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DESIGN-BUILD COMBINED CYCLE POWER PLANT PROJECT MANAGEMENT

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ABSTRACT

To successfully complete a fast track combined cycle design-build power plant project, management must maintain full awareness of all phases throughout the entire project. A successful team uses phase integration to make better technical and commercial decisions allowing them to complete required deliverables within scheduled deadlines and budget constraints. Phase integration will lead to long-term project success by optimizing resources and avoiding hidden costs later in the project.

Combined cycle power plant technology involves using combustion turbine generators to produce electric power. The exhaust from the combustion turbines is used to heat boiler water into steam in heat recovery steam generators (HRSG's). This steam is used to drive a steam turbine generator, which also produces electric power. The de-energized steam is then condensed and pumped as water back to the heat recovery steam generator.

Phase integration will require additional costs for resources and services that are not standard to a classic non design-build project. By managing these additional budgeted costs along with schedule progress, total unplanned costs due to liquidated damages; unplanned project acceleration, rework, and partner litigation can be eliminated.

KEYWORDS

Phase Integration, Design-Build, Fast Track, Coordination

1. INTRODUCTION

Design-build technology, from an owners' perspective, is a simple concept that provides the client one contractor responsible for all engineering, construction and commissioning services. Design-build technology, from the contractors' perspective, should be a philosophy that allows the implementation of phase integration throughout the life of the project

1.1 Project Phases

The phases of a design-build project are Engineering, Procurement, Construction and Commissioning. A classic design-build contractor will provide full services for each phase of the project. The engineering phase produces design documents for procurement and construction. The procurement phase produces physical equipment and detailed design documentation. Construction uses design documents and physical equipment to build the plant. Commissioning then turns a constructed plant into operating systems as part of a fully functioning power plant.

1.2 Design-Build Philosophy

A classic design-build contractor assumes full responsibility and risk for all phases of a project. The design-build contractor may also choose to employ subcontractors, or pursue contractual partners to perform specific phases of the project. Although a partnership or consortium will divide the risks and benefits that the contractor will assume, full design-build project responsibilities still lie with the partnership or consortium. These different arrangements may change how phase integration is implemented, however successful phase integration will provide beneficial results in each design-build arrangement.

1.3 Fast Track Schedule

Fast track project schedules overlap phases of the project to shorten overall project duration. Fast track schedules are standard for most new power plant projects. A summary schedule for a combined cycle power project is shown in Figure 1.

