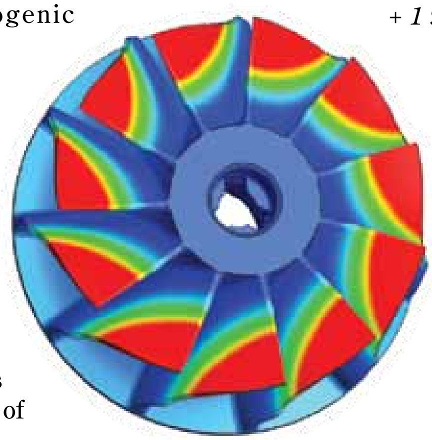
CRYOGENIC INDUSTRIES

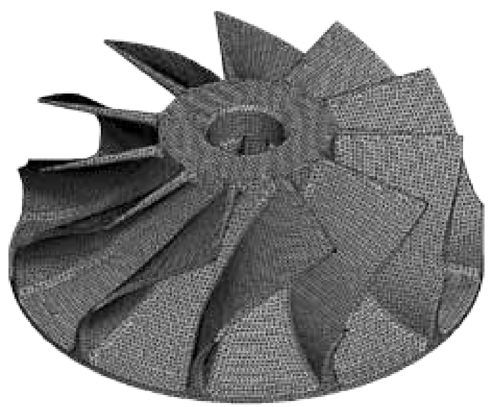
FROSTBYTE

A NEWSLETTER FROM CRYOGENIC INDUSTRIES SUMMER 2011

Impeller Frequency analysis:

The air separation industry relies on efficient and reliable turbomachinery to create the highest performance air separation plants possible. Key to this is **ACD**'s expansion turbine that expands high pressure air to reduce the temperature to cryogenic conditions and produce work.





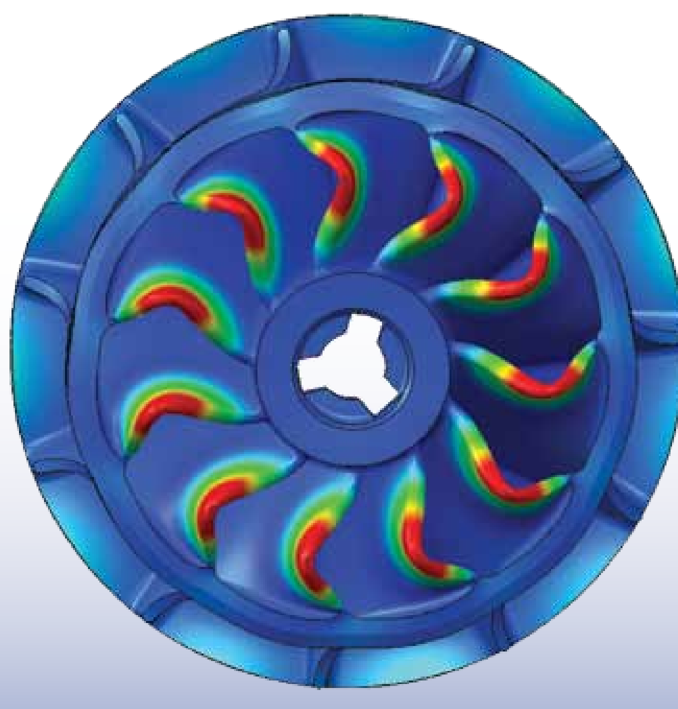
ACD uses the design analysis 'Simulation' software integrated within SoilidWorks to perform steady-state stress and modal (frequency) analysis. The use of Campbell and interference diagrams, as well as animated mode shapes from Simulation helps to visualize the potentially dangerous interactions of various impeller mode shapes and sources of excitation.

The first step in the analysis process is to transfer 3-D impeller geometry created in SolidWorks into Simulation. A very accurate representation of stiffness and mass of the impeller is required; hence the use of a sound mesh topology and a high-density parabolic tetrahedral mesh is crucial to accurate frequency prediction. The Finite Element Analysis (FEA) simulation then calculates the natural frequencies and mode shapes at either zero rpm or at design speed to include stress stiffening effects using actual boundary condition and material properties. From the plotted mode shapes, it is important to identify blade and disk modes that are critical in assessing the likelihood of dangerous resonance conditions.

The frequency analysis helps ACD avoid vibration-based failures by modifying geometry of the impeller hub and back disk including designing shrouded impeller if needed. All the geometry modification can be managed during the initial design phase thus avoiding costly rework and rejection after manufacturing and testing.

