Modularization

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A Practical and Economical Construction Technique for Process Systems in the Chemical, Petrochemical, Gas Processing, and Oil Refining Industry.

Photo: Modular Construction employed in an Ethylene Recovery Unit built by Pro-Quip for Mobil Chemical in Houston, Texas

ABSTRACT

The following paper outlines the aspects of using the modular construction concept Each point is detailed from a general perspective so that it may be applied to any industry. Major points discussed include engineering, design, equipment size, type, and instrumentation.

INTRODUCTION

Over the years the notion of modularized processing units invariably has conjured up images of equipment packed into the smallest possible area with little concern for the necessary access for safety. proper operation, and maintenance of the unit. These concerns, which more often than not are justified, have been further perpetuated over the years by many skid fabricators who, in their efforts to provide low-cost processing units for installation in the limited space often available, have built them in just such fashion.

Unfortunately, the space available for the installation of new units is still limited as most existing facilities have established and fully developed plot areas, thereby creating a challenge for both the client and the engineering contractor.

Pro-Quip recognized the need for operating and maintenance accessibility combined with the challenge of limited plot space and over the years has endeavored to change the image of the modularized process units by developing modular design concepts in such manner that safety, maintenance and ease of operation are given prime consideration. In this concept modular construction is not simply putting the most in the least space, but involves a sophisticated art requiring special expertise to engineer, design and fabricate process facilities compatible with facility operator needs.

Modularized construction has many positive aspects to consider. The modules contain the equipment, piping, heat tracing, electrical instrumentation systems, specialized coatings, fire protection, ladders, and platforms. Modules can be horizontal, vertical, single level, or multi-level depending on the plot space, equipment, and required piping configuration. The optimum split of modular & field construction efforts is determined for each individual project based upon such factors as local labor costs, transportation limitations and schedule.

As one may surmise, a true modular project has more sophisticated engineering and design requirements than a field erected project. Fortunately, the higher design costs can be off-set by minimizing downstream equipment erection that is more costly than shop fabrication work. Many, but not all, process applications are good candidates for modularization. The preliminary screening factors are equipment size and overall system complexity (i.e., quantity of pipe, valves, instrumentation, tracing, insulation, and other auxiliaries which interconnect with major equipment items). For an ideal modular project, all equipment will fit on a structural module which can be shipped, while providing adequate space for the installation of all piping, valving, instrumentation, insulation, fireproofing, and electrical systems. A plant should be modularized if it can be engineered, designed, shop assembled, tested, transported, installed, and commissioned at less cost and time than on-site construction would afford and where very close control of quality or other similar factors during the course of construction is important.

The modularization technique transfers costly, weather dependant field construction man-hours to a less costly, highly productive shop environment.

The obvious benefits of this shift are:

1. *Controlled environment for fabrication resulting in higher productivity.*
2. *Experienced staff (reduced turnover) resulting in higher productivity.*
3. *Improved quality control resulting in a higher quality facility.*
4. *Improved material control and access to material sources resulting in lower cost & higher productivity.*
5. *Significantly reduced in plant construction hours and time duration resulting in lower construction costs, less operating interference, less risk, and improved safety performance.*
6. *Better schedule control.*
7. *Lower cost overall.*

The negative aspects are:

1. ***Engineering and design must be executed earlier in the project.***
2. ***Potentially increased structural steel requirements.***

In successful modular projects, the incremental engineering, design, and structural steel costs are offset by the reduced cost of assembly, painting, piping, electrical, insulation, refractory, and other work being performed in the fabrication facility instead of the field. Transportation of the larger module is usually competitive with the combined cost of shipment of individual items. As control is more easily facilitated, complicated systems are excellent candidates for modularization.

FACTORS AFFECTING MODULAR DESIGN

The following factors affect modular unit design:

1. *Process Engineering*
2. *Equipment Selection*
3. *Equipment Layout*
4. *Piping*
5. *Instrumentation*
6. *Size of modules*
7. *Equipment Elevation*
8. *Insulation*
9. *9. Refractory*

These factors are discussed below.

Process Engineering

The process design of the plant must be carried out with modular construction technique in mind. Process design of modular units requires a thorough knowledge of available equipment. Techniques to facilitate modularization include items such as combining different heat exchanger services in a common shell. A good example is the combination of sulfur plant feed heaters in a common waste heat boiler, or locating all sulfur condensers in a common shell. Some may fear operating flexibility may be lost in the combination, however, our operating experience does not indicate a problem is created by such a combination.