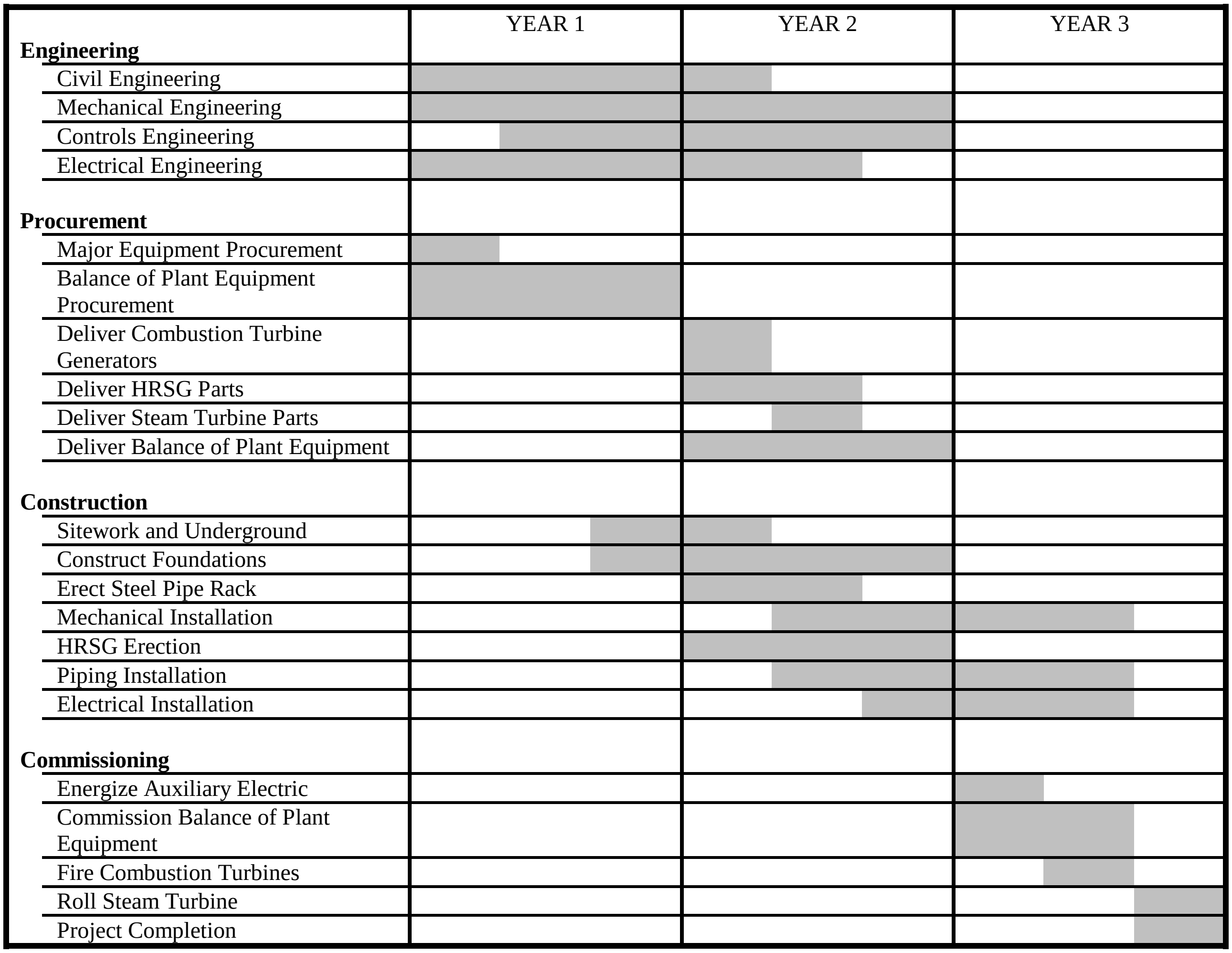

Figure 1: Fast Track Combined Cycle Project Summary Schedule

1.4 Phase Integration

Project phase integration is the ability for a team to assess overall impacts and optimize each phase's deliverables to obtain maximum value for the project as a whole. Phase integration must begin with the merger of construction and commissioning ideas into the design and procurement phases. The ability for a team to enact changes that will beneficially affect the outcome of the project becomes more difficult as the project progresses. The costs to perform these changes also increases drastically as a project progresses, consequently it is necessary to seek all phase involvement from the beginning of a project. Results of phase integration include constructability review of design deliverables, prefabrication, innovative design strategies, beneficial scheduling tools, and operational friendly power plants.

1.5 Scope Definition

Scope is defined as all work that must be done in order to design and build a project that meets specified requirements. Project scope will be determined though a combination of contractual requirements, permitting requirements, partner requirements, and equipment supplier requirements. Project scope leads to the definition of required deliverables. Each phase is required to produce deliverables that represent the completion of a specific part of that phase. For example, the engineering phase provides drawings, procurement provides plant equipment, construction provides physical structures, and commissioning provides operating systems.

2. IMPLEMENTATION OF PHASE INTEGRATION

Phase integration must occur throughout the entire fast track project. This will require additional manpower to develop and implement new concepts. Some concepts introduced by phase integration may also require additional procurement and engineering costs. These additional costs should be weighed against the projected savings obtained. It is important to weigh these options by assessing both technical and commercial benefits. By preplanning a project to use phase integration these additional costs can be forecasted and budgeted. Then by managing these additional budgeted costs, along with schedule progress, total unplanned costs and delays in schedule completion can be eliminated. A long term company wide benefit from using phase integration is the formation of cross trained project teams whose members are able to understand all functions and operations involved in the design, procurement, construction and commissioning of a combined cycle power plant.

Starting with preliminary design, the engineer must evaluate the impacts of his design on procurement, construction and commissioning. Preliminary engineering deliverables are important to allow for the procurement of plant equipment and the start of construction planning. Through procurement, equipment suppliers not only provide physical equipment, but also provide design information to aid engineering in completion of detailed design. Next, construction must provide commissioning with system completion. Finally, commissioning must use deliverables from all other phases to demonstrate to the owner operational reliability of commissioned systems.

