CRYOGENIC INDUSTRIES

FROSTBYTE

A NEWSLETTER FROM CRYOGENIC INDUSTRIES WINTER 2009

MOFS self-contained and portable gas fill plant reduces cylinder fill costs

ACD's new Medical Oxygen Filling System (MOFS) is designed to fill high pressure gas cylinders in a convenient, reliable, and transportable manner. MOFS units have proven to be the cost-effective choice for converting low pressure liquid oxygen, nitrogen, and argon to high pressure gas.

The 2'11"W x 6'3"H x 6' L (0.9m W x 1.9m H x 1.5m L) MOFS, single skid package can fit through a standard doorway and is powered by a 30 amp, 220/230 volt, single phase power cord. It utilizes a vacuum-jacketed liquid pump driven by a 5 horsepower electric motor that sends the high pressure liquid into the vaporizer and out to the cylinder filling rack or other supply application. MOFS can deliver oxygen, nitrogen or argon at up to 3000 psig with minimal product venting during operation. With two flow rates, 4100 scfh (0.6 gpm) and 8300 scfh (1.2 gpm), the unit has the ability to fill up to seventy medical 'E' cylinders in twenty minutes.

Within the compact frame of the system are a Cryoquip high pressure ambient air vaporizer, an ACD WDPD pump (.875" or 1.20" bore) with a motor and gearbox, a start/stop panel, a gas control panel, and pressure switches. The standard configuration features a quiet pump running at a conservative speed of 350 rpm, automatic shut-off capabilities, and lockable roller wheels. For the convenience of MOFS users, all system components for low and high flow units are identical with the exception of the pump fluid end, which has two different piston diameters.

Distinct advantages of the MOFS unit include an oxygen-compatible vacuum pump, a high pressure gas accumulator, a gas purge valve, and the ability to maintain continuous operation as opposed to batch filling. MOFS can be used with liquid cylinders, Microbulk or customer station liquid product supplies. It is ideal for filling Medical D/E cylinders and argon or nitrogen cylinders for small fill plant applications. Ease of operation and maintenance facilitates use in mobile or temporary applications. The self-contained system is readily transportable and no foundation is required for operation. MOFS is suitable for both indoor and outdoor operation and is ideally suited for inert gas purging or pressure testing operations.

Specifically designed for oxygen USP cylinder filling, MOFS is compliant with all applicable CGA standards. Independent, third party validation ensures compliance with FDA guidelines for 'process validation'.

MOFS is manufactured using premium quality, industry-standard components. The system is designed and produced by the industry's leading ISO-9001 certified supplier of cryogenic pumping equipment.

ACD's MOFS saves costs by reducing cylinder transportation and cylinder inventories in remote geographic locations. Distributors can lease MOFS units to end users and provide a complete customer gas supply system. With low set-up costs and excellent product support from the worldwide Cryogenic Industries service centers, the MOFS package is economical and dependable.

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Climate affects the selection of ambient air vaporizers

Many factors need to be considered when designing ambient air vaporizers. The environmental effect is one such criterion. When designing and specifying fan-assisted and natural draft ambient air vaporizers, we use four main climate zones: tropical, Mediterranean, humid continental, and marine. Each of these zones, however, may contain micro climate zones where the climate may be significantly different than the weather around it.

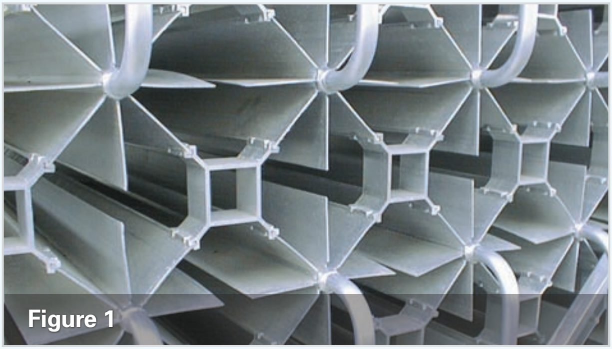
Figure 1

In discussing climatic effects, a basic understanding of the principles of ambient air vaporizers is necessary. Fan-assisted vaporizers utilize forced convective heat transfer, whereas natural draft ambient air vaporizers utilize natural convective heat transfer. Natural convective vaporizers typically are manufactured with three different fin spacings, depending on how long the vaporizers are going to be operated before complete defrost is achieved. Standard-spaced vaporizers typically operate less than 24 hours before complete defrost and have a fin tip-to-tip air gap roughly 1.5" (38 mm). (Figure 1)

