FROSTBYTE
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Choosing a Profitable Path

A developer wishing to install a natural gas liquefier is faced with the question of how much capacity to install and when. At first thought, a single train that meets the projected demand for the life of the project would make the most economic sense. However, if the plant is not fully utilized and is operating at reduced capacity to match a growing market demand, taking into account the time value of money, a developer may be better off installing multiple smaller plants. In addition to the economic benefit, multiple trains also provide the developer and its customers, assurance of supply.

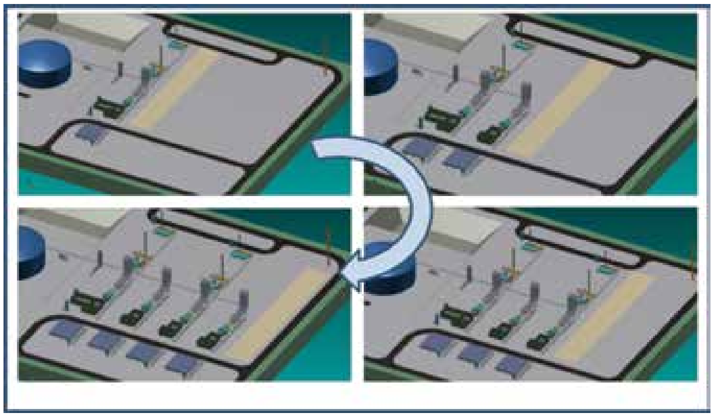
LNG adoption for vehicle, rail, marine and high horse power use is still in the early stages and many developers are faced with the challenge of raising capital for LNG production while attempting to secure sales contracts for product. Multiple-train scaling to match production is not only more cost effective, but also mitigates risk associated with market growth forecasts. Additionally, this approach also defers the requirement for capital which is appealing to lenders.

Given these not-so-obvious factors, it is very likely that the more cost effective approach for a developer is to build capacity in a manner that more closely mirrors its demand forecast. In this article we will discuss the benefits of installing capacity in small increments and we will explore these benefits with a simple case study.

There are many benefits of installing capacity in smaller increments, the most valuable of which is the ability to postpone capital investment. Furthermore, a developer that projects the future market and opts to build capacity with a series of multiple trains has the opportunity to revise and re-evaluate the conditions of the market at any time and re-plan its future expansion accordingly. A projected 450,000 gallon-per-day capacity requirement could be met, for example, with a 150,000 gallon-per-day train followed later by a second and third duplicate train. Or, if market demand is growing faster and larger than expected, a second 300,000 gallon-per-day train can be added to the first 150,000 gallon-per-day train. The flexibility to match the demand growth curve for LNG by slowing down or speeding up orders for additional trains may be well worth the trade-off in capital expenditure to many companies, especially if the full projection capacity for the market is not expected to be reached for several years or is not well defined.

A multi-train approach also allows a developer the ability to 'test' a market for LNG with a minimum of capital investment. Companies rushing to be the first into a market have to make decisions about how much capacity they believe the market can handle even before having nailed down contracts with end-users. By going into a market first with a small capacity, LNG suppliers can show their potential customers that they are serious about the market and allow both parties the opportunity for a test-run of the relationship.

Other considerations which are sometimes overlooked are the losses associated with stopping and starting and running too far turned down. By installing smaller plants, a developer can realize significantly lower operating costs when compared to the costs of running one large train. In the early stages of a project, when market demand is small, a developer that decides to install one large train for the life of the project will need to operate the plant at reduced capacity or routinely stop and start the plant to match the current market needs. Running the plant in a turned down mode or routinely starting and stopping the plant will result in a power penalty when compared to running the plant at full capacity, continuously. When starting up a liquefier, the cryogenic process takes time to cool down before liquid is produced and the power consumed during this period is essentially wasted, since it does not contribute toward making any product. A more closely matched, smaller plant will require fewer stops and starts.