2.1 Vendor Design Information

The most common problem resulting in delayed engineering design is lack of vendor information. Most combined cycle power projects have very similar equipment requirements. Without reviewing a specific project design, one can be fairly certain that a combined cycle project will consist of multiple combustion turbine generators, a minimum of one steam turbine generator, multiple heat recovery steam generators, underground circulating water pipe, a structural steel pipe rack, water treatment equipment, miscellaneous horizontal and vertical pumps, and pre-engineered buildings. Standard plant equipment can be purchased through preferred vendors that should have standard engineering design information. The design-build contractor should pursue agreements with preferred equipment suppliers that can provide typical shop drawings and engineering data used to initiate detailed design. Also make this arrangement profitable for the supplier by providing bonuses and guarantees for new additional work. This expedited design information will lead to advances on the schedule providing positive schedule float.

2.2 Project Planning and Scheduling

Construction driven scheduling

Engineering must support a construction driven schedule. To begin the schedule process, the engineer must provide the constructor with adequate preliminary design information. The constructor will use this information to produce a baseline construction schedule. The preliminary design information should consist of estimated foundation depths, underground utility layouts, plant equipment arrangements, piping & instrumentation drawings, electrical one-lines and raceway drawings. This preliminary construction plan is then combined with hard and soft delivery dates and final design deliverables to produce a project CPM schedule. Initial plans and schedule revisions must be communicated between all phases of the project. After site mobilization, the constructor must take ownership of the project schedule to drive engineering and procurement towards the common goal of project completion.

The project CPM schedule

Every design-build project should work towards a single overall schedule. Multiple schedules between equipment suppliers and contractors, or consortium partners will result in unsuccessful schedule management. Multiple schedules allow for conflicting schedule information, and poor planning due to the lack of proper information. This in turn leads to lack of faith in the project schedule and lack of direction. As part of initial project negotiations, the major equipment suppliers and project partners must agree on establishing and maintaining one master CPM schedule. This CPM schedule should include major equipment delivery dates, owner interface dates, and basic fragnets of engineering, procurement, construction and commissioning activities. Once agreed to by all parties, the schedule will then be resource loaded. The CPM schedule must not get too detailed that it becomes a burden to update or modify. The CPM schedule needs to be only detailed enough to use in planning manpower requirements and evaluating project schedule status. An example of two CPM Schedule fragnets is illustrated in Figure 2.