Wide gap natural convection vaporizers generally are designed to operate three to seven days without defrost and typically have a fin tip-to-tip air gap spacing of 3" (75 mm) or more. (Figure 2) Super-wide-spaced ambient air vaporizers are designed to operate continuously, with the possibility of manual defrost required several times per year. These vaporizers have a typical fin tip-to-tip spacing of 10" (254 mm) or more. (Figure 3) Forced convective vaporizers are designed with maximum heat transfer area in a minimum space. They typically have fin tip-to-tip air gap spacing of less than 1.5" (38 mm). (Figure 4)

Natural draft ambient air vaporizers operate on the principal of natural convective heat transfer. Air is cooled as gravitational force pulls it past the heat exchanger fins. It therefore becomes more dense and heavier. This density further promotes a downward motion due to gravitational effects. Forced convective heat transfer vaporizers rely on mechanical fan-driven forced stimulation movement of the air, therefore not relying on gravity.

The following are basic vaporizer design considerations dealing with the location and duration of operation of ambient air vaporizers. Certainly other considerations must also be reviewed, such as electrical/fuel requirements and availability of land or real estate, proximity to roads, walkways, driveways and occupied businesses or housing.

Tropical Climate Zones

For the purpose of specifying vaporizers, tropical climate zones include equatorial regions such as Malaysia, Thailand, Indonesia, Panama, Venezuela, and Brazil. Other regions such as Japan and the southern United States replicate this climate zone closely in their summer months or monsoon season, but are generally closer to the humid continental zone. Tropical climate zones are characterized by dew point temperatures greater than 70°F (21°C). Dry bulb temperatures generally range from 80°F (27°C) to 95°F (35°C) year round. There typically is not a wide variation in the temperature between night and day, since the high moisture content of the atmosphere tends to trap the infrared radiation emitted by objects at night, not allowing it to escape into outer space.

Both natural and fan-assisted draft ambient air vaporizers should be considered in tropical climates due to the large ambient air temperature driving force available. Flow rates under 57,000 scfh (1500 Nm3/hr) are likely to perform more economically with natural convection units and flow rates over 152,000 scfh (4000 Nm3/hr) with forced convection units. The main advantage of these systems is maximum vaporization capacity at minimal or no operation cost coupled with maximum reliability.

In order to maintain maximum vaporizer capacity from both types of vaporizers in this zone, the vaporizers should be switched quite often. Typical switching cycles would be about every four to eight hours. This is due to the high moisture content in the atmosphere and therefore rapid ice growth formation on the fins which rapidly reduces the overall heat transfer coefficient. Switching less than every two hours to obtain even more vaporization capacity is both unrealistic and dangerous. Both the natural and forced draft vaporizers will defrost adequately in this climate zone without any external energy source as long as the off cycles are at least half the duration of the on cycles. The fan driven units will assist in this process.

A system can be designed with a larger approach temperature (approach temperature is defined as the difference between ambient temperature and discharge gas temperature), because of the consistently warm temperature at night and during the day. This results in greater capacity from a system rated for less in other climate zones.

