CRYOGENIC INDUSTRIES
FROSTBYTE
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Rapid Engineering of Turboexpanders

An essential component of an air separation plant, which separates process fluids into pure gases or pure liquids in order to make them commercially available to the end user, is the turboexpander. The turboexpander consists of rotating assembly with expander and brake (usually compressor) located on two ends of a rotating shaft, housings, flanges, skid, subsystems to deliver seal gas and oil into the vicinity of the rotating assembly, interfaces with plant cold boxes, and junction outlets to interface with customer utilities. The rotating assembly, together with its surrounding stationary housings, is called the cartridge as shown in Figure 1.

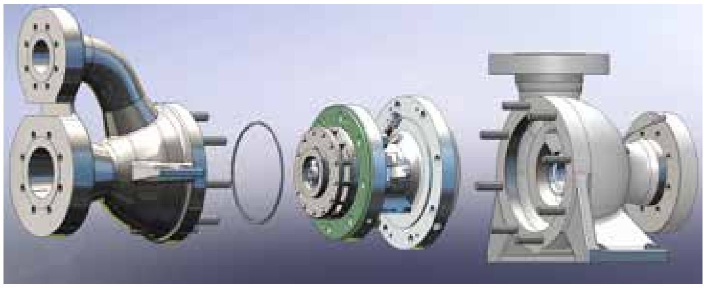

Figure 1

Industrial gas producers have changing thermal process conditions and varying plant output capacity. Therefore, suppliers of expanders are expected to satisfy needs which include low cost, high performance, high reliability, continuous operation over long periods of time, simplicity of installation, and ease of replacement and maintenance in order not to interrupt plant production.

The customer has full control over turboexpander function and output capacity because, due to electronic communication channels between plant and machine, the turboexpander function self-adjusts to match plant cold production needs. Also, because plant continuous operation is essential, ease of assembly and disassembly is required and, therefore, the cartridge is designed as an integrated unit separate from the expander and compressor housings. This allows for simple and fast cartridge replacement and/or repair, without hindering the entire plant cold production capacity for long.

ACD has, over the past 50 years, placed in operation over 1000 turboexpanders utilizing:

1. Many standard components such as inlet and outlet flanges, shafts, bearings, and expander variable-area vaned-nozzles;
2. Differentiated frame sizes in order to match customer process conditions; and
3. Aerodynamic design parameters to optimize cartridge function, reliability, and performance.

The rotating assembly is engineered using in-house test performance data, and achieving high expander and compressor efficiencies is critical. Typical expander efficiencies are in the 85% to 90% range, and typical compressor efficiencies are in the 75% to 85% range.

ACD developed proprietary computer code which selects, from among the nearly 1000 production units, the most suitable frame size. Figure 2 shows ACD's frame size series chart for compressor-loaded expanders which, depending on the process conditions (at design and off-design operating conditions), yield

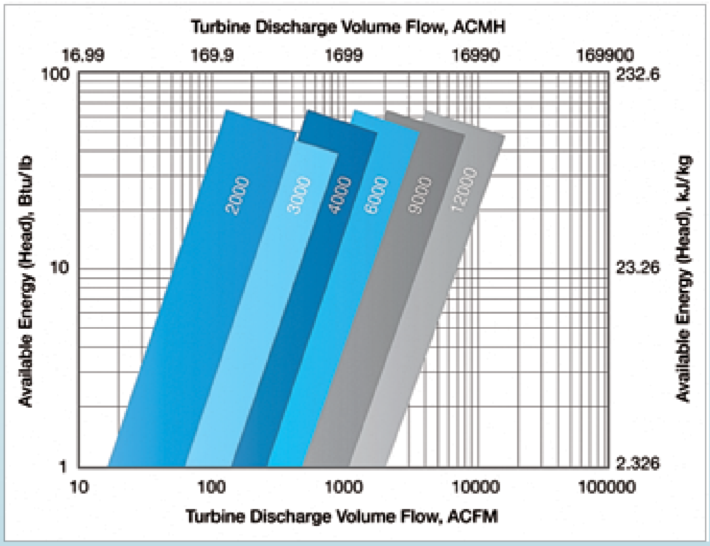

Figure 2

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the most suitable frame size, ranging from small low-power 2000-frame to large high-power 12000-frame. Benefits of the code, which utilizes actual cryogenic test database, include:

1. High-speed simulation;
2. Determines optimum configuration;
3. Accurate performance prediction with less than 1% error;
4. Predicts future replacement cartridge performance for potential increase in cold production; and
5. Guarantees aerodynamic, thermal, and structural parameters are within acceptable ranges.

