

PLANNING CONSTRUCTION ACTIVITY TO SUPPORT THE STARTUP PROCESS

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to
Support the Startup Process**

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The Construction Industry Institute
Cost/Schedule Controls Task Force**

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INTRODUCTION

The Challenge

Owners planning any new facility, particularly one which is a production facility, usually are intent upon that facility being available by a specific date to meet a market goal. Thus, they desire that any activity with the potential to influence that availability be carefully planned and made as efficient as possible. CII Publication 6-3, *Model Planning and Controlling System for EPC of Industrial Projects*, describes the procedure for optimizing the process. That publication asserts that while facility startup itself must be accomplished in an efficient and orderly sequence, it is equally important that all preceding construction activity be completed in time to support the startup process, and that procurement and engineering be completed to support the construction process.

When speaking of startup, one is referring to startup of *systems* within the facility. A *system* is any assemblage of structural, mechanical, electrical and instrumentation components providing a function or service. Just as a work breakdown structure has many levels, many levels of systems exist within a process or manufacturing facility. In effect, the entire plant is one huge system that is made up of many separate systems and subsystems.

This publication is concerned with the planning of construction to support startup. While some discussion of startup is included to help the reader understand the constructor's role in the process, major emphasis is on how the constructor converts from a mode which is most cost-effective from a construction viewpoint to one which is most cost-effective from an overall plant viewpoint. To explain, Figure 1 is a barchart representation of the major construction activities involved in the grass roots construction or major expansion of a typical process plant.

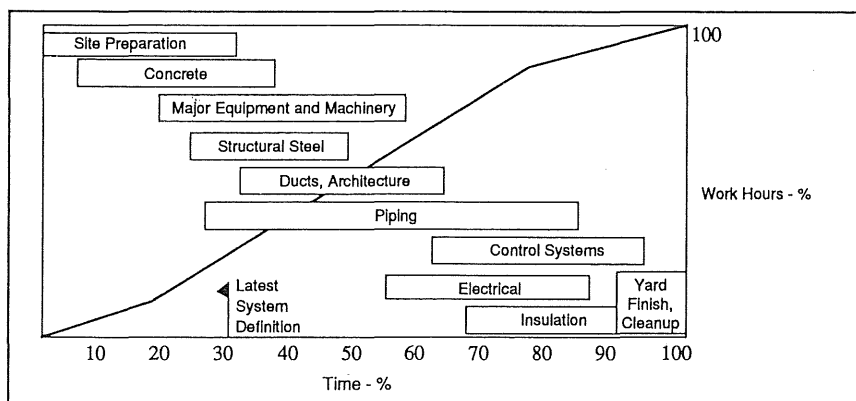


Figure 1. Construction Phase—Typical Chemical Plant

Referring to this chart, the site preparation, concrete, major equipment and machinery and structural steel activities generally can be categorized as *sequence* activities since work within most of them must be done in a strict sequence. On the other hand, piping, duct work, electrical, most insulation activities, and initial control system installation activities are *production* activities since work within each often is not strictly sequenced and can be scheduled by area to achieve maximum production. By the 30 percent point of construction, system definition must be communicated to the construction force since it is the basis for detailed startup planning. When construction is about 70-85 percent complete, system completion and precommissioning activities begin, and attention becomes focused on the proper sequencing of bringing entire systems on line. The activities from that point forward are categorized as *system* activities.

A simplified representation of these three distinct groupings or stages of the construction phase and their relationships are shown in Figure 2. The overlap between the *production* and the *system* stages, represented by the "cloud" on Figure 2, is the critical period during which the execution process must be converted from production logic to system logic. (An example project is also included in Appendix C.)

