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**EBARA INTERNATIONAL CORPORATION**

**ENVIRONMENT**

Ebara International Corporation, committed to always meet or exceed the highest possible standards of environmental awareness, responsibility and ethics in our business activities. This approach is demonstrated in our daily work through our environmental management policy that sets environmental targets and goals in our global business. Ebara International Corporation is committed to improve, where possible, the existing environmental standards.
Ebara International, Cryodynamics Division

Over the last forty years, Ebara International Corporation has been providing custom engineered products to the liquefied gas industries for a wide variety of marine, land-based and most recently, floating applications. The Cryodynamics Division is a long-established specialist and leader in the design, manufacture and test of submerged electric pumps and expanders. With literally thousands of installations around the world and being the only company in this unique industry to deliver continuous design improvements for forty years, Ebara Cryodynamics is proud to be recognized as the premier manufacturer of submersible pumps and expanders for the liquefied gas industries.

Ebara International’s Cryodynamic pumps and expanders are designed to operate in liquefied gases with a temperature ranging from ambient (warm) to cryogenic. The submerged motor is designed to operate in a non-conductive liquefied gas.

Some examples of the liquids handled by our products:

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*Ebara motors are submerged in the oxygen-free cryogenic liquid removing potential for ignition, making Ebara’s design ideal to safely accommodate caustic chemicals such as ammonia.

Ebara Cryogenic Pumps are applied in three distinct configurations:

- Serving aboard most of the world’s LNG Carriers as Cargo, Spray and Emergency Pumps are Model EC units stationary mounted at tank bottom with complete power feed and deck penetration assemblies by Ebara.
- Suction Vessel Mounted Pumps (Model ECC) are utilized as single stage transfer pumps or multi-stage for vaporizer feed and send-out service.
- Model ECR Retractable Units are designed for LNG storage tank installations via columns which contain the pump and provide a discharge. The pump weight opens a spring loaded suction valve as also supplied by Ebara. This allows a system for pump removal from a loaded tank with the column being safely inerted.

In addition to Cryogenic Pumps, Ebara Cryodynamics’ Expanders exemplify our drive for advancing LNG process technology and productivity. These machines directly produce approximately 5% increased plant output while generating substantial electricity as a peripheral benefit. Recently advanced for both Single Phase (liquid) and Two-Phase (Gas/Liquid) applications, expanders can also be provided with variable speed technology. Ebara’s Client-Partners have worked closely with Ebara’s engineers to optimize performance and reliability, giving them the outstanding, attractive results of this technology. Ebara International’s Expanders are becoming the specified standard in LNG production trains around the world.
EXPERIENCE. QUALITY. COMMITMENT.
EIC QUALITY POLICY

We believe our customers define quality.

Ebara International Corporation, Cryodynamics Division maintains a documented quality management system designed and implemented to fulfill ISO 9001 requirements. This system creates a framework for clearly defining the control of materials, processes, and verification activities, thus providing our customers with confidence that products are produced in a well-defined and controlled environment.

In addition, Ebara International Corporation has also achieved certification to the recently established ISO/TS 29001:2010 quality standards, set forth to provide more industry-specific requirements for petroleum and natural gas related companies.

DIVISION QUALITY SYSTEM:

- Do things the right way the first time, even when it is difficult
- Provide products that meet our customer’s design, safety and performance specifications
- Provide long term support, customer service and reliability
- Provide exceptional value by continually improving our products and processes
- Solicit employee expertise and experience to help direct process improvement efforts

Here at Ebara International Corporation, the division, its management and employees are all dedicated to the continuous improvement of the quality management system.
Ebara’s Sparks, NV facility includes several test vessels and heat exchangers which can be configured to test EIC’s full range of cryogenic equipment. With five pump test tanks and one dedicated liquid expander vessel, the “Test Stand” is capable of evaluating up to six different pieces of equipment each day, greatly increasing throughput and decreasing the total time spent to complete a project. For example, a typical set of marine pumps for an LNG carrier can be fully tested in as little as three days. At the peak of LNG equipment production in 2007, EIC successfully tested over 500 different pumps and expanders, setting a record that has yet to be rivaled. In addition to the day-to-day requirements of FAT (Factory Acceptance Test) activities, EIC has also offered its cryogenic liquefied gas testing services to a wide range of companies and universities for the purposes of research and product development.

