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Modularizing Containment Vessels in New Nuclear Power Plants

Using modularization in the construction of nuclear containment vessels can be one way to control both cost and schedule when building the next generation of U.S. nuclear power plants. Although the advantages of modularization can be significant, each new reactor design and plant site poses unique construction challenges and must be individually analyzed to determine the benefits of this approach.

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For currently operating U.S. nuclear plants, the average construction period was 9.3 years; the longest was 23.5 years. In Japan, close attention to modularization and construction sequencing has reduced construction times for the ABWR reactor design. In fact, units in Japan have been constructed in less than four years! One of the secrets to this speed was using modular construction techniques.

Standardization is the key to controlling both cost and schedule in building the next generation of nuclear power plants in the U.S.: standardized designs, standardized construction techniques, standardized equipment, and standardized plant layouts.

Once designs, details, plans, and procedures for the first unit are completed, they can be reused, enabling subsequent units to be built at a lower cost. Additionally, the learning curve for fabrication, construction, and project management decreases with each unit built, which improves the schedule for subsequent units.

How Modular Construction Works

One construction methodology that works particularly well with this standardized approach is modularization. By definition, modularization is the process of engineering and fabricating construction projects into shippable packages or segments that can be installed economically at the job site. The task of fabricating and assembling these segments can be carried out in a shop environment or on a nearby construction pad, if on-site space is available (Figure 1).

1. Prefabricating rings. Construction pads located adjacent to a project site are used for prefabricating containment vessel sections. *Courtesy: CB&I*



There is precedent for modularizing components and systems of nuclear plants. Containment vessels—the leak-tight steel structures used to enclose the reactor and contain any radioactive release in the event of an accident—are particularly well suited for modular construction. Because of the shape of the vessels, they can be fabricated in large rings or panels and then lifted one on top of the other to assemble the structure (Figure 2).

CB&I used this technique in the construc-

tion of nuclear containment vessels built from the 1950s to the 1980s, although it was not called modularization at that time. Construction pads were built adjacent to the nuclear island. Large pieces were assembled on these pads and then lifted into final position. A number of countries have used these techniques since that time, most notably Japan, where modular construction techniques have been enhanced to include structural segments that include mechanical components, piping, and electrical and control wiring.

Benefits of Modularization

In addition to the benefits of standardization, modularization can provide advantages of its own. Space on the job site remains an important consideration. When the currently operating nuclear plants were built in the U.S., the need to have many subcontractors working in the same small area created numerous coordination challenges for the prime contractor. It just made sense to do as much of the fabrication as possible away from the crowded activity at the nuclear island. When portions of a plant are modularized, either in a shop or on a nearby construction pad, the portions built remotely no longer compete for the same space at the same time.

Minimizing safety risks is another way modularization can benefit nuclear construction. Building modules in a shop environment does not automatically make construction safer. However, using modularization can enhance safety in a number of ways. Off-site construction limits the number of people trying to perform different activities in the same space. Less traffic in a congested area reduces safety risks. Safety can also be enhanced by the greater control of variables that's inherent in a shop environment and by minimizing the amount of elevated work performed.

Additionally, all of the fabrication and assembly of building modules is performed in a controlled shop environment. This reduces the impact of bad weather and labor shortages. It also provides a greater degree of quality assurance and quality control, which is critical in building nuclear power plants.

Evaluating Modular Construction as an Option

Using modularization for constructing containment vessels has many advantages, but it is not the solution for every situation. For all the

advantages of modularization, this technique does not guarantee lower cost or a shorter schedule. Each new project must be evaluated individually to determine whether the advantages of modularization can be used to reduce cost and shorten the schedule.

At times, modular construction may not be an option. But whenever modularization is considered for a construction project, a complete analysis must be performed and a number of factors must be evaluated, such as those that follow.

Site evaluation. How much space is available for on-site construction? The more congested the site, the more desirable modularization becomes.

Site access. What transportation options are available for accessing the plant via truck, rail, or barge? Certainly, barge access provides the optimal situation for modularization. If both the shop and the plant are connected via a waterway, enormous modules can be fabricated in the shop, shipped to the plant, and lifted into place. If barge access isn't an option, the size of the modules will need to be orders of magnitude smaller to ship by truck or rail. Nevertheless, these modules are still quite large and require careful planning to transport, as permits for using roadways and bridges must be obtained.

Module lifting. What is the lifting capacity at the site? Large, heavy modules that are constructed in a shop or on a nearby construction pad must be lifted into place. Ideally, if a construction pad is used, it is best to have a crane that can access both the construction pad and the area where the finished containment vessel will be placed on-site. As each piece of the vessel is assembled, the crane lifts it into place. If modules are shipped via truck, rail, or barge, appropriate lifting capacity must be available to lift the pieces into place (Figure 3).

On-site transportation. What space is available to transport the modules from one part of the site to another? If the modules are built on a construction pad and need to be transported to the nuclear island, a path as wide as the unit must be available.

Cost savings. Can you save money by modularizing the containment vessel? The answer

2. Lifting rings. A containment module is lifted from the construction pad.

Courtesy: CB&I



to this question varies, depending on the considerations just discussed. Modularization increases the amount of engineering that must be performed, as each module must be designed to be safely transported. A framework for transporting and lifting the modules must be engineered along with the unit itself, increasing both engineering and material cost. On the other hand, modularization can reduce the schedule, and schedule reductions, in turn, can reduce the cost of construction.

If You Choose Modularization

Although all five of the next-generation nuclear power plant concepts in the U.S. include standardized designs and support modularization of the containment vessels, careful analysis will be necessary for each individual project to determine if modularization is the best approach. If modularization is used, that decision must be made early to realize optimal benefits.

Engineering of the modules must be done early in the engineering phase so that all the details of transporting and lifting the modules can be considered and planned. Tolerances for containment construction are critical and must be established during the design phase. If due consideration is not given during the design phase, the erected modules could conceivably not match up to the piping and other connections.

Additionally, all of the parties must be involved in developing and coordinating the modularization effort, including owners, nuclear steam supply system manufacturers, fabricators, erectors, the logistics team, and even the Nuclear Regulatory Commission, whose staff will need to perform inspections in an off-site shop—a challenge not encountered during construction of the currently operating facilities. ■

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3. Stacking rings. A modularized ring of a containment vessel is set on the nuclear island containment vessel. *Courtesy: CB&I*