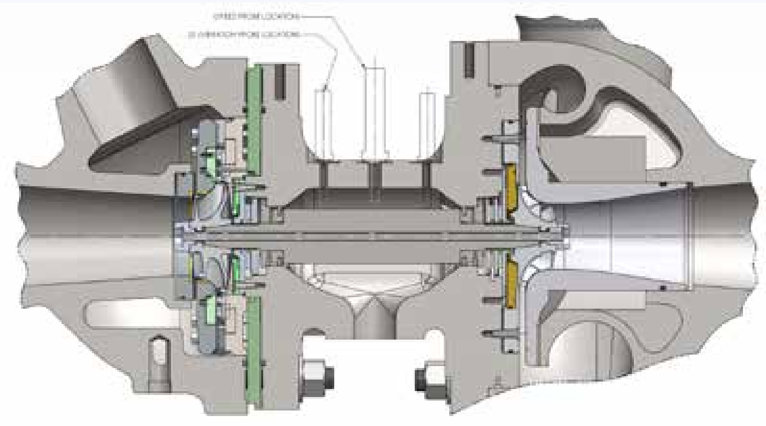

Figure 3

After the initial sizing; detailed analysis of aerodynamics, stress, vibrations, rotor dynamics, heat transfer, material selection, thrust, bearings, seal gas flows, and computational fluid dynamics (CFD) are performed. Figure 3 shows 3-D model of a turboexpander cartridge.

During operation oil is continuously supplied (and subsequently cooled) in order to cool the bearings. ACD utilizes the most common-and-reliable bearings type, the tilt pad journal-and-thrust hydrodynamic bearings which can withstand up to 500 psi load capacity. The oil flow pathways are separate from process gas and seal gas flow pathways. At no time during operation would the oil mix with the process gas on either the expander or the compressor side. This is achieved by utilizing a complex pressure-driven seal gas flow structure.

Over the past 50 years, in order to be able to select an optimum expander configuration, ACD had developed precise relationships between expander cryogenic test performance and fundamental design parameters such as the specific speed, as shown in Figure 4.

In summary; ACD produces high-performance turboexpanders at low cost and rapid delivery, by utilizing:

(a) As many standard components as possible;

(b) Production cartridge designs with excellent performance;

(c) Bearings, shafts, and seal gas subsystems with proven performance and reliability;

(d) Cryogenic test performance database;

(e) Proprietary computer code for process conditions simulation; and

(f) Designs which allow for ease of repair, replacement, and integration into air separation plant.

For more information, visit acdcom.com.