The in-house engineering staff at Ebara works closely with their customers to develop test configurations to meet the specific needs of the equipment being evaluated. Customizing flow arrangements, instrumentation and even data acquisition software provides these groups with the ability to fully evaluate their equipment in the actual field operating conditions, something they may never have been able to accomplish in their own laboratories without substantial capital investment.

We know that safety is a major concern when purchasing important equipment like a pump or expander. Here at Ebara, we uphold the highest measure of safety and that expectation reaches all the way to your facility. We have demonstrated the safety of our products through thousands of installations, giving you and your employees the peace-of-mind you have come to expect from Ebara.

**SAFETY IS BUILT INTO THE DESIGN**

EIC’s line of submerged motor cryogenic pumps and expanders incorporates the safest design for rotating equipment in the industry. By combining the pump and motor onto a common shaft, all issues of misalignment and coupling failures are eliminated. The motor is submerged in the oxygen-free cryogenic liquid removing potential for ignition; therefore, the amount of electrical components that are installed within the hazardous area is minimized. Additionally, there is no need for rotating seals thereby eliminating a source for leaks. This allows Ebara’s design to safely accommodate caustic chemicals such as ammonia. In addition, rotating components are contained within casings which are submerged within a secondary tank or vessel, further protecting personnel from potential hazards. Ebara expanders feature a radial in-flow runner which greatly decreases the runaway speed to well within acceptable mechanical limits, reducing the possibility of physical damage.
IN TANK (RETRACTABLE)
This unique design allows the pump to be installed inside a storage tank in a vertical pump column with a suction (foot) valve located at the bottom. As a result of the pump being installed through the top of the tank, all connections below the maximum liquid level of the tank can be eliminated. This design removes the possibility of major tank leakage due to a pipe or connection problem and also permits the storage vessel to be located below ground level.

The submerged pump and motor unit is designed to fit into the smallest practical column diameter by using an axial diffuser design. The column acts as a guide to seat the pump during installation and also performs as the discharge pipe from the pump to the top of the tank. Each pump is fitted with an inducer which is an axial flow impeller located at the lowest possible level of the tank to improve the NPSHR (Net Positive Suction Head Required); allowing operators to lower tank liquid levels to extremely low levels. To isolate the tank contents from the pump column, a suction valve is used, which incorporates a dual pressure sensitive seal. The suction valve is flanged to the lower end of the pump column and is closed by coil springs as well as by the hydrostatic pressure of the liquid in the tank.
SUCTION VESSEL MOUNTED

The entire pump and motor assembly are contained within a suction vessel built to the appropriate pressure vessel code for each application, making the installation safe, simple and reliable. The suction vessel functions as the outer pump casing. It is fabricated with a suction nozzle, welded couplings (for drain and liquid level indication), support brackets, a head plate with discharge nozzle, a conduit for electrical cables and a vent nozzle. The result is a compact, lightweight, uncomplicated installation having low noise levels and significant safety advantages over conventional pumps.

Frequently used as a multistage design for vaporizer feed service, the ECC model is also widely used as a single stage transfer pump. Flow capacities are available up to 3000 m³/h and differential heads up to more than 3300 meters. These machines can also be VFD (Variable Frequency Drive) driven to meet multiple duty points. For multi-stage pumps traditionally used for vaporizer send-out applications, Ebara has developed a radial, stiff shaft design, in order to provide a more compact, more reliable machine. By combining the use of radial diffuser vanes, which allows a much shorter stage length, with a much larger shaft diameter, the rotor becomes much more stable, normally operating well below the first critical speed. This new design has proven to be extremely reliable in send-out systems which require a large, multi-stage pump to perform on a continuous, 24 hour-per-day basis.
**SHIPBOARD**