Mediterranean Climate Zones

Mediterranean climate zones would include areas such as the southern and central coast of California, Greece, the Algerian Coast, and other areas like Italy and Israel. Typically, these regions are characterized by precipitation periods of about four months per year. This climate zone, like the tropical climate zone, is well-suited to the ambient air temperature driving force available. Generally, the same rules apply with regards to which flow natural

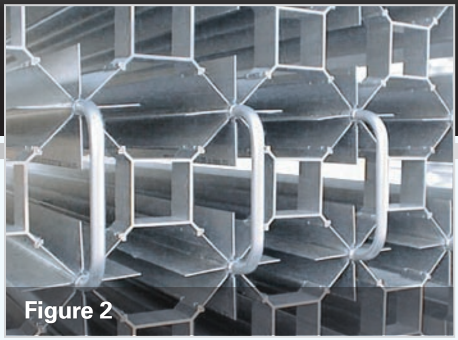
Figure 2

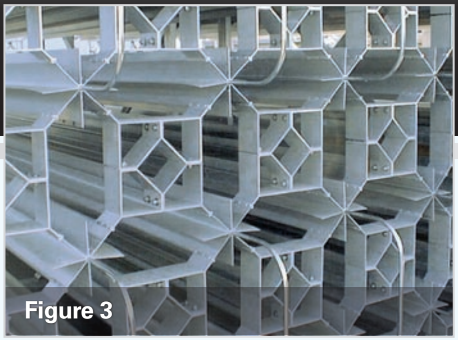
Figure 3

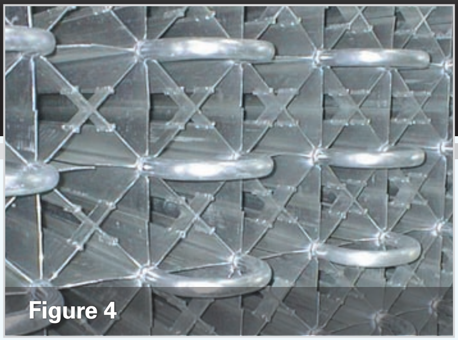
Figure 4

draft and forced draft ambient air vaporizers become economical choices.

The main difference between this climate zone as compared to the tropical zone is the low moisture content that can exist six to nine months of the year. Several unique weather characteristics result from this. Infrared radiation mostly escapes from the atmosphere at night resulting in possible colder nighttime or early morning temperatures—a consideration when designing approach temperatures for this period and ensuring minimum temperatures remain above minimum values. The benefit of this drier climate is longer switching cycles. Typically, switching less than every eight hours has little benefit, but switching should probably be done before 24 hours to obtain maximum efficiency from the units.

Humid Continental Climate Zones

The humid continental climate zone covers a vast area. In the northern hemisphere, typical areas include the interior United States, Southern Canada, Central Europe, and Central Asia. These areas are characterized by somewhat tropical dew point temperatures in the summer and extended cold, dry periods in the winter, with a combination of the two in spring and fall.

The point where forced draft ambient air vaporizers become more economical over natural draft vaporizers is much less apparent and must be analyzed more rigorously due to the larger variations in ambient conditions. A phenomenon known as the freeze period (the period of time in which ambient temperatures remain below freezing) is one key to vaporizer specifying.

Typically, fan-assisted vaporizers will require an external energy source in order to defrost during their off period. Electrical heater assemblies or gas fired external air heaters can be used. Because of these additional requirements, the fan ambient vaporizers become less attractive than other vaporizers.

Natural draft vaporizers must be sized such that each bank of on-stream and off-stream vaporizers is capable of operating for one half the freeze period. This could be up to several months in parts of Canada or North Central Asia, thus requiring much more surface area (sometimes as much as four times more) than in other climate zones. Due to the tropical nature that may exist in these areas during the summer, the switching cycles of these systems is typically based on summer conditions. Because of the potential for very low temperatures during winter months, special equipment additions like gas superheaters may be required downstream of the ambient units depending on pipeline limitations. Lower approach temperatures are often required during winter months. Fluids such as carbon dioxide and propane that may be vaporized in tropical zones by utilizing ambient units should not be considered in humid continental climates since it is more likely you will be subcooling during winter periods.

