The Trinidad LNG Project - Back to the Future

Phil Redding, Atlantic LNG Company of Trinidad and Tobago,
Frank Richardson, Bechtel Corporation (USA)

In the small Caribbean state of Trinidad and Tobago one of the most interesting and challenging LNG projects for many years is nearing completion. Interesting because it has taken a different approach to most recent LNG projects and challenging because many in the industry did not think that the project was possible a mere 4 years ago.

The differences are many. The plant under construction at Point Fortin, Trinidad is the first single train baseload LNG plant in 30 years and is the smallest grassroots facility for 20 years. (Although the train size at 3 million tonnes per annum (mta) is world class.) All other recent projects have multiple trains and are at least twice the capacity of the Trinidad plant. The liquefaction process is an updated version of the original cascade process used in the first baseload LNG plants rather than the industry leader, the Propane Pre-cooled Mixed Refrigerant Process. The equipment is different too. Frame 5 gas turbines have been used, not Frame 7's as with most other new projects. Similarly, plate fin heat exchangers, almost abandoned by the baseload LNG industry, have been used for the main heat exchangers.

The challenge was enormous. For the project to be economic, the unit cost of the plant needed to be some 30 - 40% less than that of LNG plants built in the 1980's. Furthermore, the market dictated that these reductions had to be achieved on a relatively small, single train plant. Yet, by being prepared to take a different route to that of other projects and by building on the model of one of the first LNG plants built, the necessary cost reductions were achieved.

Larger Lower Cost Plants?

Early grassroots projects were built to a capacity of 1-2 mta but capacity soon increased to 4, 6 or even 8 mta. With train sizes now topping 3 mta, most new projects are planned to be around 7 mta or larger.

The main drive behind this increase in size has been to improve the project economics by reducing the unit cost of the liquefaction facilities. But whilst larger plants have led to some unit cost reductions there is a negative side as well. The total investment in the LNG chain increases significantly. When gas production and shipping costs are included, many LNG projects are of such a scale, that even the largest companies struggle to undertake them. To counter this, many projects involve multiple partners. This has made projects much more complex and difficult to get off the ground. It is also difficult to find markets all at once for the large volumes produced by such plants. High quality buyers are required to secure the investment and it is difficult to support new markets. With the recent economic down turn in Asia it is becoming even more difficult to find large markets and several planned projects have been either shelved or delayed.

The Trinidad Project was market driven with the size set more by the demands of buyers than by the needs of the plant designers. Given the market capacity, the challenge was to build a safe, reliable, cost effective plant of that size.

The unit costs for Trinidad are in fact lower than those reported by others at LNG 12 (1). The $1 billion figure used in that paper and widely quoted as the cost of the Trinidad plant relates to

This article originally appeared in the Nov./Dec. 1998 issue of the LNG Journal.
It has been reprinted with the permission of the LNG Journal.

all project costs. This includes financing fees, interest during construction, and debt service reserve; these costs were excluded from the other cost estimates to which the Trinidad project cost was compared. On an equal basis the unit cost of the Trinidad project is 10 - 20% lower than that of other recent projects. This is all the more remarkable since the plant is half the size of the others. The unit cost of a two train plant would of course be even less.

The Kenai Model

The Kenai LNG plant in Alaska has played an important role in the development of the Trinidad project. It was completed in 1969 and originally provided around 1.2 mta of LNG to Tokyo Electric and Tokyo Gas. Built in just 26 months, the plant uses a Phillips-designed cascade process and six Frame 5 gas turbine drivers. The project has proven very reliable and has not missed a scheduled LNG shipment since it began operation.

The Kenai plant attracted the partners and engineers working on the Trinidad project for many reasons. It was small, it was a single train, it was built quickly, it has been safe and reliable, and above all it was low cost. At the same time Bechtel was getting reacquainted with the plant they had built so long ago. In the early 1990s Phillips commissioned Bechtel to perform a de-bottlenecking program to increase the capacity to 1.5 mta. Bechtel's LNG team was impressed and saw the potential for significant cost savings compared to more conventional plants. That team recommended to the embryonic Trinidad project as early as December 1992 that the Phillips process should be considered. Almost a year later, Bechtel did the first conceptual study and cost estimate, showing the potential to achieve significantly lower costs. Though the cost was not given much credence at that time, two years later the same price was very close to Bechtel's winning lump sum bid for the project.

