to enhance modularization must be determined. True standardization requires component dimensions and outline drawings up front. Therefore, preselection of vendors becomes a part of this approach. Although anti-trust and free-trade restraint concerns which may require local considerations may result, vendor preselection is a major advantage to standardization. It may be appropriate to preselect major equipment and "envelope" parameters for other critical items.

Managing Off-Site Activities

Managing the numerous interfaces will be an added challenge. The module assembler(s) must be integrated into the production control system (PCS) data base. Such integration should be thought of as managing construction activities away from the construction site. The effect on the complexity of the PCS depends, to some degree, on the freedom given these assembler(s) (e.g., freedom to purchase components within the modules). Decisions on purchase by the module assembler, the designer, or the constructor will influence the interfaces and PCS impact on this issue.

Other Material Issues

As part of the up-front project and construction plan, practices and responsibilities for material and component procurement, damage protection, and storage must be defined. Impacts of site delivery on the construction schedule and storage issues must be considered.

Standard QA Program

As part of the standardization, one standard QA program must be developed. This program will define levels of QA responsibility in particular inspection responsibilities for vendor, fabricator, constructor, and owner. A goal in defining responsibilities is the elimination of duplicate inspections. Some items to be considered are the ASME stamp on code piping and receipt inspection for transportation load-induced damage on modules.

Standard Vendor/Owner Programs

Modularization may require a change in attitude on how we deal with each other—more participation in the assurance of quality. A vendor program(s) may be acceptable provided it is compatible with the owner's program and conforms to 10CFR52. Identical forms would be used among vendors, suppliers, and fabricators. Compromise would be needed when the supplier is under his own acceptable program.

Code Reevaluation

The modularization approach provides an opportunity for code reevaluation. A "Modularization Code" or some provisions and additions to sections of current codes may be needed.

Project Labor Agreement

A Project Labor Agreement that addresses union jurisdictional issues must be established. This agreement must include the module fabricator(s) and would cover only site activities. The fabricator(s) would handle offsite activities independent of the owner or any Site Labor Agreement. Where fabricator's expertise is needed for specific site applications, the fabricator would manage the activity using site labor.

Cash Flow Analysis

Before a commitment to modularization is made, a real dollar cash flow analysis for each construction alternative must be available. Such an analysis would reveal options which could reduce utility costs (e.g., broader financial base, equity interest, and/or consortium).

Risk Analysis

A new set of risks is associated with modular construction (e.g., sensitivity to schedule-damaging events, earlier commitment and outlay of funds, owner control, procurement and inspection responsibilities, partnership arrangements). An analysis must be provided to compare these

risks to those familiar risks associated with conventional construction. Approaches should be considered that allow sharing of these risks with vendor/fabricators (e.g., bonding work based on quality and scheduled delivery of critical modules; incentives such as up-front involvement in planning, commitments, and contingency plans).

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