Marine Climate Zones

Marine climate zones pose a unique challenge to ambient air vaporizer designers. Some areas included in this zone are Britain, the northwest coast of the United States, British Columbia, Canada, the far northeast of the United States, Maine, Norway, New Zealand, and the southern coast of Argentina. Although ambient temperatures remain relatively mild throughout the year, usually between 23°F (-5°C) and 70°F (21°C), the climate is very moist with dew point temperatures commonly very close to the dry bulb temperatures as well as the freezing point of water. What tends to result is a substantial amount of condensation and added precipitation on vaporizer surfaces that quickly freeze into dense pockets of ice, reducing vaporizer capacity. Extra surface area must be added to reduce the effects of this atmospheric phenomenon. Likewise, the vaporizers need to be switched much more often to prevent the formation of very dense ice that will not defrost during off periods if levels get too substantial. Often vaporizers must be sized based on two to three day ratings, but switched every two to six hours to prevent ice buildup.

Micro Climate Zones

Micro climate zones exist in every one of the zones discussed. They are defined as zones that may result in substantially different weather conditions and may exist at distances as close as 31 miles (50 km) from one to the other. Micro climate zones may have unique wind or precipitation design requirements. An example is the area downwind of the Great Lakes region in the United States, where major snowfall accumulations can occur when dry cold winds move over warmer moist lake air causing the air to become saturated and creating localized "lake effect" snow. Other common weather phenomenon, such as the Chinook winds of Montana, the buran winds of Russia and Central Asia, the bora winds of the Northern Adriatic coast of Yugoslavia, and the Santa Ana winds of Southern California, may result in special mechanical design requirements or height limitations due to the severe winds caused by the venturi effects of local mountain canyons. Altitude effects need to be considered as well, with appropriate capacity reduction applied to the vaporizer models.

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CRYOQUIP

Cheniere Energy and Cryoquip are pioneering a green, environmentally-friendly solution for LNG receiving terminals

Liquefied natural gas (LNG) is natural gas that has been cooled to less than minus 260°F (161°C) so that it can be safely and economically transported around the world. Once delivered to a receiving terminal, the LNG must be pressurized, re-vaporized, and heated to at least 40°F (4.4°C) before it can be put into pipelines carrying the natural gas throughout the country. In the past, base load LNG regasification (vaporization) terminals have used heat from very large volumes of seawater (which can damage nearby marine life) or from burning a portion of the natural gas itself.

Cheniere Energy, Inc. (Cheniere) and Cryoquip, Inc. are pioneering an improved "green" design that is a more environmentally-friendly alternative at the Sabine Pass LNG receiving terminal in Cameron Parish, Louisiana, USA. Nearly a decade ago, Cheniere identified Cameron Parish as an ideal location for its Sabine Pass LNG receiving terminal. The site has a deep water channel, is close to open water, and has pipeline access to over 75 percent of the U.S. gas market.

Ambient air heated vaporizers, AAV's, will use the abundant heat in the air to vaporize and heat the LNG. However, unlike other technologies that pump an intermediate fluid to forced fan exchangers and into LNG vaporizers, natural draft ambient air heated vaporizers directly exchange heat between the air and the LNG with no intermediate fluid, and do not require pumps, fans, or consume electrical power. AAV's turn liquid LNG at 260°F to natural gas at 40°F using air with NO CO_2 emissions, NO fuel consumption, NO sea water impact and NO moving parts. Cold air and fresh water are the only by-products of the process.

A full scale AAV train (a series of 18 vaporizer cells connected together to form one operating element) has been installed and has passed initial performance tests, and all the theoretical expectations have been realized in practice. Cheniere is in the process of refining the design and is already permitted to expand the application to process more than 1.0 Bcf/d of LNG. At that time, this technology will reduce fuel use by 60% or more and reduce CO_2 emissions by as much as 280,000 tons per year at the Sabine Pass receiving terminal.

An Ambient Air Vaporizer, AAV, is an interconnected array of vertical finned aluminum tubes. As LNG flows through the tubes, they cool the surrounding air. As the air becomes colder it also becomes more dense and gravity causes it to flow downward through the array. This is the reverse of the familiar "chimney effect" where heated air naturally rises due to its lower density. This natural draft method requires no fuel or electricity. In fact, natural draft AAV's do not have any moving parts. In addition, the process emits no CO_2 or other harmful emissions, and uses no natural gas to vaporize the pipeline gas, unlike conventional systems.