Conversely, the process designer must also know when to separate equipment into parallel or series services. Sometimes it is necessary to design and purchase smaller sub-components to facilitate modular design rather than provide an equipment item which will not fit on the module.

Equipment Selection

Selection of the equipment is very important in applying the modular construction technique. There are certain styles of equipment which lend themselves more to modular construction than others. A simple example is vertical in-line pumps versus horizontal end suction pumps. A vertical in-line pump requires less mounting area (footprint) and does not pose the potential piping difficulties that may be encountered with a horizontal pump.

Over the years, Pro-Quip has gained considerable knowledge as to the reliability of process unit equipment, thanks to many of our client's feedback. This feedback has given us more insight in the selection of more reliable equipment for incorporation into modularized facilities. By selecting equipment items which meet client's specifications, and have proven superior reliability, the end-user can approach the project knowing maintenance costs will be reduced. Equipment is selected due to its combined safety features, compatibility with the module construction, maintenance features, and known operating reliability.

Equipment Layout

After equipment selection, the overall layout of the equipment is developed. This is the most critical phase of the design, as it defines the number of modules, length of piping runs, accessibility, and ultimately the overall plot plan.

Often, modular construction is especially beneficial for locations where plot space is at a premium. In these situations, the access is engineered into the unit; therefore, the initial layout is key in meeting these special design requirements. Special attention is required so that the layout will fulfill the following requirements.

a. Safety in Operation

b. Ease of Operation

c. Operating, Routine Maintenance, and Turn-around access.

Piping

Once the initial layout has been established, a piping study is conducted to confirm the conceptual layout. A cooperative effort by all modular design disciplines is required to optimize the layout. Only after the piping study is completed, can the module arrangement be finalized.

Primary consideration is given to access space requirements of the equipment and other systems in the plant. In field erected units the designer defines the equipment arrangement and then routes the piping, electrical, instrument air, and control systems to the individual equipment items. Field routing of the piping is quite common in traditional plant construction. Such an approach is not applicable in modular construction. Detailed module planning is required to insure optimum access is provided for operation, maintenance, and safety. This detailed planning is the main design difference in "engineered access" as provided on modular facilities versus "free access" usually found in field constructed projects.

Instrumentation

Normally, piping is arranged such that all the instruments are accessible from the periphery of the module. This arrangement allows the operator or service technician to view or service the instrument without having to enter the confines of the operating module. Such an arrangement minimizes the operators and maintenance technicians time requirements and improves the overall safety of operation in the facility.

Size of Modules

Modules can be as large as 200-feet long and 150-feet wide or larger and can weigh over a million pounds. A large module can be designed in such a way that it can be shipped as a single large module or in smaller sections. Once these sections arrive in the field they can be bolted together to become one module again. At Pro-Quip we have designed some large plants with this concept. This has proven to be a money saving approach.

The installed modules are such that, if the base is embedded in concrete, a person may not realize that modular construction has been used.

Equipment Elevation

In certain applications the relative equipment elevations become a very critical issue. For example, cascade thermosyphon loops require significant design and planning. This can be accommodated very easily in modular construction by coordinating critical dimensions between engineering, vendors and designers who may solve the problem by stacking the modules.

Insulation

Insulation is a very important part of many plants. The efficiency of the plant can be drastically reduced due to poor insulation. Quality of the insulation installation in the controlled shop environment is considerably higher than insulation installation performed in the field which can be effected by inadequate equipment, weather, moisture, etc.

In modular construction, the majority of the equipment can be insulated in the shop where quality control can be monitored. The pre-insulated piping and equipment located on the module can be shipped long distances without the fear of being damaged during shipment.

Refractory

Similar to the insulation, the refractory can also be installed in the shop rather than in the field. This is very cost effective as the refractory is installed by a very skilled person who specializes in the refractory installation. In remote areas the people of this craft may not be readily available.

MODULAR FABRICATION SCHEDULE

A company that offers fully integrated engineering, design and fabrication capabilities has a distinct advantage in meeting or improving the project schedule.

In order to meet the required module assembly and fabrication schedule, very close cooperation is required between engineering, design, drafting, and the fabrication shop. Timely issuance of the drawings, accuracy of drawings, coordination of equipment deliveries, rapid solution of day-to-day problems, and coordination of subcontracts are all key factors to meeting the project schedule requirements. With proper planning and execution, modular projects consume less time from kick-off to commissioning than do field. erected projects. Site preparation, excavation and foundation installation occurs in parallel with equipment manufacturing, and shop fabrication activities. Weather related delays are non-existent in a fabrication shop. Earlier plant start-up translates into an early market entry and early cash flow.