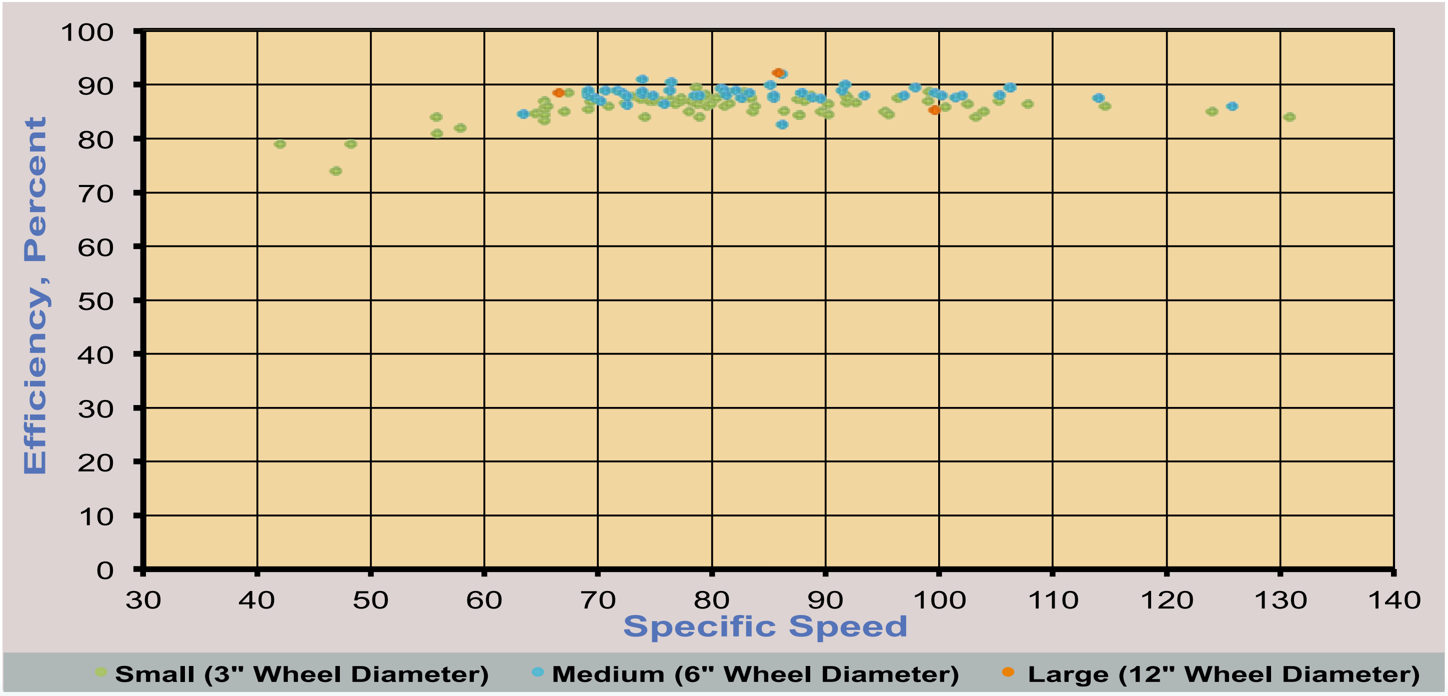

Figure 4

LNG Storage Tank Pressure-Cost Considerations for Virtual Pipelines

In the design of small to mid-scale natural gas liquefaction facilities, the decision of storage tank operating pressure can have considerable economic impacts on overall operating costs. Therefore, when deciding on tank design and operating pressure, it is important to look beyond the plant site. For virtual pipelines (where LNG is delivered to a location and gasified for end use) these considerations are different than, for example, situations where alternate engine fuel as LNG is the end use.

Next to natural gas, the second most expensive component of LNG is the energy consumption required to liquefy the natural gas. Among other factors, small changes in liquefaction storage pressure can significantly impact liquefier energy consumption. The higher the storage tank pressure, the lower the power consumption and the higher the product temperature. The opposite is true for lower storage tank pressures.

