The NOVA Series

Cryopump designs a simple, innovative, easy-to-maintain high pressure reciprocating pump

When Cryopump’s customers are introduced to the unique features of the NOVA high pressure reciprocating cryogenic pump (patent pending), the reaction is always the same: they are impressed by the simplicity of the design and the ease of maintenance. The pump consists of only five (5) subassemblies allowing routine maintenance of the pump to be quickly completed by any mechanic using standard tools.

The NOVA’s flow is unique among cryogenic reciprocating pumps: the liquid enters the pump behind the piston head, flows through a suction valve incorporated in the piston head, and continues directly out the end of the pump cylinder, through the discharge valve assembly. The suction valve technology was originally developed for Cryopump’s patented “Double-Acting” pump which has been successfully employed in the field for nearly ten years. The NOVA’s flow-through design enhances the convection-induced flow of the thermosyphon storage tanks that are becoming widely used in Europe and elsewhere. The pump virtually becomes a part of the tank’s piping system and permits circulation of the cryogenic fluid whether pumping or idle. NOTE: The NOVA works equally well with medium-pressure conventional tanks.

Another unique feature of the NOVA is that all the piston shaft seals are contained in a single seal cartridge. Replacement of these seals is quickly and easily accomplished by simply sliding a new seal cartridge into place, eliminating the time-consuming and error-prone process of installing the numerous seals, spacer rings, etc. found in other pumps. Because routine maintenance of the cold end requires stocking only 10 items rather than the 20-25 parts required by other pumps, the user’s purchasing and spare parts management costs will be greatly reduced. Furthermore, with the exception of the piston and guide rings, the routine maintenance parts are identical for all sizes of the NOVA pump. The seal cartridge can be returned to Cryopump or any of the Cryogenic Industries group service centers for overhaul on an exchange basis.

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Ambient air vaporization requires consideration of several design variables

Cryoquip reviews the issues involved in vaporizer sizing

Ambient air vaporizers are simple devices used for the vaporization of liquid cryogens. They are used in many applications in a broad range of industries. Because they have no moving parts and rely on the “heat” contained in the atmosphere to provide the energy for vaporization, they are extremely reliable. The principle of operation is simple. Liquid cryogens are passed through a number of connected tubes in various series and parallel paths. The tubes themselves are part of an aluminum extrusion which has several fins emanating from the center. These fins provide a large surface area upon which the “ambient weather conditions” impinge and provide heat energy for vaporization. Because most cryogens are extremely cold (circa –300°F) even the coldest ambient condition provides a sufficient temperature difference for adequate heat transfer. The key to achieving enough heat transfer even in the most arduous ambient conditions, is to have sufficient surface area per tube, and per vaporizer.

The correct number of elements for the vaporizer construction is arrived at by an iterative process of balancing the flow conditions, meeting the application requirements, and having sufficient surface area to provide enough heat energy for the vaporization of the flowing cryogenic fluid. Combinations of series and parallel paths through which the liquid cryogen flows takes care of the pressure drop problems associated with liquid flowing through pipes. Extremely small pressure drops are achievable. All series and all parallel paths are utilized depending on application and design of the vaporizer.

Not all designs are the same and the common practice of comparing vaporizer size and performance by counting the number of fin elements can be extremely misleading. Units that have an identical number of fin elements, even the same element length, can give widely differing performances in terms of continuous cryogen vaporization. The difference may not be self evident as fin element design concerns itself not only with the external fin surface area, but with the thickness of the fin itself, the smoothness of the surface of the fin, and the design of the internal fluid passage. All these variables affect the overall ability of the vaporizer to perform its intended function. The number of fins required in the design, the overall size, the amount of aluminum used, and the vaporizer “performance” both on-line and off-line, all affect the overall cost of the vaporizers needed to meet the application requirements. The absolute number of (fin) elements is only one of many parameters that must be considered in the evaluation of an ambient vaporizer.

Fin elements are held in place and spaced apart by clips or brackets. The resulting space between the fins is critical to vaporizer performance. As the vaporizer performs its function of vaporizing cryogens, frost forms on the fins and builds up slowly on the surface as ice. If the ice meets and fills the space between the fins, the vaporizer is rendered useless and it will no longer vaporize the cryogen. This is due to the fact that air is prevented from flowing through the vaporizer because ice has filled up the spaces between the fins. Therefore, the designed space between the fins is crucial to the long term operation of the vaporizer. Vaporizer spacing, which is rarely considered or even thought about during specifying vaporizers, actually plays a major role in the performance of the vaporizer.