Modular Expansion Grows with the Market

Running in turned-down mode has limitations and power penalties as well. It is typical to turn down the plant output to match demand, however there are limitations as to how far a plant can be turned down due mostly to inherent characteristics with rotating machinery. In addition, plants do not turn down linearly, meaning a developer will not realize an equally corresponding savings in energy with the same percentage of production turn down. Furthermore, at some percentage of turndown it may be more economical to stop and restart the plant than to continue operating in this inefficient mode. For a liquefier designed around a nitrogen expansion cycle, this turned down limit is around 30% of full capacity. A more closely matched smaller plant will not need to be turned down as much and will operate in a more efficient operating range. Take for example a developer that will initially have a 90,000 gallon-per-day demand which they expect to grow to 850,000 gallons-per-day during the life of the project. A developer would need to run at 1/8th or 10.5% of a plant's capacity if they installed an 850,000 gallon-per-day plant versus running at 50% of capacity on a 180,000 gallon-per-day facility. The energy savings in running at a higher percentage of plant capacity can be substantial, particularly in an area where power is expensive. Moreover, in some cases the savings can outweigh the capital savings associated with installing a single train versus multiple trains.

If a developer decides to install multiple duplicate trains, additional benefits can be realized. First-time engineering costs associated with the initial train are eliminated on future trains and site engineering and construction is optimized each time a train is installed. In a recent LNG Conference, a leading LNG supply company cited a decrease of 50% in cost when installing a 2nd train at their multi-train site. Multiple duplicate trains can also provide a developer with a shortened schedule for the trains installed after the first one.

Case Study

This case study will walk through a simple analysis that provides a financial basis for installing capacity with multiple trains. This example assumes an LNG supply developer is trying to enter a new market. According to its projections, the maximum demand in the area could be as high as 850,000 gallons-per-day total capacity across their prospective fueling, peak-shaving, and export businesses. But because users in the area haven't completed the switchover to LNG fuel for their engines, the current demand is only for about 90,000 gallons-per-day. Even if the developer's projection is for market demand to grow at 18% per year until maximum demand is reached, the market will still not reach an 850,000 gallon-per-day production for fourteen years. This developer will need to decide on how many trains it will install; one single train that meets the maximum demand or multiple smaller trains that grow with its demand growth projections. Figure 1 below depicts how a single train and various multi-train build-outs compare to the developer's demand growth. The graphs also depict when capacity would need to be installed during the life of a 15 year project. For example, in the two train build-out graph, a 2nd train would not be installed until closer to year nine, more than halfway through the project's life.