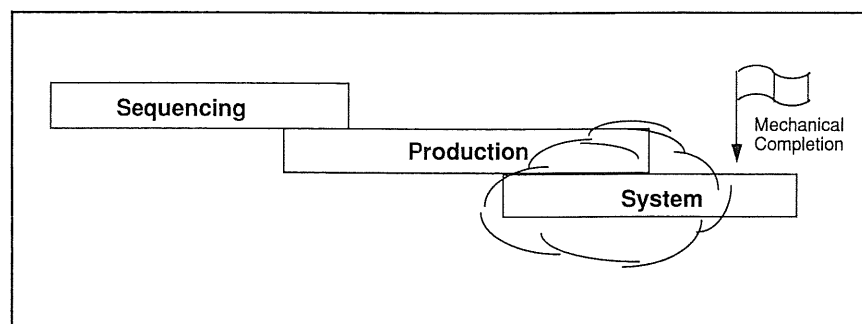


Figure 2. Construction Stages

Definitions

Numerous terms unique to the startup process are included in subsequent discussion. Definitions of these terms are provided in Appendix A.

Other Relevant CII Publications

The subject described in this report is a subset of the subject of CII Publication 6-3, *Model Planning and Controlling System for EPC of Industrial Projects*. Many subjects referenced in this document are addressed in more detail in that report. Also, many of the planning concepts are discussed in further detail in CII Publication 6-4, *Contractor Planning for Fixed-Price Construction*. Many subjects referenced in this document are addressed in more detail in that report.

THE STARTUP PROCESS

The overall startup planning process must begin early in the life of the project. The exact timing of long-range systems planning and the timing of a conversion from area to system scheduling will vary from one project to the next. The earlier the planning begins, however, the less potential for startup problems that result in increased costs and delays. Some factors that must be considered to make these decisions are discussed in this chapter.

Type of Project

Process projects range from a *grass roots* plant in a remote area to a *turnaround* in an existing plant. The scope of a *grass roots* plant will typically include the necessary offsites (infrastructure) as well as the process area. Considerations for planning a new process plant or *add-on* facility outside the *battery limits* of existing process plants are similar to those for planning a *grass roots* plant.

The simplest startup involves one process unit that can be started independently of other units. This usually means that existing utilities are in place. For projects involving *multiple startup phases*, the startup planning must be considered during the detailed engineering phase since frequently each startup phase may utilize common offsite facilities and utilities. This can affect valving configurations, electrical safeguards and access to operating areas that have already started up.

A variation of the *multiple startup* phase project is a *multiple train* (production line) project. Normally only one train is started at a time. The main difference between *multiple startup phase* and *multiple train* projects is that the construction is desired to be completed for all trains or is at least in the 90-95 percent range prior to startup of the first train.

A *revamp* project occurs within an existing plant that may or may not be in production while construction work is in progress. The purpose of a *revamp* is normally to de-bottleneck a process, upgrade the technology of a plant or convert to a different process. In many cases it will include a shutdown for piping, electrical and instrumentation tie-ins. The shutdown may be at any time during the construction duration and may be coordinated with a routine maintenance shutdown. When simultaneous with a *maintenance turnaround*, the construction activities must be coordinated with the maintenance contractor. Frequently, extensive pre-shutdown work is required. Materials planning is extremely important for this type of project due to the high cost of any shortages (lost plant production, unfavorable working conditions). The schedule is almost always a driving force in planning.

A *turnaround* always occurs in an existing plant, with the bulk of the work performed during a planned shutdown usually for maintenance purposes. Materials planning is again important since a material shortage could result in lost production time. Planning is frequently done by the hour since timing is so critical. Rehearsals are sometimes used. Normally, systems planning for turnaround type work is fully integrated with area scheduling from conceptual design of the project.

The Stages of Startup

The typical process plant will accomplish startup in stages. Given below are typical terms and definitions for these stages. Manufacturing or power plants will use these stages only to the extent applicable.

Precommissioning. The cleaning and checkout of individual components and subsystems. Completion of these activities constitutes Mechanical Completing (See Appendix A for more detailed definition.)