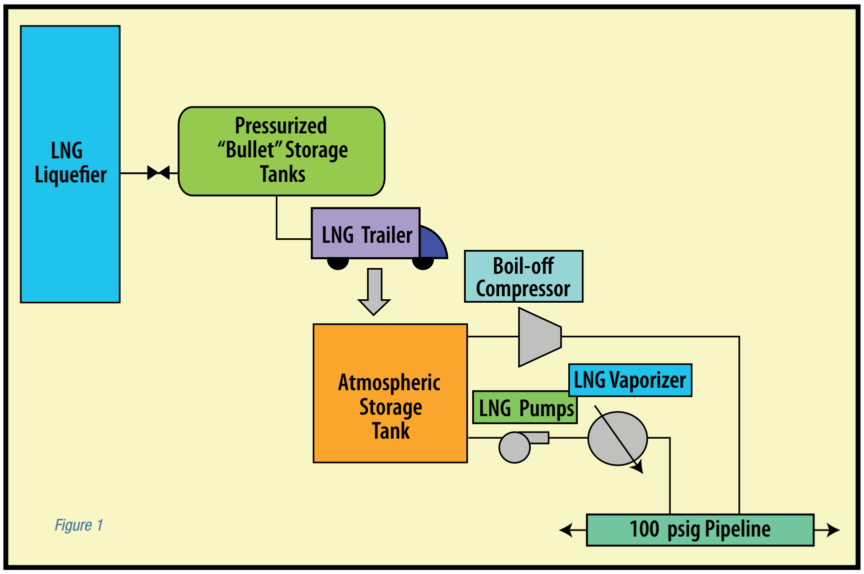

Figure 1

When transporting LNG by trailer, the assumption is typically made that colder, lower pressure LNG product put into the plant storage tank results in the lowest overall operating cost due to the reduction of flash losses. In some cases, this proves to be true. However, for a virtual pipeline, this may not be the case and therefore, an analysis of the entire supply system, from the liquefaction plant to the pipeline should be completed to ensure the system with the lowest operating cost is designed.

Take for example, the following case study. A client has pre-fabricated, high pressure storage available at the LNG production site. The plant fills these tanks with saturated LNG and the LNG is then loaded onto trailers. The trailers transport the LNG over the road to a gasification station hundreds of miles away. It is assumed that the trailer's allowable working pressure up to 20 psig will prevent any boil-off while on the road. At the gasification site, the LNG is unloaded into a large atmospheric storage tank then pumped through a vaporizer into a pipeline at 100 psig. In addition, for flash gas generated during trailer offloading into the tank and tank heat leak, there is a boil-off gas compressor to compress the flash gases into the pipeline. See Figure 1.

For this case study, the client has a choice of storing the LNG at 20 psig (warmer LNG) or at atmospheric pressure (colder LNG) or anywhere in between. The lowest cost solution will involve a comparison of the overall power consumption difference of the liquefaction power and flash gas compression between both cases. See table below for the results of this comparison for a 300,000 GPD LNG system.

In summary, you will note that producing saturated LNG at atmospheric pressure instead of 20 psig results in 774 kW more power consumption even when considering the power required to compress the flash gases at the gasification station. It is important to note that this situation was unique to this client because bullet tanks were installed at the plant site (versus an atmospheric flat bottom tank) which allowed operation at higher than atmospheric pressures. LNG was re-vaporized to a pipeline which made it easy to recover the flash losses into the pipeline (a different evaluation would occur if the LNG were being sent to a filling station to fill LNG engines where flash losses would add a different, more substantial operating cost) and finally, the trailers can operate at higher than atmospheric pressure.

Regardless of the outcome of the analysis, a nitrogen expansion cycle liquefier allows a client to dial in any product temperature and storage pressure required to achieve the goals of the project.

For further information, please visit www.cosmodyne.com.

	CASE 1	CASE 2
LNG Production	300,000 gpd	300,000 gpd
LNG Product Storage pressure	20psig	atm
LNG Product Temperature	121K	109K
Liquefaction Power Consumption	Base	+945 kW
% of Product Flash at Gasification Station	7.5%	0%
Boil of Gas Compressor Power for Flash	171kW	0 kW
Net Power Consumption	Base	+774kW

Current Experience with the Euler Turbine

Energent develops new energy technology, including new power cycles and new types of turbo machinery. One of the first new turbines developed was the patented Euler turbine. This turbine has several advantages including high efficiency, high reliability and tolerance to liquids and solids.