Impeller failures can be very costly both in terms of dollars and in lost production, making the avoidance of these failures of great interest to both ACD and our customers. The ability to predict impeller natural frequencies using Simulation coupled with experimental modal analysis (EMA) allows us to easily and accurately determine the quality of our impeller designs by providing an appropriate margin against fatigue damage.

For more information contact Asit Singhal at ACD at + 1 949 261 7533 or asinghal@acdcom.com



Cryogenic Liquid Expanders

By: Lance Hays - Energent

One of the applications for the Variable Phase Turbine (VPT) is replacement of liquid or two-phase Joule-Thomson valves in cryogenic systems. The power generated by the VPT is removed from the cryogenic process, increasing the process refrigeration. The efficiency of LNG production and air separation processes can be improved and liquid production increased.

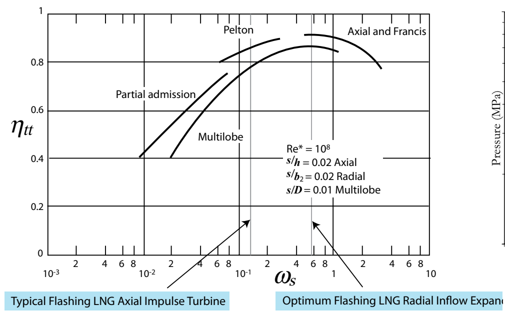


Figure 1

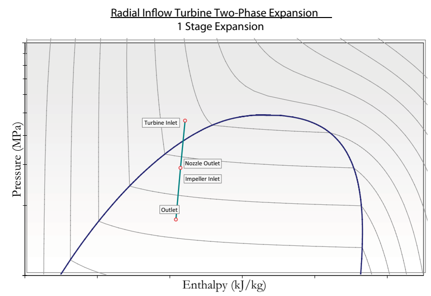


Figure 2

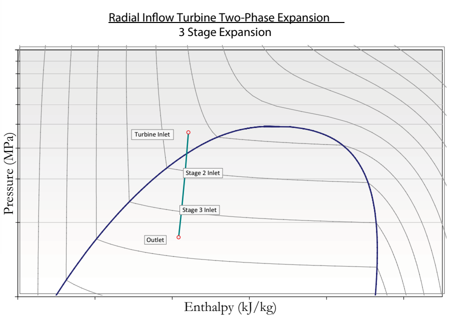


Figure 3

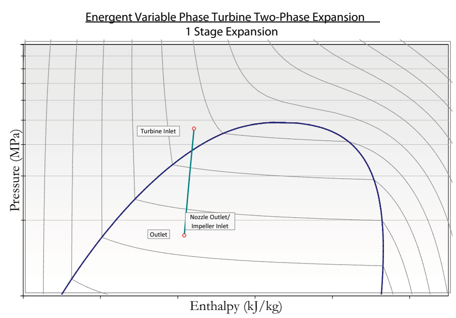


Figure 4

The VPT is an axial impulse flow expander that has advantageous features relative to radial inflow (RIF) expanders for liquid or flashing liquid expansions. **Figure 1** illustrates the specific speed of the VPT and a radial inflow expander for a flashing LNG expansion. As can be seen the optimum VPT specific speed (~.15) is about 1/3 that of an optimum radial inflow expander (~.6). The VPT, having a lower speed can directly drive a conventional generator. However, single stage RIF expanders require a gearbox or VFD drive. A RIF with direct drive of the generator requires multiple stages to optimize.

Figure 2 shows a typical expansion process for a single stage Variable Phase Turbine flashing LNG expander. A two-phase mixture is produced at the nozzle exit with a rectilinear flow path. No further flashing expansion takes place. The thermodynamic conversion process is complete. The turbine rotor is an axial impulse rotor which has been designed specifically for two-phase flow and demonstrated to have stable operation and high mechanical conversion efficiency with two-phase flows .

Figure 3 and Figure 4 illustrate the expansion paths for single stage and three stage RIFs respectively. Two-phase flow is generated within the inlet guide vanes and rotor(s) in each case. The deleterious effects of two-phase flow in radial inflow machines are well documented. Erosion from particles or liquid trapped within the guide vane- rotor gap has been observed. Degradation of performance has also been demonstrated. For example, **Figure 5** shows the results of gas in a liquid radial inflow expander. Addition of only .2% (by mass) causes a decrease in efficiency from 80% to 60%.