With a total send-out capacity of 4.0 Bcf/d and 16.8 Bcf of storage capacity the Sabine Pass terminal is the largest receiving terminal, by regasification capacity, in the world. In the future stages of Phase 2, a sixth storage tank and related facilities are planned to bring the total LNG storage volume to 20.2 Bcf. AAV technology will reduce Sabine Pass LNG's fuel use by 60% or more and reduce CO_2 emissions by as much as 280,000 tons per year, providing a truly environmentally-friendly, "green," solution to the regasification of LNG. This technology holds great promise to become the new standard in the years to come, resulting in a cleaner, less polluted environment.

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CRYOQUIP CHENIERE

Cryoquip and ACD expand into South America

Manufacturing facility opens in Brasil

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Cryoquip and ACD have opened a combined manufacturing and service facility in South America. The 3800 m2 facility is located in São Paulo, Brasil and compliments existing combined facilities in Malaysia, Australia, and India and separate facilities in Europe and China.

Strategically located near the port of Santos specifically to serve the extensive South American gas market, Cryoquip and ACD have already supplied a number of large vaporizer systems and pumps to their South American customers from their US facilities, but neither has ever been able to penetrate the local customer station and distribution markets. The ever increasing demands of the South American gas business, for a wider product range, reliability, shorter delivery times, commonality of product, and flexibility in supply, has encouraged Cryoquip and ACD to set up a manufacturing facility locally which will manufacture a complete range of each company's products: low pressure ambient, Uniflo and electric CO_2 vaporizers, water bath vaporizers for high flow rate applications, and plant back up systems. A full range of both centrifugal and reciprocating pumps, including an extensive line of LNG products and a full service, spare parts and repair center will be established.

Initially the same high quality, high performance, range of aluminum low pressure ambient vaporizers, as made in our other facilities, will be manufactured using 100% local materials, ranging from 75 – 2500 Nm^3/hr. Small capacity high pressure ambient vaporizers and electric vaporizers will also be manufactured later. ACD will offer repair and service on all makes of cryogenic pumps and manufacture will be added later.

Because of local manufacture, our South American customers will receive the added benefits of lower prices, quicker deliveries and local support with installation, repairs service and technical issues. CI Brasil's current technical sales office in São Paulo will be incorporated into the new facility.

Malaysian facilities relocate to better service local customers

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Recovering Waste Energy in Cryogenic Processes

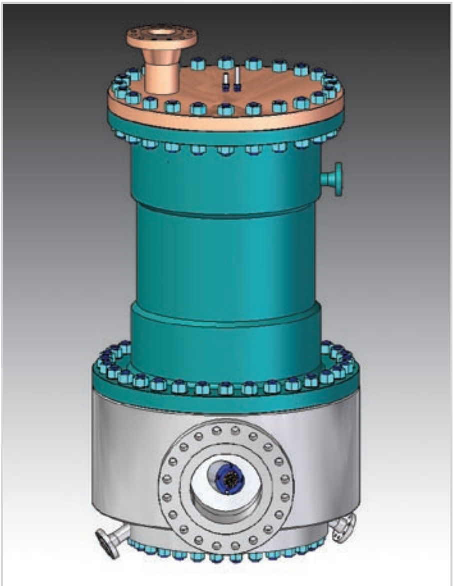


Figure 1: Two Megawatt Variable Phase Turbine for LNG

Exploiting the huge resource of lost energy to produce useful power has long been the goal of Energent Corporation, a research and development group and member of Cryogenic Industries. Currently in development are projects to recover wasted energy and improve efficiency in cryogenic processes, including air separation, LNG production, and ethylene production.

Lost energy is defined as waste heat, waste pressure, and under-utilized renewable energy. Wasted pressure energy, for example, is found in the throttling loss of an expansion valve such as the Joule-Thomson (J-T) valve in a refrigeration cycle. An example of wasted heat energy would include the use of cooling water, in conjunction with a cooling tower, to reject heat from a compressor in an air separation plant.