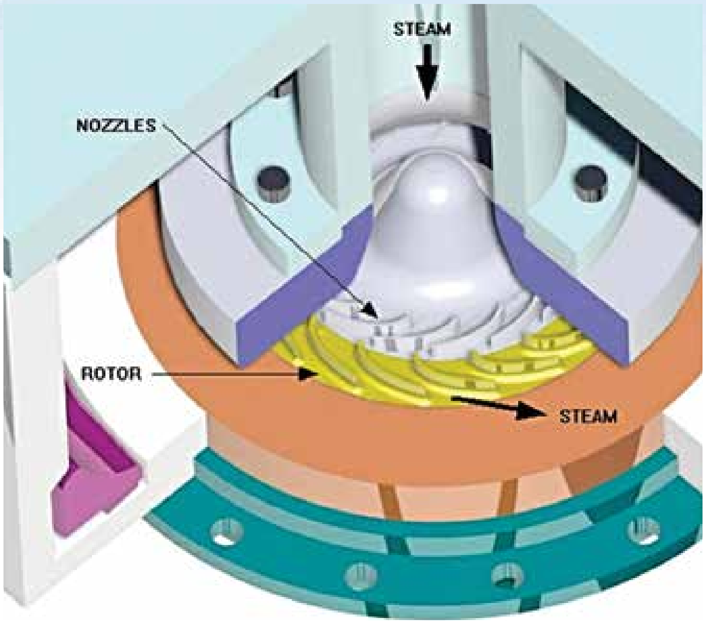

Figure 1 – Microsteam Turbine Operation

The basic principles of the Euler turbine are illustrated in Figure 1. The flow enters the center of the turbine and flows radially outward. The fluid is expanded through a nozzle row to a high velocity, driving a turbine rotor surrounding the nozzles, and subsequently exits through an annular diffuser. The use of two expansion stages results in high efficiency. Unlike radial inflow expanders, the radially outward flow enables the turbine to clear any solid debris or liquids from the interface between the nozzles and the rotor. Another advantage is that the blades are very rugged and not susceptible to vibrations or breakage as is a common problem in some radial inflow machinery.

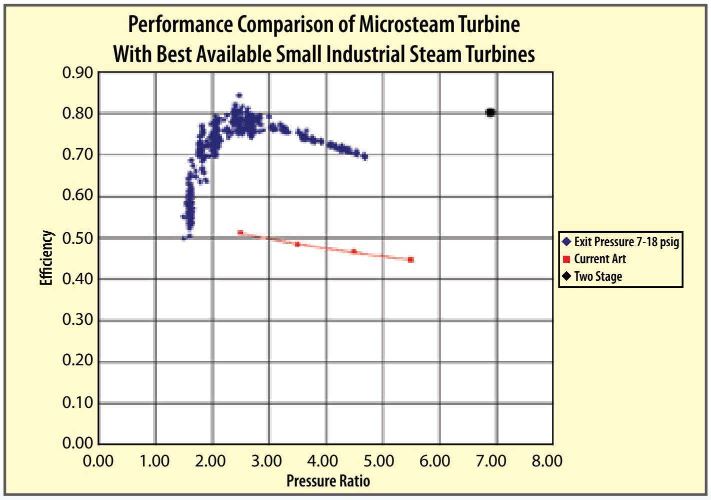

Figure 2 – Performance Comparison

The first application of the Euler turbine is known as the Microsteam® turbine. This power system has a rating of 275 kW. The application is to convert wasted steam pressure energy to useful power. Among industrial steam turbines, the Microsteam® turbine is unique in achieving a very high efficiency. Figure 2 shows measured test results of the efficiency versus the pressure ratio across the Microsteam® turbine for tests at the United Technologies Research Laboratory. As shown, efficiency peaks at 80% which can be compared to efficiencies in the 45-50% range for conventional industrial back-pressure steam turbines in this size range. Also shown is efficiency of a two-stage Microsteam® turbine which extends the high efficiency values to a higher pressure ratio.

Figure 3 – MIcrosteam Open Rotor

The rugged blades shown in Figure 3 are constructed from titanium alloy. The blades are very strong and are not susceptible to resonance-producing vibrations. An example of an installation at Con Edison in New York City is shown in Figure 4. The unit was designed with a vertical axis and a compact 34" width to enable installation through a standard doorway. The controls, electric switch gear and lube oil system are all mounted on one skid providing a complete factory built power system. This power system can operate unattended and has an automatic start and shut down.

Figure 4 – Microsteam Power System 275 kW installed at Con Edison Steam Station NYC

Currently the aggregated operating time for the several Microsteam® power systems that have been sold is 150,000 hours. They have produced more than 30,000 megawatt hours of useful power from previously wasted pressure energy. The successful application to steam led to other applications.