Ebara offers complete package solutions for all of your marine pump requirements. Similar in construction to the ECC type, these machines are usually located within the refrigerated cargo tank of a marine gas carrier to transfer such fluids as LNG, LPG, Ethylene, etc. These units are available for all applications of liquefied gas carriers and are used for main cargo unloading, stripping, spray, fuel and emergency (retractable) service. Depending on your unique requirements, flow capacities range from 5 to 3000m³/h and with heads up to 200 meters. Additionally, electric power feed cables and deck penetration assemblies to accompany your equipment are available and meet all requirements of major ship classification societies. Special designs with built-in internal filtration are available to handle cargo that is likely to suffer particulate contamination such as LPG. Whatever your situation, Ebara can create a custom package to meet your specific needs.

**CARGO**

- To date, Ebara has installed more than 1500 Cargo pumps located throughout the world.
- With Ebara’s pumps installed, an entire ship’s cargo can be unloaded in approximately 12 hours.
- A single stage design is most often used although multi-stage pumps can also be supplied if required.

**SPRAY (STRIPPING PUMPS)**

- Using the extremely low NPSH requirements of Ebara’s Spray pumps, cargo tanks can be offloaded to near zero liquid levels, increasing the amount of the delivered cargo, reducing the cost of transportation and the amount of heel product in the tanks during return voyages.
- Ebara Spray pumps commonly achieve a NPSHR as low as 0.3 meters.
- Spray pumps are often used for product recirculation.
  - Utilizing heel product in keeping the walls cool during the return voyage.
  - Reducing boil off gas during the next loading process.

*The pumps, in relation to each other, are not represented to scale.*
EMERGENCY PUMP
In the highly unlikely event that both cargo pumps were to fail onboard, an emergency pump can be used to empty the cargo pump storage tank so that the main cargo pumps can be removed and serviced. To date, thousands of Ebara’s cargo pumps have been delivered and Ebara is not aware of any of our Emergency pumps ever having to be used in service; a testament to the reliability of the Ebara design.

FUEL
To meet the growing demand of LNG fueled vessels, Ebara has developed low flow, high head LNG fuel pumps. These submerged pumps are designed to meet the rigorous conditions of marine fueling applications. The rugged construction of these pumps allows years of uninterrupted service, even while operating with fuels containing some amount of contamination.

DUAL DUTY
Ebara also provides Dual Duty pumps. These machines offer two points of available operation, one being the Spray duty and the second being the Fuel duty; adding more versatility and scope of your cryogenic equipment.

FLOATING
EIC’s line of submerged motor pumps and expanders are well suited to the growing business of floating installations. FSRU (Floating Storage and Regasification Unit), FPSO (Floating Production Storage and Offloading) and FLNG (Floating Liquefied Natural Gas) vessels benefit greatly from EIC technology. The compact design of a submerged motor pump results in a machine approximately half the size and a third of the weight of an equivalent external motor pump; an important advantage where space and weight are at a premium.

All of EIC’s product lines are available for floating service. ECC model pumps are used in high-pressure send-out service on FSRUs and in several process services on FPSOs. Retractable ECR model pumps service the storage tanks on the vessels. Liquid Expander model LX is found on the FLNG topside module. EIC’s experience of marine service such as shipboard Cargo and Gas Fuel pumps, is used to maintain high performance and reliability in floating service.

Floating service pumps are subjected to additional loads due to ship hull motion. These loads are present during sea towing and during operation while moored at site. Vessel mounted pumps (ECC and LX) incorporate additional lateral supports to reduce the loads on the vessel mounting lugs. These supports are derived from shipboard Cargo pumps (model EC). Within the pump’s vessel, the pump is protected from lateral loads by the use of a lower support rod. In-tank retractable pumps use a deep-seat style suction valve or a rigid retraction system to eliminate the possibility of the pump unseating from the valve seal surface during hull motion. In the cases of extreme loads, it is also possible to fit the pump with a shaft locking device. This device prevents any movement of the shaft during shut-down while the ship is subjected to severe motions. It can be externally controlled and wired into the plant safe-guarding system with appropriate interlocks. All floating service pumps and expanders use the proven TEM® thrust balance system.
THE EXPANDER REVOLUTION
Ebara International, Cryodynamics division (EIC) has developed the world’s first site-proven variable speed, liquefied gas expander and most recently, the first variable speed two-phase expander. At EIC, we look beyond traditional concepts to find new, innovative ideas that will meet our customer’s needs. The development of the variable speed submerged generator cryogenic expander and now the two-phase adaptation are both prime examples of our commitment to providing the safest, most reliable products with proven performance for the liquefied gas industry.