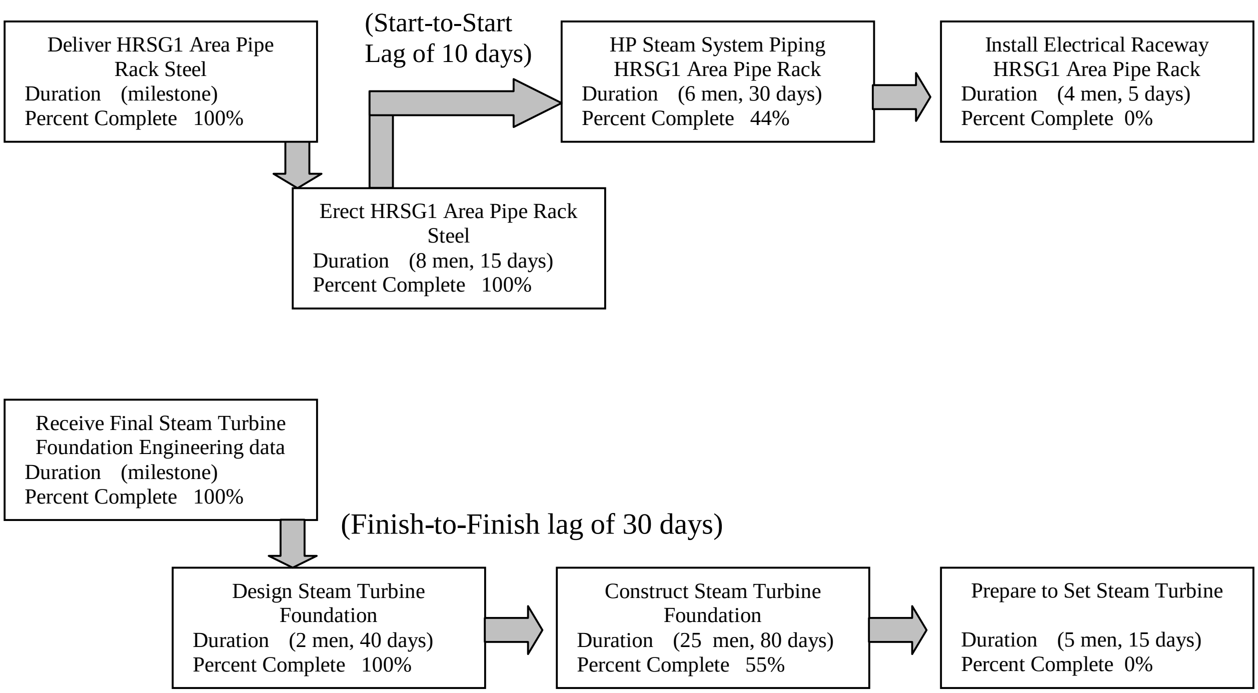

Figure 2: CPM Schedule Fragnets of Activities

Project schedule updating and tracking

Input for providing schedule progress should be obtained through detailed spreadsheets used to gather installed data. An example of a progress monitoring spreadsheet is illustrated in Table 1. These spreadsheets will then be used to update the broader activities that make up the CPM schedule. For example Activity "HP Steam System Piping, HRSG1 Area Pipe Rack", in Figure 2, can be statused as 44% complete per the detailed progress credited in spreadsheet Table 1. Also in Figure 2 activity "Construct Steam Turbine Foundation" can be updated as 55% complete per the status spreadsheet Table 1. Spreadsheets are a valuable tool to track detailed progress and roll it into larger more meaningful CPM schedule activities. This will reduce schedule activities and schedule complication in turn making the schedule more reliable.

Table 1: Progress Tracking Spreadsheet

HP Steam Piping HRSG1 Area Piperack	**Original Quantity**	**Revised Quantity**	**Installed Quantity**	**Percent Complete**	**Weighted Value**	**Weighted Percent Complete**
Layout and install large bore hangers	5 each	5 each	5 each	100%	10%	10%
Hang Pipe (linear feet)	200 lf	200 lf	150 lf	75%	15%	11%
Weld out Pipe (weld count)	5 each	5 each	3 each	60%	30%	18%
Install Large Bore Valves	2 each	2 each	1 each	50%	10%	5%
Install Small Bore trim including hangers and valves (linear feet)	300 lf	400 lf	0 lf	0%	30%	0%
Hydro HP system	100 %	100%	0%	0%	5%	0%
TOTALS					**100%**	**44%**
Steam Turbine	**Original Quantity**	**Revised Quantity**	**Installed Quantity**	**Percent Complete**	**Weighted Value**	**Weighted Percent Complete**
Excavate (cubic yards)	200 cy	300 cy	300 cy	100%	5%	5%
Utilities (linear feet)	1000 lf	1000 lf	750 lf	75%	15%	11%
Layout & Forms (square feet)	2400 sf	3000 sf	1500 sf	50%	25%	12%
Rebar (tons)	30 tns	30 tns	30 tns	100%	20%	20%
Anchor Bolts (pounds)	1500 lbs	500 lbs	500 lbs	33%	20%	7%
Pour (cubic yards)	750 cy	750 cy	0 cy	0%	5%	0%
Strip, Rub & Backfill (% Comp.)	100%	100%	100%	0%	10%	0%
TOTALS					**100%**	**55%**

Project planning

The CPM schedule should be used as a guideline to develop a standalone three-week-look-ahead. The three-week-look-ahead is an essential construction management tool. It is used to coordinate and plan day-to-day project work. When developing a three-week-look-ahead, the constructor must assess each activity to ensure that all resources to perform that activity will be available. These resources include design documentation, manpower, material, construction equipment, and tools. Activities that lack a resource and cannot be started should not be included in the three-week-look-ahead. These delayed activities will eventually show up as critical activities in the CPM schedule. The constructor must also assess the coordination requirements involved with each activity. On a weekly basis, representatives from all phases of a project should jointly review and discuss the content of the three-week-look-ahead. A portion of a three-week-look ahead, for completion of CPM schedule activity "Construct Steam Turbine Foundation" is shown in Figure 3.