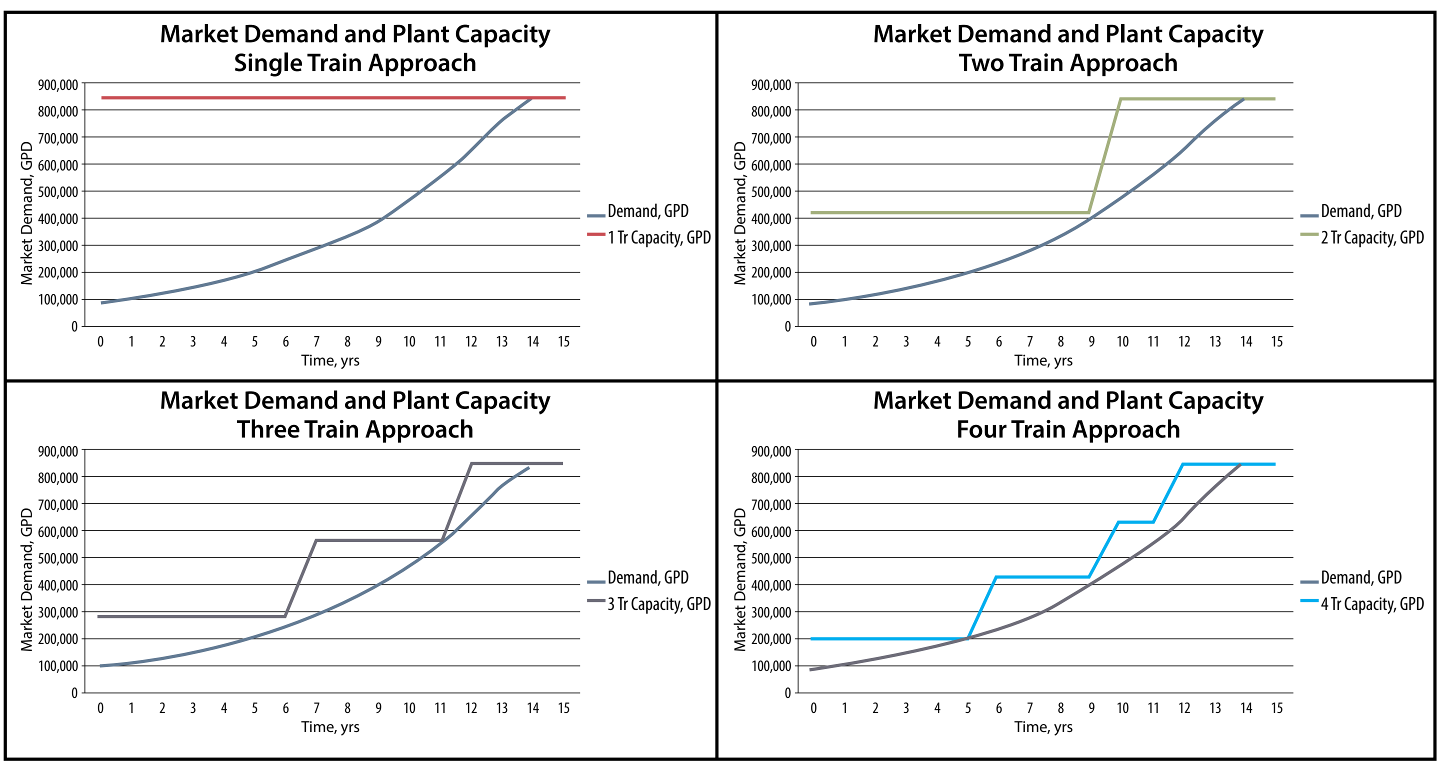


Figure 1: A Multi-Train Approach Wastes Less Capital as the Market Grows to Full Demand Over Time

Continuing with the study, a present value of the capital associated with each of the configurations in Figure 1 is calculated using a discount rate of 15%. The capital values assume the following design basis. First, natural gas is liquefied using a nitrogen expansion cycle. The simple design, wide range of operating flexibility, and low capital cost of a nitrogen cycle liquefier makes this technology the optimum choice when considering capacities of this size. Furthermore, nitrogen liquefaction cycles use standard "off-the-shelf" machinery which lends the technology to offering liquefiers of various sizes. Second, the developer will install the infrastructure necessary for the entire capacity required for the life of the project, up front. This infrastructure includes gas pretreatment for the 850,000 gallons-per-day of required capacity and a field erected storage tank. In a more rigorous analysis, this assumption can be further explored to determine the optimum pretreatment and storage capacity build-out rate.

The results of this present value calculation finds that though the nominal capital cost of the single (850,000 gpd) train is significantly less than for any other build-out mode, when the investments are discounted back to present value the two-train approach (2 x 450,000 gallons-per-day) it actually costs less.

Next, a present value for operating expenses is calculated. In this case study, the OPEX model only accounts for energy (electrical) consumption. It assumes an electrical price of $0.12/kWh and takes into account the varying efficiencies of running the plants at different rates of turn down while demand grows. When the OPEX present value is added to the CAPEX present value, the three-train solution becomes the overall lowest cost approach.

Figure 2 below depicts the CAPEX and OPEX contribution to the present value result for each of the plant configurations modeled. The differences in present value between the 2, 3 and even 4 train build outs are small in this analysis. Further refinement of the model will lead to a clearer picture of the optimum solution. However, it is clear that the one train approach is not the optimum solution.

For clarity, the summary table [Figure 3] on the next page is an example of the table of values used to calculate the CAPEX and OPEX contribution depicted in Figure 2. A similar table was built for each of the options modeled.

It is important to explore the sensitivity of the model under the given circumstances. Modifications to the IRR, demand growth rate, or projected maximum demand can each have a significant impact on the results of the analysis. In the given example, raising the IRR to 19% pushes the lowest-cost build-out to the 4-train approach, and likewise decreasing it to 13% pushes the lowest-cost build-out to the 2-train approach. Increasing the demand growth rate to 26% points to fewer trains, whereas decreasing it to 14% points to more trains. And changing the maximum projected market demand to 725 thousand gallons a day decreases the number of plants in the optimum train build-out mode, while changing it to 1.25 million gallons a day increases the number of plants in the optimum train build-out mode. The results of the analysis may be fairly conclusive to changes in some of these variables, but on some variables, the results may lie in between two optimum solutions. In that case, it will be worth considering the results in both situations and determining which leaves the developer more flexibility to change its plans in the future when there is more clarity regarding the true value of the variables. The table on the following page [Figure 4] summarizes the results of the sensitivity analysis presented here.