Figure 5 – Microsteam Turbine installed in a Kalina Cycle Power Plant in Taiwan

Another application is in a Kalina cycle power system to produce power with an ammonia-steam mixture. Figure 5 shows a Microsteam® turbine installed in a Kalina cycle power plant in Qingshui geothermal field in Taiwan. The unit was successfully demonstrated, generating power from previously unused geothermal brine.

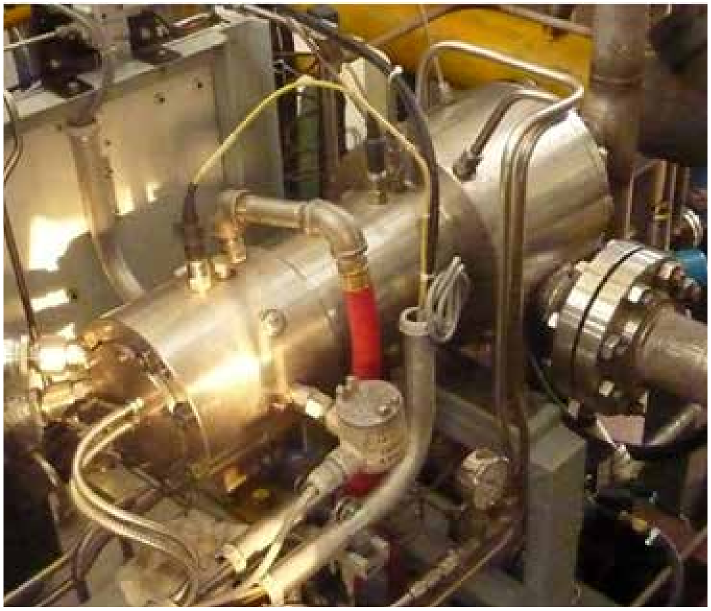

Figure 6 – Nanosteam Turbine Generator operating in Kalina Cycle Power Plant

In order to meet the needs of customers a 100 kW unit, the nanosteam® turbine was developed. Figure 6 shows that turbine operating in a Kalina cycle power plant with ammonia-steam fluid. This particular unit was operated in Shanghai, China. A twin unit is being operated in a geothermal hot springs power plant in Japan.

The nanosteam® turbine is currently being applied to generate power from wasted steam energy in New York City and also to generate power from biomass power plants in Italy.

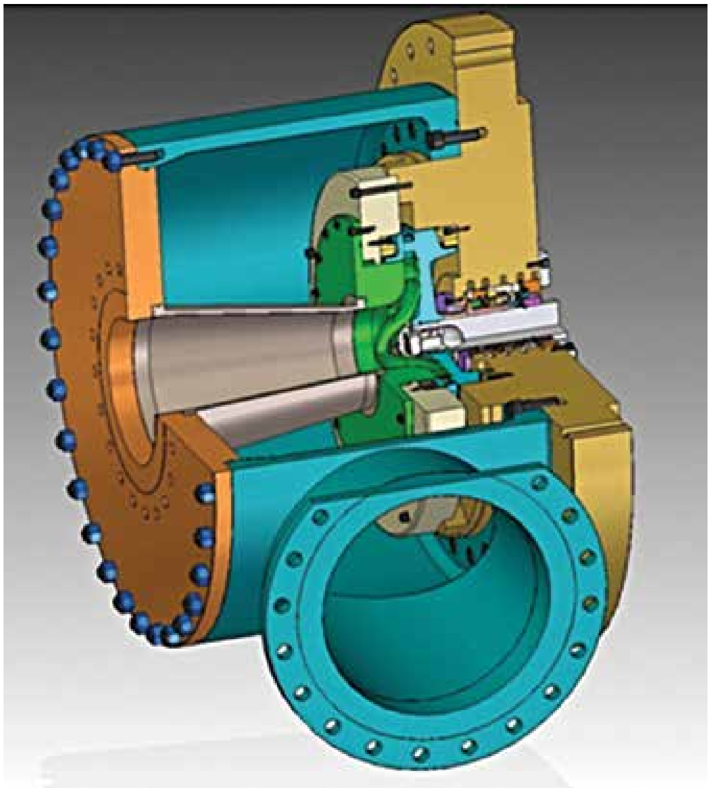

Figure 7 – SSNE SINOPEC 4MW Euler Turbine Generator Project

The successes at smaller scale led to interest in applying the Euler turbine to larger power systems. Figure 7 is a three-dimensional model of a 4 megawatt Euler turbine being constructed for a waste heat recovery system in Hainan China. This unit will operate in a power system which converts the energy in waste hot water to useful power.

