The Chemical Plant of the Future

Customization vs. Modularization: Can World-Scale Plants Be Made Up of Standard Modules?

The 2008-2009 crisis signaled the start of a paradigm shift in chemical plant engineering and construction. Traditional EPC (engineering, procurement and construction) suppliers (general contractors based in the Western industrialized nations) are facing increased competition from Asia. At the same time, the plant engineering teams at global chemical companies are intensifying their partnerships with EPC suppliers and spreading the workload across the international engineering resource base.

The recent economic crisis is nothing more than a distant memory for the chemical engineering, procurement and construction sector. In 2011 alone, chemical projects valued at more than $150 billion worldwide were announced, with the construction work to be carried out over the next three to four years. Even after that, the engineering teams are likely to remain busy.

Significant Expansion Projects

BASF, the world's largest chemical company, is planning to invest $30 billion to $35 billion in new facilities between now and 2020. The chemical industry is pursuing two general strategies. Producers of bulk chemicals (commodities) such as fertilizer and primary plastics including polyethylene and polypropylene, which are used in foil production, are locating production facilities near the sources of raw materials such as the Middle East.

Working within the framework of the Sadara joint venture, Dow Chemical Co. and Saudi Aramco began construction of an integrated chemical complex at Jubail (Saudi Arabia) last July. The $20 billion project is scheduled to begin producing 3 million MT of chemical products a year by 2016.

Producers of specialty chemicals and high-performance plastics are setting up operations in the sales regions. Following investments by BASF, Bayer, Evonik and Lanxess in Asia running into the billions, more projects have been announced recently.
Bayer plans to invest an additional €1.8 billion in Asia between now and 2015, and BASF has earmarked €10 billion to €12 billion for construction projects in emerging countries. Special chemical producers Evonik and Lanxess made headlines last year with projects such as the €400 million butyl rubber investment (Lanxess) and a roughly €500 million methionine plant (Evonik) in Singapore.

However, the horizon extends beyond the emerging countries and Asia.

Significant expansion is also taking place in Europe. In addition to a number of other new multimillion euro construction and expansion projects, which run well into the double-digit range, expansion of the chemical cluster is planned at the Port of Rotterdam (approximately €10 billion) and BASF has announced a €9 billion to €10 billion investment at its Ludwigshafen site. The company hit the headlines in January when it gave the green light to construction of a production complex for the flexible foam precursor toluene diisocyanate (TDI). The project is scheduled for completion in 2014, and the cost of the project is estimated at around €1 billion.

This project illustrates a number of paradigm shifts in the chemical industry and in plant engineering, procurement and construction. Now that chemical producers have made sustainability and energy efficiency a major strategic priority, synergies in production at the sites are becoming increasingly important.

"The investment decision on the TDI facility was based on more than just the production operation per se. The evaluation process included a holistic assessment of the energy and heat flows at the Ludwigshafen site," said Peter M. Gress, head of engineering at BASF.

The company plans to leverage advantages of scale and efficient integration in order to become Europe's most cost-efficient TDI producer. Claas-Jürgen Klasen, who is in charge of process technology and engineering at Evonik, shares the view that synergies on site are becoming increasingly important: "The central infrastructure at chemical parks provides opportunities for enhanced integration of energy and material resource utilization, which is why these parks are playing an increasingly important role in the industry."

Owner's engineers have outgrown the role of internal service departments at chemical companies. Their goal is to add value to the corporation. What may sound like marketing hype actually has real substance. Investment projects do not run in isolation. Instead, they are designed to make the greatest overall contribution. Higher investment costs may be deemed acceptable if, for example, integrated heat management, which includes other operations at the site, can reduce overall energy consumption. Klasen outlined the differences between conventional EPC and
owner's engineering as follows: "To come up with the best technical solution, you need a detailed understanding of the markets, the specific product requirements profile, the raw material markets and overall production costs."

Jürgen Hinderer, head of engineering at Bayer Technology Services, agreed: "Completion on time and within budget in compliance with all of the quality and safety parameters requires a joint effort by the users, our highly skilled and experienced international engineering team and our suppliers throughout all phases of the project. That is what differentiates owner's engineers from other engineering and construction companies. The customer's money is our money."

In November, Bayer MaterialScience opened a large TDI plant (250 kT/a) in Shanghai. Production is based on new technology (gas phase phosgenation).

Technology and scale-up are not the primary considerations on the TDI project in Ludwigshafen. The real emphasis is on finding the best way to integrate the various elements of the project into the intricate workings of the site.

**Collaborative Model**

The holistic approach also results in a new collaborative model for allocating responsibilities among the chemical producer (user), the in-house engineering team and external EPC service providers. Instead of awarding a general contract to an EPC for delivery of a turnkey plant based on the user's own conceptual design where the project follows a rigid sequence from detailed design and procurement to construction, the project phases are now dovetailed. The EPC service provider is involved in the conceptual design at an earlier stage, and the user gains the flexibility to make changes during later phases of the project.

This level of trust and close collaboration can develop only within the framework of strategic partnerships that transcend the boundaries of specific projects. These relationships can be built up between a chemical company's in-house engineering team and independent contractors.

The chemical industry will be relying on these long-term partnerships and framework agreements over the coming years to manage the large project workload ahead. Only in the context of these relationships will EPCs be willing to act as an extended arm of the owner's engineering team.