Recent tests of a VPT with flashing liquid nitrogen demonstrated the advantages. **Figure 6** shows the VPT during testing with flashing liquid nitrogen. The turbine was directly connected to a generator which was immersed in the liquid nitrogen. The expander has no gearbox or external shaft seals. Close agreement with predicted output was demonstrated.

The first application is planned for an LNG production plant. The addition of a single VPT to the first stage flash will increase the entire plant output by as much as 3%. Substituting VPTs for each of the six (6) Joule-Thomson flashes in the process can increase plant output by more than 6%.

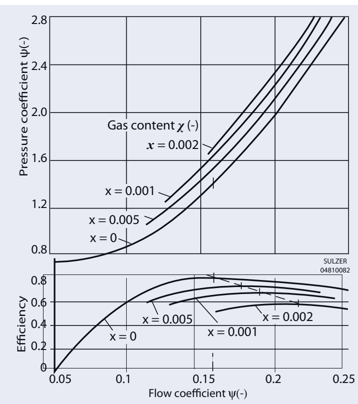


Figure 5: Performance of a 3 stage centrifugal pump operated as a radial inflow turbine in water with changing amounts of air vapor content at the turbine inlet. The *x* stands for the mass fraction of vapor in the flow at the turbine inlet. Note the 20 points decrease in efficiency as *x* goes from 0 to only 0.2% mass fraction (which is 0 to 30% volume fraction). [reference: Gülich, "Centrifugal Pumps", 2010, 2nd edition].

Figure 5

Figure 6

For more information contact Lance Hays at Energent at + 1 949 261 7533 or lhays@energent.net

1 Hays, L., History and Overview of Two-Phase Turbines, International Conference on Compressors and Their Systems, Institution of Mechanical Engineers, London, September 1999

Natural Gas Fired CO_2 Production System

In February, 2010, the **Wittemann Company, LLC**, contracted with BOC Bangladesh Limited (A Member of the Linde Group) for the supply of a 16.5 MTPD Natural Gas Fired CO_2 Production System. The plant was engineered at Wittemann's Engineering Headquarters in Palm Coast, Florida, USA, with fabrication and assembly done at Wittemann – India, Baroda, India, using components supplied from four continents. The plant was shipped in September, 2010, and successfully commissioned by Wittemann service personnel from India, Egypt and the Philippines, In January, 2011.

To the delight of BOC Bangladesh, the plant is operating at its design capacity of 16.5 MTPD and meeting ISBT CO_2 Quality Specifications, while operating costs are below guaranteed levels.

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Purchasing Small To Medium Size Merchant Air Separation Plants

Introduction

Cosmodyne reviews with prospective purchasers the numerous factors to consider when purchasing a small to medium sized merchant air separation plant. While price and efficiency may be the most prominent factors, there are other important less obvious factors to consider.

Background

Typically, small to medium size plants are defined as plants with total liquid production capacity of 4 to 200 metric tons per day. Merchant Plants are usually defined as air separation plants producing liquid oxygen, nitrogen and argon for packaged gas and bulk liquid applications. Small to medium size merchant plants are popular in growth economies since there are fewer supply scheme opportunities (providing "over the fence" gas to an anchor client). There are numerous reasons for a customer to purchase a small to medium sized merchant air separation plant to meet their market demand. Three most common reasons are: (1) merchant plants can be located at a most favorable site with low land cost and electric power costs since they are stand alone plants that are not tied to any gas supply schemes; (2) a single plant can service a wide customer base, usually, depending on the region, a merchant plant can serve customers within a 300 miles (500 km) radius; and (3) small to medium size merchant plants offer standard designs and modular packaging, allowing for low installation and maintenance costs.