SHIPPING LIMITATIONS FOR MODULES

Modules are usually shipped via trucks if they are no larger than approximately 14 ft wide, 12 ft high, and 55 ft long. Weight limits vary by state, but are typically limited to 100,000 to 250,000 pounds. A more costly alternate is rail transportation, where up to 16 feet wide and up to 100 feet long modules can be shipped. Weight is not usually a limitation in rail transportation. Water transportation removes almost all the barriers, but usually at a cost premium.

Sometimes the transportation of the modules from the facility gate to the unit block poses interesting problems because of low pipe racks, and tight corners. These items of concern are reviewed and addressed as part of the shipping study required at the beginning of the project to support the development of the proper layout.

DIFFERENCES BETWEEN MODULAR AND FIELD ERECTED PLANTS

Modular plants can be more compact than their field constructed counterparts. They can consume less real estate and also require less working space during installation. Rather than free access, the modular plants have "engineered access" to equipment, instrumentation, etc. which is engineered into the unit from the initial stages of the project. To insure that essential operating and maintenance access is provided, more engineering, design, and planning time is required initially. Because of the early engineering and design input, compliance to customer specifications is distinctly better. Facility operators may be concerned because of the great influx of drawings, specifications, etc. early in the project and the time constraint problems this may impose on them. However, most facility operators agree that knowing the great majority of the details of the facility early in the project eliminates many of the surprises often encountered when the design process is carried out over an extended time as in field constructed projects.

FACTS ABOUT MODULAR CONSTRUCTION VERSUS FIELD CONSTRUCTION

- Modular construction requires a higher level of initial planning, project administration, and control in order to facilitate "engineered access".

- Due to the high level of concern placed on access, quality, safety, and schedule, engineering costs for modular units are generally 10% to 15% higher than field constructed units, however, for modular units the overall project cost is reduced due to reduced field construction costs.

Foundation design is simplified with a modular design.

Modules must be designed to withstand the rigors of shipping, therefore structural steel cost is typically greater for modular projects.

- Modules are shipped with conduit, light fixtures, and other electrical equipment in place and, therefore, do not require field installation of these items.

- The quality of the paint, piping, and all other craft work done in a controlled environment like a shop is better than if the work is done in the field.

- In general, all the insulation and refractory can be installed in the fabrication shop prior to shipment.

- Weather related delays are avoided in the fabrication shop portion of the modular construction, therefore, the overall project schedule is shorter.

- Modular construction requires approximately one-third of the field construction duration of a totally field constructed facility.

- A modular unit requires cranes and other lifting equipment with heavier lifting capacity, but on the other hand, the duration for which this equipment is required on-site is limited.

ADVANTAGES OF MODULAR PROCESSING UNITS

Advantages of modular fabrication are well documented. Among these advantages are:

1. The productivity of skilled shop craftsmen is 30% to 50% higher than field craftsmen. This difference results in a considerable savings in the total project man-hours. This savings offsets and can even exceed the difference in greater modular engineering costs.

2. Weather related delays do not occur with shop fabrication.

3. Temporary construction site facilities are not required to be very elaborate as total man-hours and durations are greatly reduced.

4. Availability of skilled craftsmen in certain areas is a major problem. For remote locations, skilled craftsmen may have to be relocated from other areas which adds cost to the project.

5. Labor disputes are a part of the site-construction scene and can have adverse affects on the cost and schedule. In the shop, the labor relations are predictable and are often much better due to the stability of the work force. This, in part, is also due to the better working conditions and environment in a fabrication shop.

6. In modular construction, the site construction time is very short, it is often possible to schedule the installation of the modules during the most favorable time of the year.

7. The foundation requirements are simplified. As most of the concrete work cost is labor, this simplification often results in considerable savings.

8. Quality control in the fabrication shop environment results in a higher quality plant at lower inspection and testing cost.

9. Control of the incoming materials and issuing materials to the shop floor are simplified by standard procedures. Inventory control in the shop is far better than the field due to the stability of the situation.

10. Availability of different disciplines at the fabrication shop such as insulation, paint, non-destructive testing, pressure testing, etc., results in shorter schedule and increased cost savings.

11. Shorter overall project schedule.

12. Lower overall project cost.

SUMMARY

The modular construction technique is applicable to almost any project. However, it has increased advantages under certain conditions. Such as:

- Limited plot space.
- Difficult labor conditions and high labor cost at the plant site
- Restricted quality of skilled labor at plant site.
- Remote site location.
- Bad weather conditions at plant-site such as extreme heat or cold, frozen ground, snow, etc.

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