As reported in the 2008 summer issue of Frostbyte, Energent Corporation is developing technology to recover both forms of wasted energy and convert them into valuable power. This technology is readily applicable to many cryogenic and high-temperature, industrial processes.

Recently, the design of a 2 MW Variable Phase Turbine (VPT) was completed for ConocoPhillips Company. The ConocoPhillips Optimized Cascade® Process currently uses a J-T valve for the expansion of high pressure, flashing LNG. Application of a VPT will not only produce power, which would otherwise be lost in the J-T valve, but will also increase the refrigeration of the expansion, boosting the LNG output of the entire plant by approximately 3%.

Smaller units suitable for air separation plants are being developed. A hermetic 25 kW unit with a submerged generator will soon be qualified for flashing liquid nitrogen service.

Waste heat generated in a cryogenic process can be recovered in a heat engine power cycle. By utilizing heat exchangers and a working fluid, this waste heat can be converted into electricity.

The conventional power cycle used for waste heat recovery is the organic Rankine cycle (ORC). Figure 2 illustrates the ORC in a heat recovery application. Hot water transfers heat to a working fluid in a vaporizer, generating a high pressure vapor. A separator is required to separate liquid carry-over. The vapor drives a high speed turbine, conventionally a radial inflow turbine, which spins a generator through a reduction gear. The vapor leaving the turbine is then condensed and sub-cooled. To close the cycle, the sub-cooled liquid is pumped back to the vaporizer.

As can be seen in the temperature-enthalpy diagram, the boiling heat transfer occurs at a constant temperature over most of the heat exchange. Consequentially, a "pinch point" is created, limiting the minimum water outlet