As previously mentioned, this is a fairly simplistic economic model but it is enough to explore the point. A more rigorous model will include refined capital investment numbers, operational costs for utilities other than electricity, operational costs for maintenance, sales and property taxes, variations in demand growth and variations in interest rates over time, among other things. It will also independently analyze for the optimum pretreatment and storage capacity build-outs. The model can be as rough or as refined as needed. A key takeaway from this case study is the importance of building a new model for each investment opportunity, since two opportunities with similar projected maximum market demand numbers may not have the same lowest-cost build-out mode.

Today, LNG suppliers can benefit from looking at liquefaction plants of various capacities instead of deciding on one large plant to meet a forecasted demand. Among other things, a multi-train strategy to building capacity can lead to a more profitable project that is better able to withstand the risks associated with today's LNG markets. Cosmodyne has been able to help many clients with this analysis and offers a large range of liquefiers from 5,000 gallons-per-day up to 500,000 gallons-per-day.

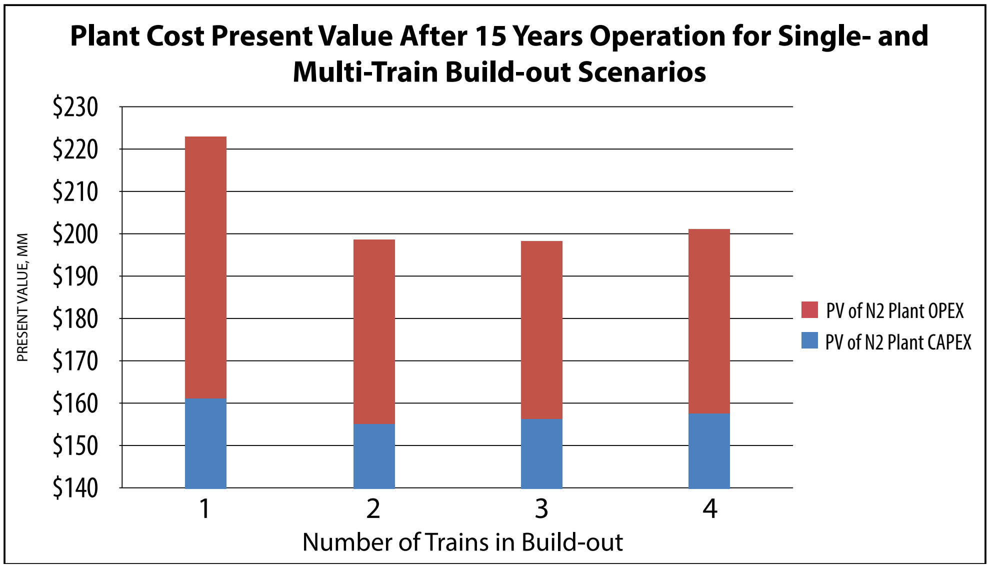


Figure 2: The Total Three-Train Build-out Present Value is Lowest for this Application