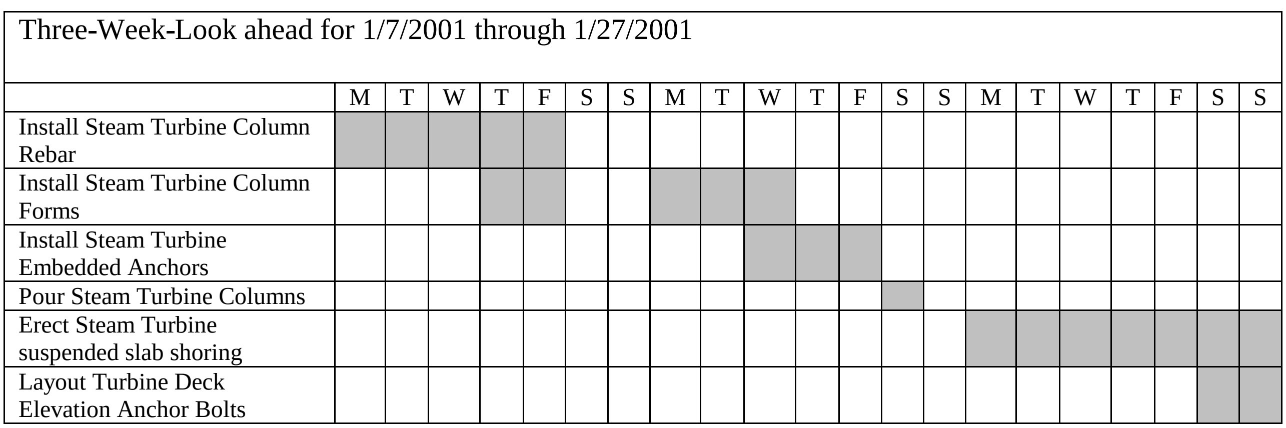

Figure 3: Three-Week-Look-Ahead for CPM Schedule Activity "Construct Steam Turbine Foundation"

2.3 Innovative Design Strategies

To meet construction requirements and design deliverable deadlines, engineering will have to implement innovative design strategies. These strategies involve both technical and commercial decisions that will seem insignificant if each strategy is viewed separately. Significant results will be accomplished if multiple innovative design strategies are implemented on a project wide basis.

Design and procurement capable of supporting construction by volume

The construction of a combined cycle power plant is naturally divided into basic volumes. At a minimum these volumes include the HRSG, HRSG Pipe Rack, Common Pipe Rack, Steam Turbine, Yard Above Ground, and Yard Below Ground. Construction by volume is a proven, productive construction technique. Engineering and procurement by volume is an innovative strategy devised to better implement construction by volume. The constructor, engineer, and major equipment suppliers must agree to an integrated volume strategy during project conception. A phase integrated, volume driven project will help support fast track schedule deliverables.

Epoxy anchor bolts

The use of epoxy anchor bolts expedites engineering and construction schedules. Epoxy anchor bolts allow both the engineer and the constructor additional schedule time to layout equipment, and position the anchors bolts. Traditional cast-in-place anchor bolts are easily damaged between foundation completion and setting equipment. The use of epoxy anchors, where design permits, limits this damage. To avoid confusion, the engineer should use the foundation drawing to roughly locate epoxy anchor bolts, and provide general details for anchor installation.

Sacrifice conservative design to maintain project schedule

Certain situations may require engineering to complete design drawings based on conservative estimations. Waiting on third party information to size foundation thickness or finalize the depth of a cast-in-place vault may be seen by the engineer as a way to save on material costs. The construction schedule setback that will result from this engineering delay may far exceed in value the savings that the engineer can realize in material costs.

Partial release of foundation drawings to support rebar detailing and fabrication

The engineer should release completed portions of foundation drawings to the rebar detailer. This will give the detailer a head start, and may even allow them to detail and fabricate sections of the drawing that will be needed for early foundation construction. When possible, engineering should release segments of foundation drawings in the order that construction will require them.

Pre-engineered building design and erection

On a power project, pre-engineered buildings are commonly used to house electrical equipment, water treatment equipment, fire pumps and administrative offices. The design-build contractor should control the design coordination and installation of these buildings. Segments of the detailed building design and installation may be subcontracted to local engineers and installers familiar with local codes, but the ultimate responsibility for installation coordination must be with the design-build contractor. This will allow the design-build contractor the freedom to install building specific equipment such as HVAC, lights, and plumbing based on schedule requirements for the project as a whole. This will also help avoid costly back charges from a subcontracted builder that is only looking at his scope of supply.

Pipe support and structural steel design coordination

The structural designer must provide adequate steel layout and capacity to allow for the installation of all pipe supports, electrical raceway and sample tubing. Steel piperack design precedes most small bore and cold piping system design. This will require conceptual piping layouts between the mechanical and structural engineers to complete steel design. Equipment arrangement drawings can also provide input for the layout of required pipe rack steel.

Early issue of steel foundation and equipment foundation drawings

Avoid allowing underground utility arrangements and utility stub-up details to delay the issuance of entire equipment or building foundation drawings. The civil engineer should consider designing foundations for building support steel and plant equipment independently of finish floor foundations. This will allow the constructor to install these foundations and expedite the placement of plant equipment prior to placement of the finish floor.