BACKGROUND
For many years, the traditional method to let down pressure in a liquid stream used a Joule-Thomson (J-T) valve. An improvement in the overall efficiency of this let-down process can be achieved by replacing the J-T valve with an expander. In doing so, the overall plant efficiency will increase, reducing operating costs and increasing LNG production.
In addition to the LNG capacity increase, these expanders provide the benefit of electrical power generation. A typical expander has a power generation potential of from 1.0 to 3.0 megawatts and with an expander efficiency of 88 percent, an output of 880 to 2640 kW can be realized. Over the course of a year, this can total more than approximately 23,000,000 kilowatt-hours, and at a cost of about $0.12 per kilowatt-hour, more than $2,800,000 of power is produced per year. With these significant economic benefits realized, the potential payback time for investing in an Ebara Expander System can be less than 1 year and sometimes as short as a few months.

LESS POWER CONSUMPTION + MORE PRODUCTION = SIGNIFICANTLY REDUCED ENVIRONMENTAL IMPACT

GREEN BENEFITS

- Expanders increase production of liquefied gas by ~20 tonnes per day.
- Removes energy from the LNG stream, decreasing the total power consumption and further cooling the cryogenic fluid.
- Each Megawatt of generated power increases the LNG production by ~60,000 tonnes per year.
SINGLE PHASE (LIQUID)

In recent years, single-phase expanders have become standard equipment in most new liquefaction plants. Used in the pressure let-down section of the process in place of a conventional Joule-Thomson valve, these machines improve process efficiency by up to 5% (even higher with a two-phase expander). The single-phase expander reduces the pressure of the liquid in a near isentropic expansion. The enthalpy reduction results in energy that is removed from the liquid and which can be exported as electrical power to the plant power grid.

The entire expander and generator assembly are contained within a dedicated vessel built to the appropriate pressure vessel code for each application, making the installation safe, simple and reliable. The configuration is identical to that used for our line of vessel-mounted pumps. The result is a compact, lightweight, uncomplicated installation having low noise levels and significant safety advantages over external air-cooled generator designs.

With over 100 units installed since 1997, Ebara’s liquid expanders have been used in APCI, APX, Linde and Shell DMR processes and account for more than 80% of all the cryogenic liquid expanders in our unique industry. Superior performance and reliability is achieved by utilizing the same TEM® and submerged motor/generator technology proven in our line of cryogenic pumps.
TWO-PHASE (LIQUID AND GAS)
Taking the existing single-phase expanders to the next level, two-phase machines operate at sub-bubble point outlet pressures. Differing from a single-phase machine, a two-phase expander may be used in any liquefaction process in which large downstream pressures are not required in order to extract more energy from the liquid. The increased energy extraction is accomplished by allowing larger pressure reductions into the two-phase liquid-vapor region. Two-phase expanders reduce, in one step, the high pressure condensate to a low pressure liquid-vapor mixture, extract energy from the process stream, and increase the amount of liquid production. By doing so, process efficiency can be increased from an approximated 5% up to 8%.

By operating in the two-phase region, these unique machines are ideal for mixture distillation processes such as nitrogen rejection. They can also be used in the pressure reduction phase of a Rankine refrigeration cycle.