**Strategic Partnerships**

The EPC supplier base for the global chemical industry is no longer restricted to companies based in Western countries. Particularly in the wake of the economic
crisis, Asian EPCs have become serious competitors. Prior to 2008, Chinese and above all Korean EPCs were often regarded as welcome junior partners that relieved Western engineering firms from responsibility for the labor-intensive and risky construction end of the business. Today, companies like Samsung often act as general contractors and only buy in technology from European companies.

They attract business through aggressive pricing, a willingness to take risks, favorable strategic financial arrangements, political support and above all a willingness to take on large projects right through the construction phase. German EPCs understand the problem and are working hard to resurrect their own construction expertise, increase their level of vertical integration and enhance their presence in proximity to the customer.

EPCs and in-house engineering teams are also working on the price issue. Procurement of the equipment accounts for more than half the total value of an EPC contract. The strategy is based on best cost country sourcing. More of the labor-intensive equipment is now being procured from low-wage countries. For that strategy to work, the procurement team has to find the best trade-off between low purchase price, quality assurance costs and transportation charges. Stringent controls and personal relationships with suppliers are more important in China than water-tight contracts, according to industry insiders.

In order to systematically develop the necessary intercultural skills and reduce quality assurance overhead, owner's engineers and European contractors also intend to develop their human resource base in the procurement markets. Linde, for example, introduced a new procurement organizational structure in 2010. Six procurement centers act as the point of contact with suppliers in the regions. Chemical companies that are investing in China, India and South America are planning to take on additional engineering staff in those countries.

"The intention is to give country employees responsibility for local project management and work with local contractors to provide quality assurance services," Klasen said.

In addition, chemical companies want to leverage the strategic partnerships with global EPCs to gain access to their procurement expertise in global markets.

"We are giving our external partners greater responsibility for procurement without, however, relinquishing control," Gress said.

Doing the design work in Asia for plants that will be built in Europe and Germany has now become a reality. During the course of project activities in recent years, companies like Bayer Technology Services have developed engineering resources in
Asia and have carried out plant design work there based on German standards. Jürgen Hinderer provided the following explanation of the Bayer strategy: "We continue to develop our engineering expertise in close proximity to our customer's production sites, so that we can provide optimal system availability and turnaround management. Owner's engineering is a lifecycle concept which is directed at sustained value creation for both partners."

**Customization vs. Modularization**

One trend that has been predicted on a number of occasions has not yet materialized in the chemical industry, namely world-scale plants made up of standard modules. At large plants, users customize the technological solutions to gain a competitive advantage. In the future, the integrated material flows discussed above will become increasingly important beyond the boundaries of the existing local units at a chemical production site. Integrated structures shared by multiple chemical companies at the chemical parks of the future will create synergies that contribute to the business success of the individual firms.

In the recent past, new developments in a number of conventional large-scale processes including chlorine electrolysis, ethylene oxide production and chlorine recycling have resulted in significant improvements in raw material and energy consumption, selectivity, and yield. "There will continue to be quantum leaps in innovation at world-scale plants in the plastics and rubber industry and even in conventional sulfuric acid production. However, batch mode production is still widespread in the pharmaceutical industry, and there is still plenty of room for innovation," Hinderer said.

In contrast, new trends are appearing in multiproduct and fine chemical production. For special products that are produced in small volumes, time to market is vital along with a reduction of the market risks that exist between the product development phase and start of production. Small, versatile production operations based on standard modules, including containerized modules, appear to offer significant potential, and a number of research projects are under way. The Flexible Fast Future Factory (F3 Factory) concept is based on container-size modules that can be put together to create a production line.

Investigations are now in progress at the Invite research center, which recently opened at the Leverkusen Chemical Park. Special chemicals producer Evonik is taking a similar approach. The company is developing small-scale production systems in a sea freight container, which could be used for running the process at different locations. All of the process steps needed for production are housed in the container. If demand proves to be higher
than expected, production can be expanded to multiple containers. Using this approach, lab development and basic engineering can take place in parallel, which saves time. The company has been producing silane compounds using a compact Evotrainer at its Rheinfelden site since 2010.

Under the umbrella of the EU Copiride research project, the company has been investigating ways of designing highly compact production systems in partnership with the universities of Eindhoven and Stuttgart and the Institut für Mikrotechnik (Institute for Microtechnology, IMM) in Mainz, Germany. A multipurpose container is expected to be ready this year for industrial-scale production of a special polymer at the Marl Chemical Park.

Container-scale chemical production may hold a lot of promise, but customized multiproduct solutions also will continue to have a place in the future production landscape. However, the budgets on these projects are normally so tight that little room is left for "future options." The production assets are tailored exactly to the intended application.

**Summary**

Three years after the world economic crisis, there is plenty of work to do in the chemical plant engineering and construction sector. The heavy workload is forcing engineering departments at chemical companies to forge strategic partnerships with traditional EPCs. To improve the sustainability and energy efficiency of the facilities that are on the drawing board, the industry is not only building world-scale plants on green field sites. It is also taking increasing advantage of integrated energy and raw material flows at chemical parks. Customized plant design remains the norm. There is no sign yet of modularization and standardization to any significant extent. Continued development of conventional production techniques in recent years has led to a series of quantum leaps in innovation. Strategies for modular, container-size production are under development in the special chemicals sector.

The article is based on a trend report compiled by specialized international journalists on behalf of Dechema Gesellschaft für Chemische Technik und Biotechnologie (Society for Chemical Engineering and Biotechnology), a nonprofit scientific and technical society based in Frankfurt am Main, Germany.

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Kontaktieren

Dechema e.V.
Theodor-Heuss-Allee 25
60486 Frankfurt/Main
Germany
Telefon: +49 69 7564 0
Telefax: +49 69 7564 272