Commissioning. The operation of the systems, some with test medium. Completion of these activities constitutes Plant Commissioning (See Appendix A for more detailed definition.)

Raw Material Introduction. The introduction of fuels, feedstocks and other liquids and gases normally required for full operation of the plant.

Operation Testing. The test running of the plant under partial load conditions. Successful completion of this stage constitutes Startup Completion.

Performance Verification/Acceptance Tests. The test running of the plant under full operating conditions to verify actual performance characteristics.

Commercial Operation. Putting the plant into commercial production.

Order of Startup

As a general rule, systems will be started in this sequence:

- Control room or buildings to house operating staff
- Power for facilities and equipment
- Utilities—steam, air, water, nitrogen
- Instrumentation and controls
- Storage facilities, load out
- Process facilities

Factors Affecting System Completion and Startup

A number of factors and considerations are involved in the system completion and startup process. Those of greatest significance are described in following paragraphs.

Offsites. Although very few schedule constraints from outside influences are expected, the owner usually will need to commission all offsites prior to commissioning any other part of the plant.

Operations Requirements. Operations personnel frequently have significant input in how a plant is started up or restarted. This input will involve the sequencing of the startup of individual systems, the duration of the startup and any individual system milestone dates to be met.

For most projects, the owner's organization is responsible for developing the concepts and details of the startup schedule. The design engineering contractor frequently provides some level of service for this activity. The exception to this rule is generally when a plant is owned by investors who are not familiar with operating plants; in this case, a contract operator may be used to provide startup service. For new process facilities, the owner's operations team will probably be in a learning mode, will probably not be familiar with each other and will not have previously worked together as a team.

Certain plant operating requirements and standard practices must be considered when developing the startup plan. Typical questions to be answered are:

Should we service test utilities instead of separate hydrotests?

Is flushing required and when? Will hydro draining by conventional methods suffice or must operations do a water test run?

Should operator training be conducted during construction, particularly on distributive control systems?

Who will inspect or witness certain activities?

Who will provide engineering support?

Who has steam blowing responsibilities?

What is the energizing procedure?

Who will install and remove temporary blinds and strainers?

Who will install catalyst, dessicants and other vessel packing?

Must construction assistance be provided during startup? If so, by whom?

What are in-line instrument installation practices?

Will hot-bolting be required?

Who has lubricant application responsibility?

Who operates equipment and turns valves and switches?

What are the labor jurisdictional considerations?

The Startup Plan should include a detailed checklist and schedule for all activities that must be performed both prior to and during the startup operation. The plan will also include identification of individuals or groups responsible for each activity.

The schedule in the Startup Plan will include a sequence in which systems are to be commissioned (such as steam, raw water, firewater, nitrogen, natural gas, and butane); however, the word “system” is meant to refer to several services which together make up a functional system (an example is the raw water treatment system in a water treatment plant which may require several services such as raw water, cooling water, steam, acid, and caustics). The owner’s Startup Plan will show any required lag times between commissioning of systems or plants.

Use of Permanent Facilities. It is often convenient and economical to use permanent facilities during construction and to support startup. Unless a system is pre-existing, this will put a priority on completion of those needed. Examples might include the following:

- Firewater or service water system for construction water requirements
- Permanent electrical transformers and switchgear for temporary power
- Plant air system for construction compressed air needs
- Permanent warehouse or storage tank for temporary warehousing
- Permanent vessels for storage of demineralized water for hydrotesting
- Steam for heating lubricating oil during lube oil flushing

Safety Regulations and Practices. Startup activities must comply with operating safety regulations and practices. When electrical systems are energized, the workmen must adhere to rigid lockout procedures to make certain that no one can be put in the position of working on an electrical system or electrical equipment that has been energized. Energized electrical equipment and lines (whether overhead, in trays or conduit, or underground) pose additional safety risks.