Like all expanders in our product line, two-phase expanders are compact, efficient, and reliable. They can operate in a variety of liquids, and when combined with a variable speed drive offer a wide range of performance and applications. In operation since 2003, EIC two-phase liquid expanders use the same TEM® and submerged motor/generator technology proven in our line of single-phase expanders and cryogenic pumps.
force, the pump shaft and all of its rotating components move upward. This movement reduces the gap between the impeller and the stationary plate (variable orifice), thus restricting the wear ring leakage flow and causing the pressure in the upper chamber, inside the upper wear ring to increase. Due to increased pressure in the upper chamber, the thrust is reversed and now acts in a downward direction. This causes the rotating assembly to move downward, thereby opening the gap between the stationary plate and the impeller throttling ring, allowing the pressure in the upper chamber to decrease. The gap between the stationary plate and the impeller’s throttling ring then adjusts automatically to produce pressure in the upper chamber sufficient to offset the upward thrust. The end result is an equilibrium created between the upper and lower impeller surfaces to provide an extremely stable system with zero thrust loads on the bearings. This feature substantially increases the reliability and life span of the bearings and reduces equipment maintenance requirements.

The TEM® is EIC’s means of removing thrust loads on bearings in submerged centrifugal pumps and expanders. The TEM® is verified during performance testing by the use of a proximity probe placed at the end of the shaft to measure actual axial movement. The validity of this approach has been demonstrated through thousands of pumps delivered and millions of hours of successful operation.
Each electrical penetration seal assembly is pressure tested, helium leak checked and subjected to a high potential test before being accepted for use.

Each feedthru system uses a vapor space either between two feedthrus or internal in a double seal arrangement which can be purged with nitrogen to provide a safe, reliable method of installation.

Junction boxes and systems supplied are in compliance with the requirements of the U.S. National Electric Code and NFPA 59A for electrical penetrations into liquefied gas vessels, or to standards such as ATEX or IECEx, meeting the appropriate Exe and/or Exd classifications.

VIBRATION MONITORING SYSTEMS (VMS)

EIC can supply vibration monitoring systems, providing continuous trend monitoring for your specialized equipment. Depending on your project, the VMS system can be designed with either a PCB 4-20mA transmitter arrangement or a Bently Nevada compatible interface module. These systems are inclusive of instrument racks, accelerometers and in-tank instrument cables. If desirable, EIC can also install head-plate instrument boxes with accelerometers as requested.

All systems are custom engineered to meet the stringent requirements of increased safety for hazardous area locations and to provide the most reliable signal possible for condition monitoring.
SUBMERGED MOTOR GENERATORS

At Ebara International, every motor and generator design is project specific and based on the requirements of a given application. Each pump and expander design is then verified by complete performance testing prior to shipment. From design concept to finished product, every Ebara motor and generator machine is built to withstand the extreme operating conditions of the application. Using proprietary insulation systems, highest quality materials and best in class assembly techniques, rugged and durable service is ensured for Ebara’s demanding customer applications. Every Ebara motor and generator meets the NEMA MG-1 electrical test standards for insulation systems. However, since the machines can only operate safely in cryogenic fluids, standard temperature class testing is not relevant.

The concept of operating an electric motor or generator in cryogenic applications such as LNG or LPG pose many design and operating challenges and advantages which Ebara has addressed. For example, the influence of heat generated by the motors or generators is negated due to the cold fluids which pass through the windings, thus allowing a large power density ratio compared to typical air motors. Also, since there is an absence of oxygen in the pump during operation and no concern for an explosion, hazardous area classification standards do not apply.

INDUCERS

When low suction pressure or low tank levels are expected, Ebara pumps are fitted with a high-solidity helical inducer as the first hydraulic stage. This allows the unit to operate at extremely low tank levels which virtually eliminates “dead stock” while maintaining stable operation over a wide flow range.

The inducer blades are tapered, with a thicker blade width at the root, to provide the strongest blade design possible. This design has proven extremely effective and reliable in all Ebara pumps built to date. Combining the well proven technology with Computational Fluid Dynamics (CFD) software continues to improve NPSHR and pumpdown suction performance allowing for lower liquid levels.

POWER CABLES

Ebara’s electrical Power Feed Cable System is specially designed to be submerged in cryogenic liquefied gases and remain flexible at minus 200 degrees Celsius. The cables have been formally tested and accepted by Underwriter’s Laboratories (UL E129750) and listed as Power Feed Cable for Liquefied Gases up to ±200 degrees Celsius.