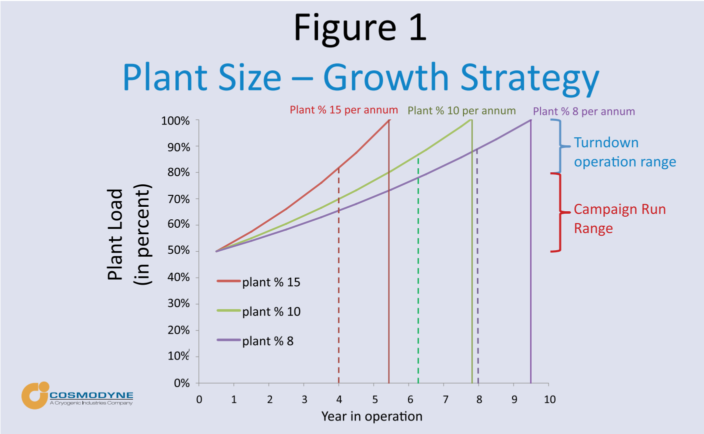
Factor to Consider 1: Plant Size

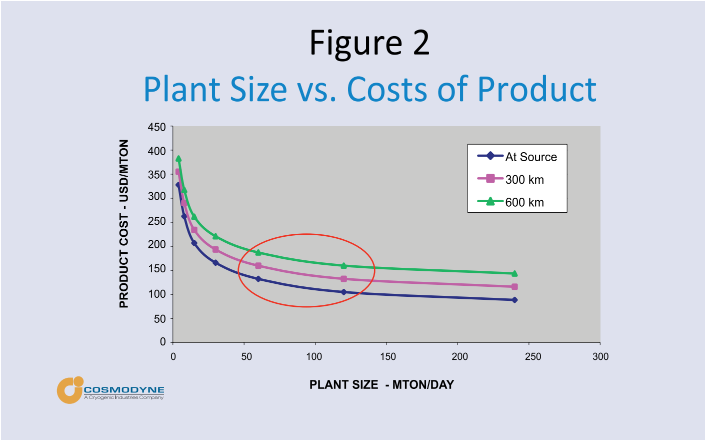
One of the critical factors in selecting the right small to medium sized merchant air separation plant is the plant size. Selecting the right plant size requires a detailed evaluation of various factors from future growth rate to transportation distance of the product to the customer.

Figure 1 shows year of operation versus plant capacity. The growth curves represent various annual growth rates. Traditionally, customers purchase merchant plants with initial plant loading of about 50% to account for future growth. However, depending on the growth rate of the merchant business, this simple rule of thumb may not be sufficient. The curve representing an annual growth rate of 15% (red curve) shows that the plant will reach full capacity in about 5-1/2 years. Similarly, with an annual growth of 10% (green curve), the plant will reach full capacity in 8 years and with an 8% growth rate (purple curve), the plant will reach full capacity in a little less than 9-1/2 years. This means for an operation with a 15% annual growth, the purchased plant would reach full capacity by year 6 of operation. Hence, the company would need to make another decision on the future growth plans in about year 4 of plant operation (to purchase another plant) since a new plant requires about 16-20 months from purchase to production.

Factor to Consider 2: Distance to Customers

Another factor to consider in plant sizing is the transportation distances of the product to the customers. **Figure 2** shows Plant Size versus Cost of Product. The different curves represent the Cost of Product at different delivery distances.

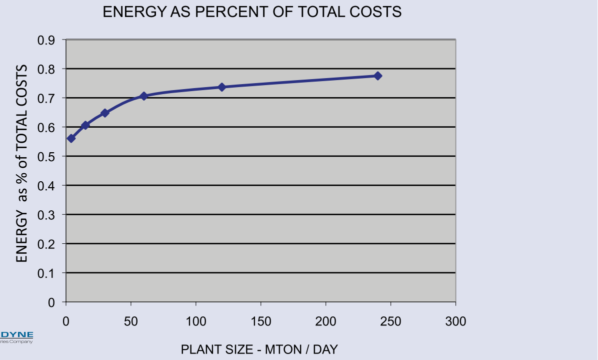




The obvious trend is the larger the plant, the lower the product cost. The slope of the graph shows that there should be a strong incentive to purchase a 50 metric tons per day capacity or larger plant. Another interesting aspect is that in some cases, depending on the distance of the customer base, larger may not always be better. The graph shows that a 60 MTPD plant with a 300 km delivery distance (magenta curve) has the same product cost as a 120 MTPD plant transporting the product 600 km away (green curve). In such a case it may be better to purchase two 60 MTPD plants to cover the 600 km range than to purchase one 120 MTPD plant. The two plants will allow for redundancy, less impact from changing fuel costs, and sharing of spare parts.

Figure 3

Cost of Power



Factor to Consider 3: Cost of Power

Another critical factor in selecting the right small to medium sized merchant air separation plant is the cost of power. For many customers, the purchasing decision usually comes down to capital versus power. It sometimes means choosing a less efficient plant (higher power consumption) to minimize the capital investment. However, recently there is a paradigm shift in this capital versus power balance due to the escalating energy costs and current low interest rates. Customers are now scrutinizing the plant efficiency and examining the cost of power when evaluating plants, since capital remains relatively inexpensive (low interest rates) while energy cost has soared and will continue to rise.