The high efficiency and reliability of the Euler turbine in these applications has led to interest in others including organic Rankine cycle systems, gas dehydration, and refrigeration.

For further information, please visit www.energent.net.

Installation Tips and Considerations for Ambient Vaporizers

Ambient vaporizers use the ambient air as the heat source for vaporizing cryogenic fluids and have been used in countless cryogenic applications all around the world and in every climate. Although designed to perform for the particular locations and applicable ambient conditions, the installation and piping layout of these units are important aspects of the performance. There are many factors that contribute to the performance of ambient vaporizers besides weather conditions. The installation considerations below will help promote proper performance.

Situation 1 – Clearances Between Ambient Vaporizers and Surroundings

One of the most important aspects when installing ambient vaporizers is to make sure the fog and cold air downdraft being created has the clearance to properly disperse and dissipate to allow new warm air into the vaporizer array. This is done by having the proper clearance from the ground and other surrounding objects. Walls, tanks, and other vaporizers are common obstructions that prevent the proper dispersal of cold downdraft. When obstructions prevent proper air flow, the downdraft dissipates at a very slow rate and can even become stagnant at the bottom of the vaporizer. This can lead to insufficient air flow circulation, low discharge temperatures, reduced runtimes, and longer defrost periods. Though a recommended minimum distance between ambient vaporizers and obstructions is approximately 1 meter, this has to be used in conjunction with the number of vaporizers, surroundings, and available height the vaporizers can be mounted from grade. Many sites are very footprint limited and do not allow for the clearances between a vaporizer and obstructions. In these situations the vaporizers can be raised off the ground on plinths to help offset these other factors. Ultimately the downdraft must have enough escape area to dissipate and mix out the fog over a fair distance from the vaporizers. Cryoquip has a clearance guide that can assist in the layout of ambient vaporizers. By using a simple calculation which accounts for the overall vaporizer footprint areas and escape distances between obstructions, whether it be a single vaporizer or a bank of switching units, a proper footprint layout and plinth height can be determined.

In a situation where the site layout limits distances from obstructions or plinths, a Fog Reduction Module (FRM) can help reduce the fog. The FRM is a fan assembly that mounts on the top of existing ambient vaporizers and forces air through the array. This promotes better mixing of the downdraft and improved performance. Please see the Fall 2012 issue of FrostByte at cryoquip.com for more information on the FRM.

Situation 2 – Gas Side Switching Valves

An ambient vaporizer naturally begins to build up ice as it's running, decreasing its performance over time. Continuous flows require switching to an idle vaporizer to maintain the proper discharge temperatures. There are two different ways of positioning the switching valves on a switching ambient vaporizer system. In the first, you have the valves on the liquid side of the vaporizers. This is a common setup which does not allow liquid cryogen to enter into the idle vaporizer. However liquid valves tend to be expensive because they are designed for cryogenic service. The alternative is to have the switching valves on the gas side (discharge side) of the vaporizer, which does not require cryogenic valve construction. A problem that arises in a gas side switching system is the continued flooding of liquid cryogen into the liquid header of the idle vaporizer. This liquid will remain in the inlet header of the idle vaporizer and create continued ice growth even during the defrost cycle. This problem will increase over time and promote permanent ice growth on both vaporizers which reduces available surface area and adds stress to the inlet headers. One solution to this is to install vertical loops on the liquid piping just before it enters each vaporizer. The loops create a vapor trap that stops the liquid cryogen from entering the idle vaporizer. A recommended liquid loop height is about 1m. Liquid loops are a practical fix to this problem and can also be installed into existing systems if needed.