Summary Table For Three-Train Build-out Analysis

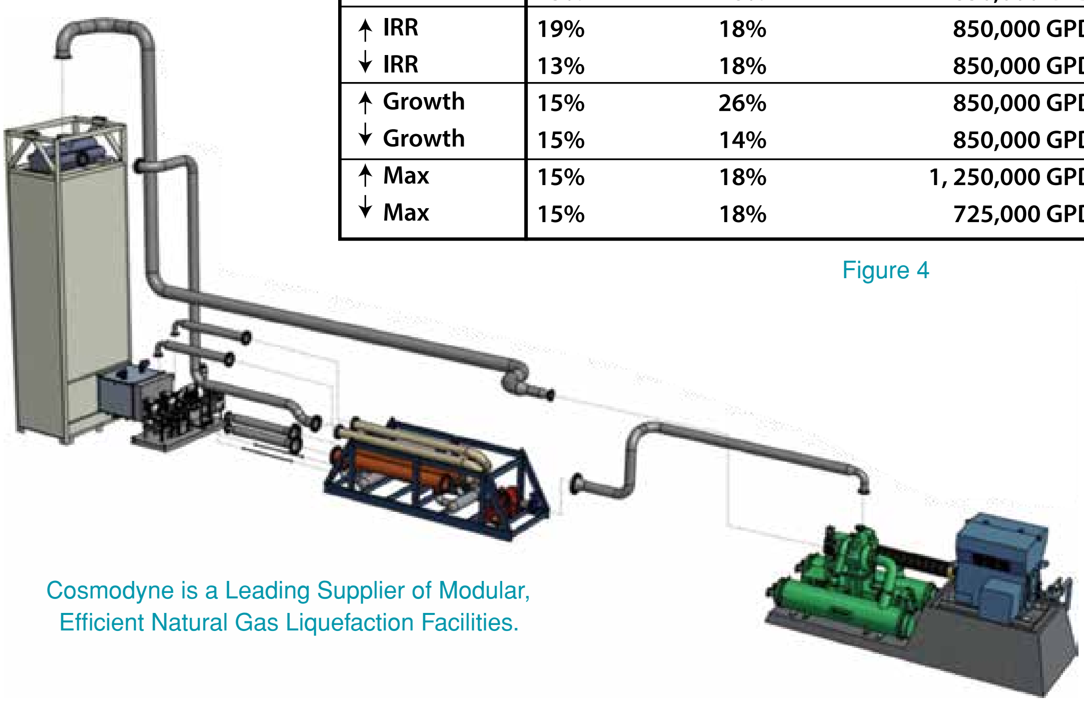
Years	Market Demand, GPD	Trains Installed	Installed Capacity	Turndown Ratio	Electrical Demand, kWh	Capex, MM	Opex, MM
0	90,000	1	283,333	0.32	47,258	$ 135,840,000	$ 1,980,000
1	106,200	1	283,333	0.37	54,197	$ -	$ 2,280,000
2	125.316	1	283,333	0.44	63,683	$ -	$ 2,670,000
3	147,873	1	283,333	0.52	76,654	$ -	$ 3,220,000
4	174,490	1	283,333	0.62	94,390	$ -	$ 3.960,000
5	205,898	1	283,333	0.73	118,639	$ -	$ 4,980,000
6	242,960	1	283,333	0.86	151,793	$ -	$ 6,380,000
7	286,693	2	566,677	0.51	147,798	$ 34,460,000	$ 6,210,000
8	338,297	2	566,677	0.60	181,244	$ -	$ 7,610,000
9	399,191	2	566,677	0.70	226,974	$ -	$ 9,530,000
10	471,045	2	566,677	0.83	289,500	$ -	$ 12,160,000
11	555,833	2	566,677	0.98	374,990	$ -	$ 15,750,000
12	655,883	3	850,000	0.77	388,429	$ 39,950,000	$ 16,310,000
13	773,942	3	850,000	0.91	499,835	$ -	$ 20,990,000
14	850,000	3	850,000	1.00	580,223	$ -	$ 24,370,000
15	850,000	3	850,000	1.00	580,223	$ -	$ 24,370,000
						Total Present Value	$ 198,680,000

Figure 3

Sensitivity Analysis Summary

	IRR	Demand Growth Rate	Max Projected Demand	Optimum Build-Out
Base Case	15%	18%	850,000 GPD	3 Trains
↑ IRR	19%	18%	850,000 GPD	4 Trains
↓ IRR	13%	18%	850,000 GPD	2 Trains
↑ Growth	15%	26%	850,000 GPD	2 Trains
↓ Growth	15%	14%	850,000 GPD	4 Trains
↑ Max	15%	18%	1, 250,000 GPD	4 Trains
↓ Max	15%	18%	725,000 GPD	2 Trains

Figure 4



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How To Properly Operate And Maintain Steam Sparged Water Bath Vaporizers

Compact Configuration with
Process and Pressure-Building Bundles

Vertical Insulated Unit

Steam sparged water bath vaporizers are an extremely effective way to provide vaporization for a diverse range of applications and offer a high level of reliability where steam is available as a heat source. Cryoquip designs steam sparged units to meet a variety of needs, but their best features include a compact configuration, high reliability, cost effectiveness, and versatility.

Overview

The vaporizers are designed in various sizes and in both vertical and horizontal configurations, to meet a wide range of flow rates. Typically, vertical units are used for smaller applications or when there is a small footprint limitation, and horizontal units are used for larger applications or extended ballast requirements. Because of their relatively small footprint, these are very convenient for large back up systems. For additional space savings, multiple bundles can be arranged in a single tank, to allow for several process and pressure building flows.