The cables are TFE insulated and are protected by braided stainless steel armor. They are UL approved for use with supply voltages up to 8000 VAC. Sizes range from 4 to 250 AWG/KCMIL (on 600 volt units) and 2-4 AWG/KCMIL (on 5000 volt units).
PROJECT MANAGEMENT

For every Ebara project, a dedicated Project Manager is assigned who is the main point of contact for the customer. The Project Manager is responsible for EIC performance as related to every aspect of company processes from the initial receipt of a contract through planning, engineering, documentation, manufacturing, testing and the closeout of the contract. The Project Manager provides planning, project team leadership, awareness of activity requirements and status plus the control of internal and external communications assuring all commitments are met or exceeded.

Project Management’s goal is to provide leadership, communication and accountability for each individual project to ensure predictable results which meet or exceed the goals and requirements for every project. Our experienced, dedicated Project Management staff provides coordination between project disciplines with the ultimate goals of Customer Satisfaction, Quality, On Time Performance, Cost Control and Risk Management.

RESEARCH AND DEVELOPMENT

EIC Cryodynamics Research and Product Development groups specialize in the development and application of submerged technology for liquefied gas pumps and expanders. Many of our customer’s processes require equipment which is not commercially available and by building upon existing technology, we develop new concepts to solve customer problems. We continually work with our customers to review how our technology will meet their needs. By exploring the application of new technologies to products and systems, we bring significant and fundamental improvements to the marketplace, built upon a base of existing, proven equipment.

Ebara’s Research and Product Development groups follow a three tier approach to build in the voice of our customer when developing new products. The first stage is identifying opportunities for new products and services. In this stage, our customer’s needs are analyzed to investigate the problems, benefits and conceptual features of a newly envisioned product. During the next phase, resource management, creative engineering, process design capabilities and information technology are used to convert each new product specification into a detailed design. The final stage of this approach involves introducing our new product and service portfolios to our customers.
AFTERMARKET SERVICES

We provide a full package of aftermarket services and parts for your Ebara cryogenic pumps and expanders. We are your partner in maintaining your equipment at peak reliability levels. Let us work with you to keep your plant operating with the high levels of availability that you require.

With thousands of pumps and expanders delivered, our team has years of experience with helping customers operate, troubleshoot and maintain their equipment.

Our specialists can assist you with any aspect of pump installation, maintenance and repair. We also provide operation and maintenance training.

Our factory support team stands ready to supply OEM spare parts, technical support, upgrades and improvements.

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• Suction Vessel Mounted Pumps (Model ECC) are utilized as single stage transfer pumps or multi-stage for vaporizer feed and send-out service.

• Model ECR Retractable Units are designed for LNG storage tank installations via columns which contain the pump and provide a discharge. The pump weight opens a spring loaded suction valve as also supplied by Ebara. This allows a system for pump removal from a loaded tank with the column being safely inertered.

In addition to Cryogenic Pumps, Ebara Cryodynamics’ Expanders exemplify our drive for advancing LNG process technology and productivity. These machines directly produce approximately 5% increased plant output while generating substantial electricity as a peripheral benefit. Recently advanced for both Single Phase (liquid) and Two-Phase (Gas/Liquid) applications, expanders can also be provided with variable speed technology. Ebara’s Client Partners have worked closely with Ebara’s engineers to optimize performance and reliability, giving them the outstanding, attractive results of this technology. Ebara International’s Expanders are becoming the specified standard in LNG production trains around the world.

ENVIRONMENT

Ebara International Corporation is committed to always meet or exceed the highest possible standards of environmental awareness, responsibility and ethics in our business activities. This approach is demonstrated in our daily work life through our Environmental Management Policy.

We encourage each of our employees to practice these principles and behaviors at the office, home and throughout their daily lives. Starting by making a difference at home in Sparks, Nevada, we can then carry these values out into our worldwide business. With the help of our customers, we can then make a difference around the globe.
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ENVIRONMENT