The Phillips Optimized Cascade Process

The Phillips Optimized Cascade Process is a modified version of the process used so successfully at Kenai. The process uses three pure component refrigeration circuits: propane, ethylene and methane. The final methane circuit is an open cycle loop, recycling auto-refrigeration flash gas. This open cycle allows easy rejection of nitrogen and allows the boil off gas to be re-liquefied in the main process eliminating the need for a large boil-off gas compressor. The additional complexity of the extra refrigeration loop is offset by the simplicity of operating pure component refrigeration systems as opposed to mixed refrigerant systems.

One recent process comparison claims that the unit cost of a cascade process is 40% more than the Propane Pre-cooled Process (2). This was certainly not the case for the comparisons examined for the Trinidad Project. Based on comparable detailed designs developed in parallel, with the same annual production rate, and on lump sum bids to the same specifications and contract conditions, the Phillips based plant won out over the Air Products (APCI) based plant.

Bechtel and Phillips are continuing to invest in the process and the LNG plant product to improve customer value and sustain their competitive advantage and that of their customers in the LNG marketplace.

Frame 5 Gas Turbines

Against the trend of other recent projects and most other planned projects Trinidad has chosen to remain with Frame 5 gas turbines rather than move to the larger Frame 6s or 7s. An extensive lifecycle evaluation showed that the same unit cost reductions could be achieved

This article originally appeared in the Nov./Dec. 1998 issue of the LNG Journal.
It has been reprinted with the permission of the LNG Journal.

through the use of multiple Frame 5s. This is because the lower unit costs of the Frame 6 and Frame 7 gas turbines themselves are offset by many other factors: Expensive variable frequency drive motors are required to start the Frame 6 and 7. These also require additional power generation capacity. Frame 6 and Frame 7 drivers stretch compressor technology to the limits, requiring extensive and expensive testing before they leave the manufacturer's shop. This adds to both cost and schedule. Spare parts for Frame 6s and Frame 7s are much more expensive than those for Frame 5s.

Frame 6 and Frame 7 designs require such large sizes of pipework that there are actually diseconomies of scale in some areas. For example, valves are of such a size that vendors are limited and designs are non-standard, making one of them more expensive than two smaller, standard valves. Even more importantly, Frame 6 and 7 gas turbines require about twice the scheduled maintenance of Frame 5s. For an air-cooled design, the gas turbine maintenance usually controls scheduled downtime for the plant so a Frame 7 design will have a lower overall plant availability. Also, with multiple small machines the gas turbines and compressors can be configured in parallel improving reliability even though there are more pieces of machinery. When one gas turbine or compressor trips the plant can still run and achieve 65 - 80% of normal production rate. A conventional two train plant would lose 50% and the whole train would have to be restarted. This is a much longer process than bringing one gas turbine back on line, especially if the plant has begun to warm up. This was a critical issue for a single train plant and it is worth noting that Kenai has just this parallel configuration. This concept is fundamental to the Phillips 'two trains in one" reliability.

Plate Fin Heat Exchangers

Another important area in LNG plant design is the cryogenic heat exchangers. Nearly 90% of the current baseload LNG capacity uses the APCI spiral wound design; this includes all plants built in the last 20 years, apart from Trinidad.

Although less expensive, plate fin heat exchangers have in the past been considered too unreliable. Much of this comes from the poor experience with plate fin heat exchangers on the Skikda plants in the 1970's, which was reportedly due to mal-distribution of two-phase flow to the exchangers and failures which occurred due to mercury and water ingress.

Whilst the concerns are understandable the complete rejection of plate fin heat exchangers seems unreasonable, especially since water and mercury would have caused similar problems in an aluminum spiral wound heat exchanger. In the rest of the cryogenic industry plate fin heat exchangers have completely replaced spiral wound exchangers because they cost less and have shorter delivery times. A high reliability is demanded from many air separation plants and plate fin heat exchangers have not proven to be a problem in these applications.