Commissioning of certain piping systems also involves special safety considerations. Once hydrocarbons or other potentially hazardous services are introduced in an area, all “hot work” in that area must be performed under strict guidance from the operations and fire and safety personnel. This will require that the operations personnel assure that the area is free of hazards. Only after this assurance will a permit be issued to the construction personnel to start work. Such a permit should include a time limit; therefore, the permits will have to be renewed on a periodic basis, usually each shift. Commissioning of a sewer can present similar problems since it can potentially carry flammables that might originate anywhere in the plant.

Contractual Requirements. Contract documents may include definitions of *mechanical completion*, *commissioning*, *startup completion* and *commercial operation* and outline responsibilities of each project participant to achieve each of these milestones. This is a necessity on fixed-price projects. Contracts may also include milestone dates for completion of specific parts of the plant and/or achievement of intermediate milestone dates for commissioning of certain process systems.

Plant Configuration. Because of the plant layout and configuration, some systems may need to be commissioned in increments. In some cases it may be impossible to commission a partial system because a design requirement to minimize leaks restricts the inclusion of valves and blinds that may be used to isolate parts of the system.

Weather Factors. If a project is located in a harsh climate with extremes of hot or cold, the completion of construction and beginning of commissioning activities may be dictated by the weather. For example, hydrotesting must be done with a fluid that will not freeze. This may introduce environmental problems in that the antifreeze and/or fluid used to decontaminate the line after testing requires controlled disposal as a hazardous waste.

Leak detection in a rainy climate is extremely difficult. Also, performing construction services inside an unairconditioned building in a hot climate can have a significant impact on productivity.

Regulatory Factors. Some plants are located in areas where local building inspection organizations have jurisdiction. Other plants, such as nuclear power plants, have extensive involvement by government inspectors at critical points during the construction and startup phases. In both cases, these inspection milestones must be inserted in the schedules.

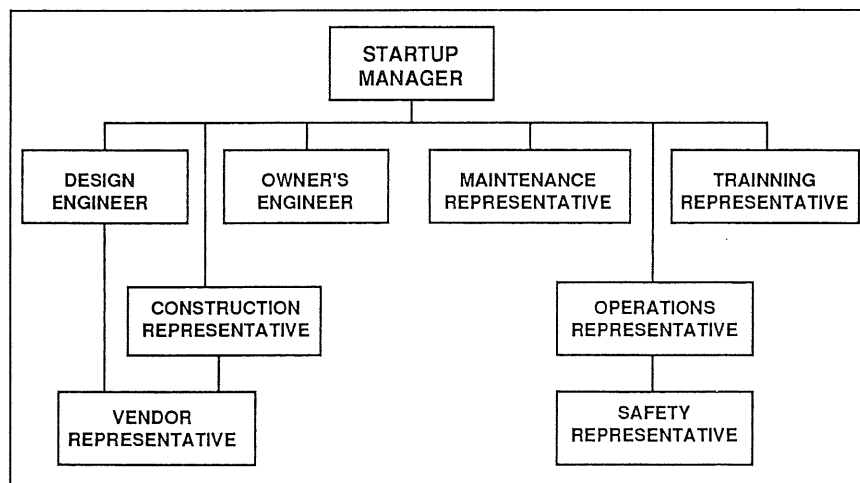


Figure 3. Typical Startup Team Organization

Jurisdictional Restrictions. Operating and maintenance personnel come on site prior to startup for training purposes. They also may be designated to perform certain of the startup functions. Thus, it is essential that planners determine who will do the work and in what sequence.

At some jobsites, labor jurisdictional rules come into play. These rules affect allocation of work among operating, maintenance and construction personnel and among the several trades, and must be in accordance with labor agreements affecting the project to avoid the potential for adverse labor problems.