2.4 Specialty Trades, Design and Installation

The lead discipline engineer and construction superintendent must be intimately aware of project scope. However it is difficult for the design engineer and superintendent to catch all local, state and federal code requirements for specialty trade design and installation. Missed permitting codes in the design phase, and even more so in the construction phase can cost a project time and money. For example, construction progress in an entire area of a job can be brought to a standstill waiting on the state to approve the application of a type of underground pipe. Local subcontracting of the detailed design and installation of certain specialty trades such as plumbing; fire protection, natural gas line installation, cathodic protection and lightening protection can be beneficial. In many areas it is required to have a licensed designer and installer for these trades. A dedicated in-house review team, required to review the design of specialty trades and regulated systems, can also prove to be beneficial. These concepts will require additional resources, but the additional costs may be realized as savings if as little as one design omission or construction violation is avoided. This review team can also act as a focal point for design optimization within the company.

2.5 Construction Friendly Design Deliverables

Phase integration requires the engineer to provide construction friendly design deliverables. Constructability reviews and discussions must take place between all disciplines and all project phases. Results from these reviews must be discussed with engineering and implemented where possible.

- Use a single set of plant coordinates and reference lines for all design documents
- Integrate foundation screed dimensions with plant arrangement drawings to provide adequate drainage in important areas.
- Where required by construction for a specific excavation, incorporate sheet piling into the engineering design. This will save the time and expense of having construction sheet piling designed.
- Include applicable specification requirements on design drawings. For example show bedding requirements on underground pipe drawings, show rebar splice lengths on design drawings, show concrete finish requirements on foundation drawings, include detailed bolting and gasket requirements on piping isometric drawings, and include electrical raceway details.
- Where possible, design or construct foundation dimensions to allow the use of standard formwork.
- Prepare minimal required site development packages. This will enable the constructor to provide adequate site drainage and meet all Storm Water permit requirements, without performing unnecessary wasted work.

2.6 Operational Friendly Design and Construction Deliverables

Phase integration also requires the engineer and constructor to produce operational friendly design and construction deliverables. Operational reviews and discussions must also take place between all disciplines and project phases. Operational friendly systems will be easier to commission, saving the project time and money.

- Do not simply recycle design documents from a previous job, rather contact operating plants and ask for input to the operation of design.
- Install concrete curbs for the base of drywall in areas that potentially will see high water. This will avoid having to rework rotten drywall
- Provide extra large drain bell-ups to gather rerouted and additional drain lines.
- Galvanized structural steel eliminates the need for construction and maintenance painting. The savings will be realized in less painting costs and a potential client change order credit.
- Design bolted flushing connections in piping systems that require pre-operation flushes.
- Consider using duplex strainers in critical piping systems to allow online cleaning of strainer baskets.
- Provide local start/stop control for balance of plant equipment that may be required to operate prior to completion of plant controls system

2.7 Prefabrication

Offsite prefabrication of specialized equipment provides cost and schedule savings. This equipment is generally fabricated cheaper and quicker with the benefit of mass production. Equipment fabricators can also provide higher quality products in the controlled environment of their shop. Offsite prefabrication is advisable for pipe hangers, skid mounted equipment, pipe spools, and smaller tanks. Onsite prefabrication can also save schedule time by freeing up work areas and limiting clutter. Examples of onsite prefabrication are rebar cages, ductwork, HRSG stacks, piperack segments, and piping isometrics.

3. CONCLUSION

On a power plant project in Colorado we debated having the structural steel fabricator install hanger attachments to the pipe rack steel at their shop. The concept was not used because we were afraid that too many attachments would be mislocated or design would change between the time of steel fabrication and hanger installation. After the 80' high pipe rack was erected we began to layout and weld hanger attachments. The complexity of this assignment required 120' manlifts and hours of maneuvering to install one attachment at a time. Then in some cases, due to design busts, the initial site-installed attachments were not even used. The lesson learned from this scenario is that we probably would have saved overall project costs by paying the steel fabricator to install all attachments even if only 50% of the shop-installed attachments were effectively used.

Fast track design-build power plant projects offer the opportunity for all phases of a project to work together to optimize project results. Take advantage of this opportunity and create a partnership that is dedicated to the bottom line of the project. Utilize concepts such as prefabrication, preferred vendors, construction driven CPM schedules, operational and construction friendly deliverables, and subcontracted specialty design and installation. These are only a few examples of phase integration and its ability to enhance overall project success.