Despite their deserved reputation for reliability and robustness, spiral wound heat exchangers are not without problems either. In particular, tube leaks lead to shutdowns on some plants and cause others to run at reduced efficiency until the next planned shutdown. Data collected from the manufacturers of both types of exchanger showed that the failure rates and times to repair translated into a similar impact on the overall plant availability.

In a cascade process the use of pure refrigerants and the step-wise nature of the process eliminates two phase flow feed distribution problems to the plate fin heat exchangers and limits the potential for thermal shocks. In all the years of operation at Kenai there has been not been a single problem with any of the plate fin heat exchangers.

This article originally appeared in the Nov./Dec. 1998 issue of the LNG Journal.
It has been reprinted with the permission of the LNG Journal.

Engineering Approach

As has been pointed out many times, the liquefaction plant is only a portion of the overall plant cost and liquefaction technology is limited in its ability to save costs. Well aware of this, the Trinidad team realized that they had to be as cost effective as possible in every aspect of the plant design.

Specifications are a key factor that impacts the whole of the plant design. One of the Atlantic shareholders had recently streamlined their specifications to rely more heavily on industry standard practices and allow vendors to bid their state-of-the-art cost effective designs. This overall approach includes developing alliances with high quality vendors and having pre-approved standard designs and pricing.

This approach was adopted for the Trinidad project and the project specifications are largely based on widely accepted industry standards. For years Bechtel had been developing "alliance vendors" and for this project determined to use "fit for purpose" specifications and maximize the scope of selected vendors. As well as saving equipment and bulk costs, this approach also eliminates the need for some design reviews, some inspection, and saves engineering hours. This has sometimes been referred to as the "gas plant approach".

Some have challenged this approach on the basis that it will affect safety and reliability. However, it must be noted that the Trinidad plant is fully compliant with widely accepted codes and standards, and in fact has followed NFPA 59A more rigorously than some other projects. None of these industry proven standards are being changed. However, owner preferences and non-standard items that are often very expensive for a vendor to provide, are being changed and eliminated.

Civil Engineering

Civil Engineering is a crucial aspect of most LNG projects, having a significant impact on both cost and schedule. Geo-technical expertise and major civil execution know-how are critical for low cost solutions to soil stabilization issues, soil liquefaction possibilities, selecting foundation types and designs, and for engineered structures. As with many LNG projects, the difficult soil conditions for the Trinidad project presented unique challenges. A late change in plant location stretched the civil engineering abilities of the contractors to the limit. Different solutions presented very different risks, costs and schedules and Atlantic LNG insisted on the contractors taking considerable site risk.

The current site is located on land that was reclaimed over 15 years ago through hydraulic dredging. It appears that there was little or no segregation of the deposited materials and the soil is a non-homogeneous mass of clay, sand and silt randomly dispersed. Trinidad is a zone three seismic area giving concern over the liquefaction of this soil structure.

Bechtel's review of all the possible methods available in the industry to densify ground led to the selection of stone columns as the most effective means to provide a sound foundation base. Stone columns are inserted by a "vibro-replacement" technique developed by Keller in 1957. A large vibrating poker is used to insert a column of aggregate fill into the ground. The reinforcing and compacting action of the stone columns serves to significantly improve the load bearing and settlement characteristics of the ground. Because of the non-homogeneity of the reclaimed land this was the best technical solution and cost less than other more conventional solutions.

This article originally appeared in the Nov./Dec. 1998 issue of the LNG Journal.
It has been reprinted with the permission of the LNG Journal.

Construction Approach

The project sponsors agreed early on to an aggressive goal to maximize Trinidad content. A minimum target of almost 20% of total EPC cost was set with a stretch target of 25%. The minimum target will be exceeded. In some areas this conflicted with the design philosophy to maximize the scope of key vendors. For example, the large liquefaction "cold boxes" were complete vendor packages supplied from the USA. Furthermore, the turbines and compressors, the air coolers, and most other equipment could not be sourced in Trinidad. This left a challenging assignment to achieve the Trinidad content from the site construction effort.