Situation 3 – Downstream Regulators

Creating proper backpressure on an ambient vaporizer is important to ensure proper heat transfer and proper distribution within and among vaporizers. This is commonly done by placing a regulator station immediately downstream of the vaporizer(s). By creating proper back pressure on an ambient vaporizer, the potential for fluid expansion is reduced. Expansion happens when there is too large a pressure difference between the inlet and outlet pressure of the vaporizer. When the pressure difference between the inlet and outlet of a system is too great, the fluid can mal-distribute through the volume of the vaporizer. The larger the pressure difference, the faster the fluid moves, which reduces the amount of heat being transferred to the fluid. A downstream regulator produces the proper back-pressure to the vaporizer creating the proper pressure difference between the inlet and outlet of the vaporizer and allows the fluid to have the proper distribution and residence time in the vaporizer. This is also very important when the vaporizers are fed by a cryogenic pump. Without the proper backpressure on the pump the flow of the pump can increase (i.e. the pump rides out on its flow curve) as the downstream pressure falls too low and can lead to overcharging of the vaporizer.

Situation 4 – An Uninsulated Liquid Line Location

The location of an uninsulated liquid line that feeds the vaporizers is very important, and improper installation can result in unnecessary problems. The liquid line should not be installed directly underneath or too close to the array of the vaporizer, or too close to the ground. When an ambient vaporizer's runtime cycle ends it begins to defrost. If the liquid line is directly beneath or too close to the vaporizer, water resulting from the defrosting and melting ice will freeze on the liquid line. That liquid line, which is still holding the liquid cryogen, will freeze the water and melting ice, creating increasing layers of ice. This can cause cracks in piping, foundations and large ice formations. To avoid this problem, set the liquid line away from the defrosting section of vaporizers, lift off the ground, or insulate.

Situation 5 – Dead Legs

When designing liquid feed lines to ambient vaporizers, dead legs should be avoided. A dead leg is a piece of piping or tubing that branches off from the mainstream and dead ends. Having dead legs in the liquid-side piping can lead to surging or "cryo-pumping". When liquid cryogen is introduced in the liquid line, the dead leg will fill with liquid. This trapped liquid will eventually boil off and create vapor that mixes into the main line and can result in misdistribution within the vaporizer and also promote pressure surging in the system. When surging exists, it becomes difficult to maintain a flow rate, proper performance and distribution throughout the unit. Eliminating dead legs is a very simple tip to help promote proper vaporizer performance. Placement of liquid side switching valves should reduce the potential volume of 'dead legs'. In some cases dead legs are unavoidable, but they should be minimized.

Situation 6 – Hybrid Units and Systems

A frequent installation error occurs when installing hybrid ambient vaporizers. Hybrid ambient vaporizers have a variety of fin counts, some of the most common having a combination of 4-finned and 12-finned extrusions. Hybrids are typically used in long freeze period locations, where the ambient temperature remains under 32° F for long periods of time. The installation error occurs when a hybrid ambient vaporizer is installed backwards, putting the high density fin extrusions on the inlet side of the system. Because the majority of heat transfer occurs in the boiling region of the vaporizer, the high density fin extrusion (more surface area) is thought to be placed where the most heat transfer is needed. Although this logic might make intuitive sense, the performance of hybrids degrades when installed in this way. A 4-finned extrusion is designed for ice buildup due to the large gap between fins. This large gap reduces the possibility of ice from bridging across fins and allows the ice to shed under its own weight much easier than high density fins. When installing hybrid ambient vaporizers, be sure to install the low fin density section on the liquid side of the system.

For further information, please visit www.cryoquip.com.

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CRYOGENIC INDUSTRIES NEW HEADQUARTERS

Last Fall, Cryogenic Industries relocated its headquarters offices from Murrieta, CA to Temecula, CA. The new facilities house administrative, finance, treasury, legal, internal audit, regulatory compliance, marketing, human resources and tax functions.

North America

ACD • Atlanta • California • Houston • Pittsburgh • Red Deer • Toronto
Cosmodyne • Cryoquip • Energent

South America

ACD • Cryoquip

Australia

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South Africa

Cosmodyne • Durban

Europe

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Middle East

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Asia

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