The units feature an atmospheric water bath tank, process bundle or coil, and internal steam sparger manifold with spargers. The tank water temperature is monitored so when the process flows through the bundle, which causes the water temperature to drop, the steam valve opens to inject heat through spargers. The system typically operates on a 10°F dead band with the control valves operating with an 'on-off' action (i.e. to open at 140°F and close at 150°F). This type of operation offers significant cost savings as steam will only be injected when there is a load on the system or as needed to make up for heat losses to the environment.

The hot water in the tank acts as heat storage (commonly referred to as ballast) which provides vaporization for a specified period of time after steam flow is lost, without damaging the equipment and with acceptable process outlet temperatures.

To ensure the life of this equipment it is important to use properly treated, saturated steam at the designated pressure, correct valve operation, perform regular maintenance checks, and installation on an adequate foundation. When properly cared for, steam sparged water bath vaporizers can be a valuable asset to a facility for many, many years.

Quality of the Steam

The condition of the steam is essential for proper operation as well as longevity of the unit. There are several factors to keep in mind:

Saturated – The steam needs to be injected at saturation temperature so the heat can be absorbed by the water in the tank.

Super-Heated Steam – Super-heated steam requires a special design to ensure that the heat of the steam is absorbed by the water. In a standard saturated steam design the bubbles created by super-heated steam are too hot, so they cannot transfer all of the heat to the water. This results in a very loud banging noise, vibration, and damage to the unit as the steam bubbles pop at the top of the tank, instead of injecting smoothly into the water.

Free of Condensate – It is critical to install a condensate trap upstream of the unit to remove condensate formed in the piping to the unit to prevent damage. If condensate is in the steam, it can cause the control valves to leak and the spargers will not be able to inject the steam appropriately.

Steam Treatment – Steam needs to be properly treated under the direction of a water quality specialist to minimize corrosion and maximize the life of your equipment. An imbalance in the composition and certain chemicals such as chlorides, can corrode through several of the components including the steam train, control valves, internal steam piping, process piping, and the water tank itself.

High-Pressure Steam – The standard steam pressure for this equipment is between 100 psi and 150 psi. Higher pressure steam will have similar issues as super-heated steam, due to the higher saturation temperature in a standard unit. A high pressure steam design is available utilizing components including control valves and spargers to meet the high pressure requirement.

Multiple Process Bundles

Installation, Operation and Maintenance of a Steam Sparged Unit

The installation, operation and maintenance of steam sparged water bath vaporizers is critical to the performance of the unit. Below are some of the key concerns:

Strainer – Before the steam gets to the control valve, all of the particulates from upstream piping need to be filtered out with a strainer. Both the strainer upstream and the strainer that is included with the unit need to be cleaned out on a regular basis so the flow of the steam is not inhibited.

Valves – A RTD (Resistance Temperature Detector) water temperature sensor is included on the water bath to allow the customer to monitor the water tank temperature. Typically the customer will wire up to the RTD sensor to operate the steam control valve in an 'on-off' type action. This results in the smoothest operation. If the actuator is not properly positioned or the seat is damaged, it is possible for the steam valves to leak. Leaking valves will allow the tank temperature to rise above the set point, possibly up to boiling.

Overflow Piping – The overflow connection must be piped to a drain where it can be recycled to avoid the hot water from flowing out the top of the unit. The injected steam adds mass to the tank which needs to be removed safely, especially when the unit is operating frequently.

Foundation/Civil Design – Due to the energy contained within the steam that is being absorbed by the water, it is usual to have some noise and vibration associated with this type of equipment. It is very important that the foundation be sufficient enough to both support the unit and not magnify the vibration which could cause damage to the vaporizer.

Extended Ballast

Special Features / Options

- Removable process bundles and coils, for ease of maintenance
- Multiple bundles in the same unit for multiple streams, including pressure builders
- Steam control valves using pneumatic or electric signals
- Top-mounted removable spargers – simplifies maintenance by eliminating the need to drain the tank in order to service the sparger
- Single 100% control valve or dual 100% steam control valves, which provide redundancy for higher reliability
- Water circulation pump option
- Insulated tank
- Extended ballast
- Stainless steel water bath tank and steam manifolds
- Low-pressure steam design and superheated steam design
- Local water temperature controller
- Low water level switch and alarm
- Low discharge gas temperature switch and process shut down valve
- Low water temperature switch and alarm
- Can be used for trim heating

When installed and operated with these points in mind, steam sparged water bath units are an extremely reliable and cost-effective form of vaporization that can be designed to meet a wide range of needs.

For more information, visit www.Cryoquip.com.

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