Figure 3 shows the energy cost as percent of total plant life cost versus plant size. The graph clearly shows the significance of power consumption for plant evaluation. For example, the energy cost for a 200 Metric Tons per Day plant is about 75% of the total plant life time costs that includes plant purchase price, power cost, maintenance, spare parts, etc. This is significant and is one of the reasons why there is a paradigm shift in the market. It makes considerable sense to invest in a more efficient plant to alleviate the ever-increasing energy costs and utilize the historically low cost capital available.

Factor to Consider 4: End of Life Cycle Strategies

The next important factor to consider is the end of plant life cycle strategy. What happens to the plant when the plant reaches full capacity or has come to the end of its useful life? There are many options available but considering such strategies during the initial plant purchase can provide for longer plant life and added value. Some of the strategies to ponder are:

1. Design the plant site to allow for easy installation of an additional plant(s) or a liquefier (to liquefy tail gas) to increase the production capacity;
2. Purchase a plant with modular design to allow for easy portability hence allowing the plant to be moved to another location;
3. Negotiate the possibility of a trade in or compare the resale value of the plant between the manufacturers;

Conclusion:

The above features are just a few of the less obvious factors. There are many more factors to consider when evaluating and purchasing a small to medium sized merchant air separation plant. All factors from plant process operation to installation and after service should be evaluated and considered. Cosmodyne has been in business for over 50 years. We have built over 400 air separation plants installed worldwide. We will be glad to assist customers with our experience and expertise in selecting the best plant for the customer's specific application. Small to medium sized merchant air separation plants are a big investment. Plan well.

The information and data given in this presentation are typical only and does not apply to any specific markets. While thespecific numbers may not apply, the slopes and the trend should generally apply to most situations. Each case should be looked at case by case basis.

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LNG Vaporizer Technology Review

Cryoquip reviews the increasing constraints which dominate the selection of best available technologies for LNG re-gas facilities. The optimal decision for LNG vaporization varies depending upon an ever-changing landscape of environmental concerns and proven technologies. Major sources of heat remain the same, but how they are applied individually and in combination may well determine the immediate and long-term viability of a project.

The five available sources of heat have not changed much in all of history. These are fuel, mechanical energy, heat sinks of water and air, and solar radiation. The sources are listed in order of their cost, fuel being the most expensive source of heat, water and air being the least costly, while radiation remains prohibitively expensive to capture. The order shown also represents the ease of accessibility of the heat as well. Air is the most difficult of the four practical main sources of heat, while fuel is the easiest and to date solar energy is impractical as a source of heat supply. However, there is one technology currently available that benefits significantly from solar energy Ambient Air Vaporizers (AAV's).

Any company may choose to weight the wide variety of decision drivers differently, but the range and type of drivers are about the same for most facilities that were questioned. In summary fashion, these include:

1.	Initial capital cost	(CC)
2.	Space required	(SR)
3.	Installation cost	(IC)
4.	Installation time	
5.	Operating cost including maintenance and chemicals	(OC)
6.	Life cycle cost [key integrated measure of cost]	(LCC)
7.	Ease of operation – Simplicity	(SC)
8.	Range of effectiveness	
9.	Efficiency	
10.	Reliability	
11.	Operational flexibility	
12.	Environmental impact	(EI)

Graph Trim Heat Required for Competing LNG Vaporizer Technologies

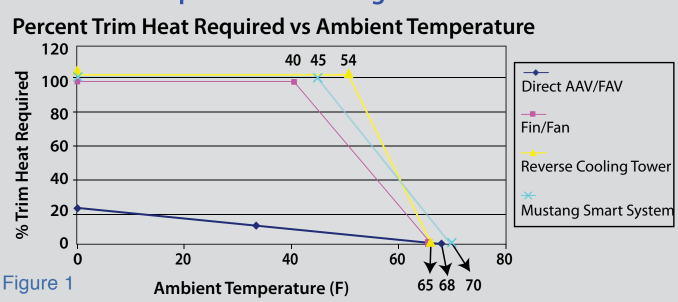

Figure 1

Below is a list of technologies used historically as well as several proposed within the past 10 years. Some have since been successfully applied, others remain under consideration.