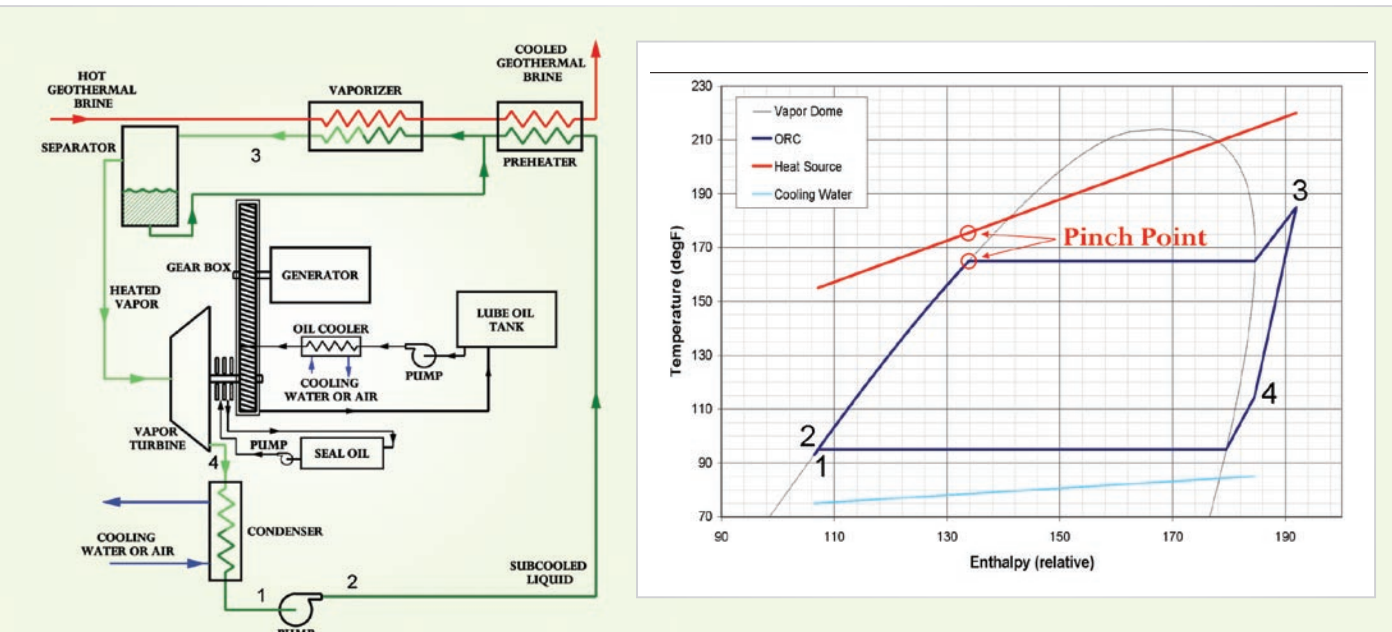


Figure 2: Organic Rankine Cycle Waste Heat Power Cycle

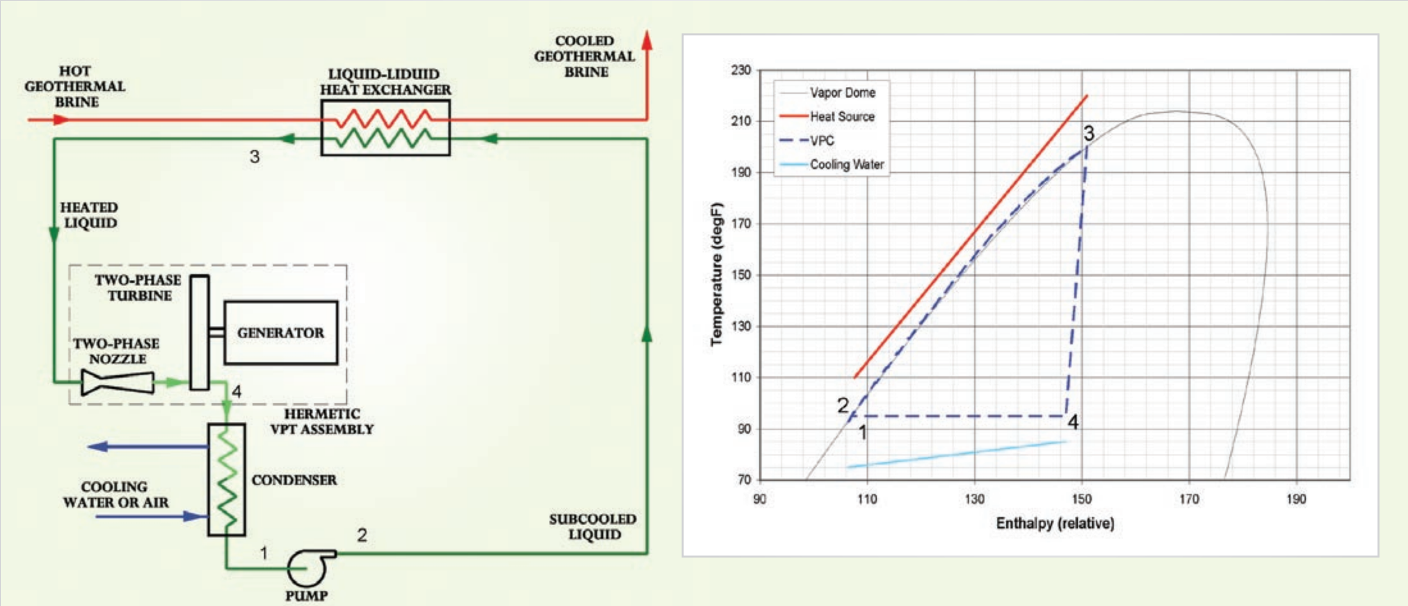


Figure 3: Variable Phase Turbine Waste Heat Cycle

temperature, and therefore the amount of heat that can be transferred into the power cycle.

To minimize the cost of the power cycle and to maximize the power produced from the waste heat, a new power cycle, the Variable Phase cycle (VPC), is being developed. The thermodynamic cycle and process diagram of the VPC is illustrated in Figure 3. The waste heat source, such as compressor cooling water or geothermal brine, transfers heat to the working fluid in a simple liquid-liquid heat exchanger. Heated liquid working fluid then flashes in a Variable Phase Turbine and generates power. The resulting vapor is condensed and sub-cooled in the condenser. Subsequently, the sub-cooled liquid is re-pressurized by a pump and returned to the heat exchanger to close the cycle.