The Startup Organization

The startup organization is responsible for getting the plant safely and efficiently commissioned and started while considering all parties' interests. The first step in defining this organization is the development of a Division of Responsibility Matrix, which catalogs responsibilities during the startup phase. This matrix will show responsibilities for the engineer, constructor, vendor representatives, project personnel, operations personnel and maintenance personnel. On a fixed-price project, this matrix should be included in the bidding documents or presented in pre-bid discussions. On a reimbursable project, it is advisable that it be available at about the project's 30 percent construction completion point and no later than the 50 percent point. (An example is in Appendix B).

The startup team is formally created and refinement of original startup planning commenced when the project is 50-70 percent complete, although startup representatives will have participated in general planning from conceptual engineering. The typical organization of this team is shown in Figure 3. General responsibilities of the individuals on this team are as follows:

Startup Manager. This individual normally will come from the owner's operating staff, but may come from the constructor, the engineer or an outside consulting firm and will coordinate the team's activities. Whatever the manager's source, it is imperative that this individual be thoroughly knowledgeable of the process involved.

Design Engineer. This individual represents the design engineering organization and should be familiar with the process, power, control and mechanical systems. More than one individual can be assigned, but it is desirable to keep representation to as few as possible. This representative serves as the technical advisor.

Construction Representative. This individual must be familiar with construction activity to date and be in a position to coordinate future construction activity to facilitate the startup process.

Vendor Representatives. These individuals represent their manufacturing firms as technical experts on the assembly and startup of major items of engineered equipment (turbines, compressors, other rotating equipment, water treatment package plants and other package equipment) which require field assembly.

Owner Engineer. This representative is from the owner's organization or from the owner's construction manager's organization and will coordinate any owner participation in startup. This individual should be familiar with the plant's process and included systems.

Maintenance Representative. This individual is assigned to the team to coordinate resolution of any maintenance problems that develop during startup activities.

Operations Representative. This individual is from the future operations staff and will represent operations' interests during the planning and actual startup.

Training Representative. Since training activity will parallel startup on the various systems, this individual will coordinate the operator training schedules with the startup schedule.

Safety Coordinator. This individual must represent both construction and operating safety interests.

PLANNING CONSTRUCTION TO SUPPORT STARTUP

In consideration of the requirements of startup, the planning of construction activity to support that startup can begin. This chapter will provide the basics involved. Appendix C provides a detailed example.

Methodology

Almost all process and manufacturing plants are built with the use of either process flow diagrams or mechanical one-line diagrams. These diagrams show the various process, utility and mechanical systems required to support the plant from the receipt of raw materials through shipping of the finished products. The diagrams also are the starting point for detailed engineering. As the configuration and layout of the plant is developed to optimize the manufacturing process, the engineering emphasis gravitates toward an area basis because construction is most efficiently accomplished if done by area. The logic required for orderly completion of the systems, however, ultimately returns as the primary basis for construction activity planning and the development of area detailed, look-ahead schedules. Up to that point, construction within an area can be planned to proceed in whatever order seems most efficient for the constructors. When that point is reached, however, the sequencing of area work becomes governed by the dates system components must be available for testing and startup. This transitional phase, when construction activity must shift from area orientation to system orientation, is always a hectic time for any project since construction is near the peak of activity. A systematic, logical approach is needed to make this transition smooth.

To illustrate the general approach involved, consider the process portion of a project as represented in Figure 4. This is a project with four construction areas (1-4). Within these areas are three Process Units (I-III), which are served by Systems A and B. Components of the two systems are identified by a letter (representing the system) plus a two-digit number. The first digit in the number represents the area in which the component is located, and the second digit is a sequential number identifying the component itself within the area. A new number is used each time the specifications of the component change (e.g., a pipe changes from 8" to 6").

In developing the overall schedule logic, the planners must first consider the sequencing required to complete each component of each system to support the startup plan. For this example, assume these units must be started in sequence — I, II, III. To startup Process Unit I, the unit itself must be in place plus all components of Systems A and B leading to and tying into it. These components must be given schedule priority over components servicing