One way to achieve the goal was to maximize the scope for subcontractors. It had already been decided to subcontract the bulk of construction work. This was an easy decision as there are a variety of construction contractors in Trinidad with good experience from the ammonia, methanol, gas processing, and steel related industries, which are present on the island. Local subcontractors have been awarded wide scopes of work including management, planning, scheduling, pre-commissioning, and in some cases, engineering and design. Mirroring the main EPC contract, schedule, quality and safety incentive schemes were included in all major subcontracts. This has resulted in some notable successes and some good lessons learned on both sides.

Some of the major subcontractors are:

Ballast Nedam	- jetty civil work, mechanical erection and piping
Damus, Ltd (T&T)	- mechanical erection and piping
Hafeez Karamath (T&T)	- structural steel erection
Insertech (T&T)	- instrument and electrical
Noell-Whessoe	- LNG storage
Raghunath Singh (T&T)	- concrete/civil and buildings
Westminster Dredging	- harbor dredging

Even the international subcontractors have made substantial use of the skilled and well educated local labor and supervision, either through direct hire or their own subcontracting arrangements with local companies.

Safety has been made a top priority for everyone from top management down to the individual workers. Every person working on the site is given lengthy safety training and regular reminders. Local subcontractors and their workers have responded very well to the initiatives taken by Atlantic and Bechtel.

Commissioning and Start-up

Bechtel's scope of work is truly "turn-key". There is to be a single final turnover of the complete operating plant only after the final plant capacity test run for contractual guarantees. Bechtel will supply all operating, maintenance, supervision, and technical service until that turnover.

This article originally appeared in the Nov./Dec. 1998 issue of the LNG Journal.
It has been reprinted with the permission of the LNG Journal.

Schedule

Another benefit of these design philosophies and approaches is to help improve the project schedule. The EPC schedule for Trinidad is 36 months from lump sum EPC contract signing to final turnover of the performance-tested, fully operating facility to Atlantic LNG. For three months prior to the EPC contract there was a small limited commitment to allow for site clearing and for engineering to begin on the compressors and the LNG tanks. Nowadays it seems that 42 months is more typical for LNG projects, even to the completion of the first train. Here again Trinidad is setting a new benchmark for the modern LNG industry.

Back to the Future

The Trinidad project marks a return to traditional, well proven technologies that has resulted in an economic project of manageable size. This market driven approach allows new projects to be developed much more easily. In some ways the Trinidad LNG project steps back in time, but on the other hand it shows the way forward, both technically and commercially, for many LNG projects. It is indeed "back to the future".

References

(1) "LNG Plant Costs: Present and Future Trends", R.N. DiNapoli and C.C. Yost, Proceedings LNG 12 Conference, Perth, Australia,1998.

(2) "Comparison of Baseload Liquefaction Processes", K.J. Vink and R.K. Nagelvoort, Proceedings LNG 12 Conference, Perth, Australia,1998.

Biographies

Phil Redding is currently Atlantic LNG's Engineering Manager for the proposed expansion. As Lead Process Engineer and Engineering Coordinator he played a key role in the strategy and detailed development of the project. He has been with BG (formerly British Gas) for 17 years, much of this time involved in the design of LNG plants. He is a graduate of Imperial College London, a chartered engineer and a Member of the Institute of Chemical Engineers.

Frank Richardson is LNG Technology Manager for Bechtel and is currently in Trinidad managing the commissioning of the plant. He has many years experience in LNG plant design, construction and operation, first with Huffco and now for 9 years with Bechtel. He has worked on many LNG projects and carried out Bechtel's conceptual study work for the Trinidad project starting in 1992. He holds degrees in chemical engineering from Lehigh University and New York University and is a registered professional engineer in New York and Texas.

This article originally appeared in the Nov./Dec. 1998 issue of the LNG Journal.
It has been reprinted with the permission of the LNG Journal.