Advantages the of the Variable Phase cycle include the elimination of the vaporizer and separator required by the ORC. Also, the Variable Phase Turbine spins at 50 or 60 Hz, allowing for the direct drive of the generator, which eliminates the gearbox and lube oil system required by an ORC. Elimination of the vaporizer simplifies the controls and makes the system more robust. In addition, a hermetic turbine-generator eliminates the seal system and potential seal failure.

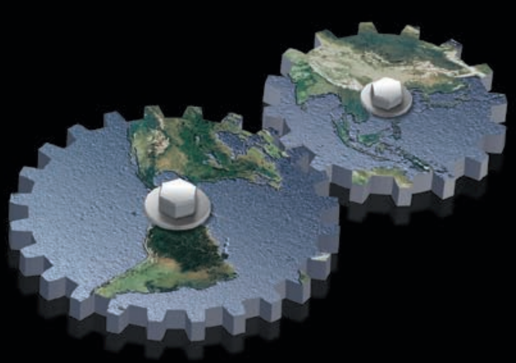
Notably, the most significant benefit of the Variable Phase cycle is the use of a liquid-liquid heat exchanger, which eliminates the "pinch point" limitation encountered by the ORC. As shown in the temperature-enthalpy diagram, Figure 3, the water temperature can be dropped lower in the VPC. When compared to the ORC, 200% more energy is transferred into the power cycle. The end result is typically a 20-30% gain in electricity production by using the Variable Phase cycle.

Energent recently received a U.S. Department of Energy award to build and demonstrate a 1 MW Variable Phase cycle waste heat system. The waste heat source is 225°F geothermal brine produced as a byproduct at a geothermal power plant in California. Analysis of large air separation plants has shown that the same VPC system could generate 1 MW from the compressor cooling water, improving the plant efficiency.

A worldwide market is emerging for the production of power from waste heat and pressure. By replacing two-phase Joule-Thomson valves with Variable Phase Turbines and converting waste heat to power with the Variable Phase cycle, Energent can improve product yields and plant efficiency.

For more information contact Lance Hays at Energent, lhays@energent.net, +1.949.261.7533.

ENERGENT



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Poplar-12 commissioned in Latin America

Cosmodyne expands Poplar merchant plant series range, 150 to 200 TPD

Cosmodyne announces the successful start-up and commissioning of a Poplar-12 air separation plant for Productos del Aire in Guatemala, an affiliate of Air Products and Chemicals. The plant will supply oxygen, nitrogen and argon products to meet the fast growing market demands of Guatemala as well as other Central American countries.

The Poplar-12 produces 150 to 200 tons per day of liquid while maintaining a relatively compact design. Because the cryogenic components are configured into only two cold boxes, installation and freight costs are minimized. Even with the pure argon option, the overall height is minimized, greatly reducing foundation requirements. This is an industry-first for a plant of this class.

Cosmodyne designed and selected components to achieve high efficiencies, resulting in specific power (kWh/unit of flow) comparable to larger plants. Air, at medium pressure, is used in the recycle refrigeration loop since it is more effective than nitrogen with regard to efficiency and packaging. Additionally, the Poplar-12 for Productos del Aire is capable of less than 1 PPM of oxygen in argon product to meet the special market requirements for higher than normal argon purity. The plant central control system is PLC based and can be remotely accessed for monitoring and operating adjustments. It also provides the primary controls for the feed air compressor, recycle compressor and chiller. This simplifies the controls and increases the reliability.

Juan Carlos Serra of Productos del Aire, commented "We are very pleased with the efficiency and operating flexibility the plant demonstrated during commissioning. The plant is actually producing more liquid than we were promised. We look forward to a successful, long term relationship."

Two similar size plants are scheduled to be commissioned in the next six months.

For more information contact George Pappagelis, General Manager for Cosmodyne, +1.562.795.5990, gpappagelis@cosmodyne.com.

COSMODYNE
A Cryogenic Industries Company

Productos del Aire