Considered Technologies

Amb Air Vap, Direct contact [Nat Draft]	(AAV)
Air w/ Intermediate Fluid Vaporizer	(AIFV)
Direct Seawater Shell &Tube	(SS&T)
Direct Seawater Open Rack Vaporizer	(ORV)
Fan Assisted Amb Air	(FAV)
Heated Water Circulating Vaporizer	(WCV)
Seawater Intermediate Fluid Vaporizer	(SIFV)
Submerged Combustion Direct Contact	(SCV)
Waste Heat Recovery	(WHR)

Cost Analysis Spread Sheet

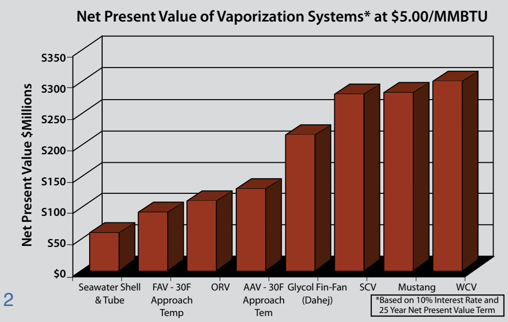

Figure 2

Doing a quick, but thorough economic analysis results is a chart showing the Life Cycle Cost of the various options. [see Figure 2]

Conclusions

All of the recently developed ambient air vaporizer systems examined were capable of heating LNG to suitable pipeline temperatures. All of the ambient systems will require some trim heat at ambient temperatures below the pipeline target temperature. All have different cut off temperatures where the systems are unable to economically withdraw heat from the atmosphere. [see Figure 1] This is where a significant difference first appears in the comparisons.

For more information contact Lyn Himmelberger at Cryoquip at + 1 610 349 3444 or lhimmelberger@cryoquip.com

Rhine Engineering, a Jewel in Cryogenic Industries Crown

RHINE ENGINEERING PRIVATE LIMITED is a specialized fabrication facility and a captive resource for the manufacture of products and components for the Cryogenic Industries group of companies. In its own right it is an acknowledged fabricator of Pressure Vessels, Dryers, Rotary Kiln dryers, Portable Chemical Transportation, Process Valve skids, Columns, and Reactors for diverse applications.

Rhine has a 12,500 sq. meter manufacturing facility, set on over 17 acres of land at Por-Ramangamdi an industrial estate about 22 km from Vadodara, Gujarat, India. Vadodara is becoming a large Engineering and Fabrication hub catering to the giant Power sector and the Gas Sectors of Industry to meet the growing demands of national and international markets. Industry leaders like Siemens, ABB, Alstom, Bombardier, AREVA, Linde etc, have large facilities in the area to meet the future growth potential which in turn develops ancillary units and a vendor base to cater to their growing needs.

The Company was formed in 2003 and has four divisions manufacturing group products. The "Cryoquip India" division started manufacturing Cryoquip Vaporizers for the Indian gas industry markets in 2004. A full range of natural draft and forced draft ambient, and steam bath vaporizers are manufactured, and Cryoquip now has a market share of over 70% in the ever growing Industrial Gas market in India.

The "Wittemann India" division started fabrication of carbon dioxide recovery systems for the Brewery and the Distillery domestic markets and generation plants for the export markets in 2005. There is excellent growth in the Brewery and Distillery industry in India, and the Wittemann India division plays a lead role among the organized players in this market.

ACD service center in Rhine

The "ACD India" division identified a need for servicing ACD and competitors cryogenic pumps and turbines in India and established a "Service Centre" in the facility in 2010 supporting domestic Indian customers. This year they have opened up a second "Service Centre" in Kolkata to better serve their customers in the eastern parts of India.

The "Rhine Products" division uses the heavy fabrication machinery assets of the facility, Plate Bending Machines, Hydraulic Press, CNC Press Brake, Welding Machines, Drying Oven and EOT Cranes, and its specialized expertise in manufacturing technology, design, and engineering for the fabrication of pressure vessels, transportation tanks, rotary dryers, kilns, and specialized fabricated items for the hydro and coal power sectors and provides similar engineered products for industries ranging from Chemical, Petrochemical, Food, Oil & Gas, Refinery, Power plant and Steel making.

In addition the machine shop is well equipped with 'State of the Art' machines suitable for large, round machining operations on fabricated components. We also have necessary testing facilities for dye penetration and pneumatic and hydraulic testing.

The facility is a "one stop shop" for our customers, who approach us for fabrication, machining testing and total supply capability requirements.

The Rhine products division has a diverse customer base comprised of recognized companies in a number of markets. Our quality control systems enable fabrication of equipment under all third party inspection agencies including Lloyd's (LRIS), DNV, BVIS etc., and is accredited to manufacture ASME Coded and Stamped Pressure Vessels in accordance with Section VIII, Divisions 1 & 2, and is also approved by the Chief Controller of Explosives.

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Rhine facility bays and some products made in India

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