Obviously, another significant parameter is the actual fin element surface area. The science of vaporizing cryogens is simple. The energy required to vaporize the required amount of cryogen is directly proportional to the surface area. Despite the numerous and elaborate technical specifications eluded to in ambient vaporizer design, the bottom line is, without sufficient surface area the vaporizer will simply not work. Not all fin elements are the same. They look similar, and their size is rarely mentioned in specifications, but size is critical to performance. Fins can be as large as a full eight (8) inches tip to tip or as small as five (5) inches tip to tip and everywhere in between. The
surface area difference between the eight and five inch fins is a factor of 1.7 which makes a great difference to the surface area of two vaporizers with the same number of fin elements.

The fin thickness is also something seldom considered, but it plays an important role in a cost effective vaporizer design. The thinner the fin element the less aluminum is used per linear foot, hence the less expensive the materials used to build the vaporizer. Additionally, the lower the fin mass, the quicker the fins will warm up and start to shed ice build-up. This shortens the overall defrost time and more quickly readies the unit for service, and enables better utilization of the unit.

The smoothness of the fin surface area also contributes in this regard. A smooth fin element tends to quickly shed the ice build-up, so a combination of thin, smooth (fin) elements helps considerably in the defrost performance of the vaporizer.

Not all fin elements are thin and smooth. Very specialized extrusion techniques are required to extrude the fin elements, especially in lengths up to 40 feet, which Cryoquip produces on a regular basis. There are some fins that are grooved on the premise of increasing surface area. This benefit is outweighed by the added thickness of the fin element, and the fact that the grooves provide a key for the ice to stick to the fin, slowing defrost time and limiting the overall performance of the vaporizer.

There is one additional variable of the fin that can be overlooked—the inner cryogen fluid passage. In many fin elements the passage is simply a hole, a smooth round orifice. This is not an ideal arrangement for flowing liquid cryogens. Due to the vast difference between the temperature of the cryogen and the fin element, the liquid flows unpredictably through the pipe. Temperature gradients are set up quickly and two phase flow occurs readily. On short length units this can lead to slugs of liquid finding their way through the vaporizer without actually vaporizing. This leads to gas exit temperature inconsistencies and low temperature problems.

Cryoquip’s internal fluid passage is, in fact, internally finned to promote turbulence and boiling of the cryogen, as well as providing increased internal surface area to enhance the heat transfer into the cryogen as it flows through the vaporizer. The internal fins ensure rapid nucleate boiling of the cryogen and prevent the formation of liquid slugs which become entrained in the gas flow. This improves the overall efficiency of the vaporizer and eliminates the problems with gas exit temperature.

For more information, contact Bryan Smith at Cryoquip, Inc.

See related article for an analysis of ambient vaporizer switching issues, FrostByte, Winter 1996.
ACD utilizes computational fluid dynamics to improve engineering design

ACD, Inc. is in the early stage of incorporating state-of-the-art computational fluid-dynamics (CFD) analysis capability into the company's engineering design process. CFD is the science of simulating fluid flow on computers.

The aerodynamic design of turbomachines and other equipment involving fluid flow has traditionally relied on the use of simplified analytical fluid-dynamics analysis in conjunction with experimental testing. Typically, a preliminary design is first produced based on analytical analysis of the flow field. A prototype of the design is then built and tested to evaluate its performance.

Several iterations of this design cycle are usually required to arrive at the final configuration with the desired performance. Although the analytical/experimental design approach has worked successfully in the past, it does have limitations. First, in order to analyze complex fluid-flow problems using analytical methods, simplifying assumptions and empirical approximations have to be made based on existing test data and prior design experience. However, these assumptions and approximations frequently neglect important features of the geometry and flow physics. Consequently, the resulting design may have to be modified and re-tested several times before the desired performance is achieved. This iterative procedure is both time consuming and costly. Also due to the time and cost constraints, it is not always feasible to conduct parametric studies in order to systematically analyze the effects of geometric characteristics such as shapes and sizes on the performance of the design. Understanding of such effects would allow the development of an optimum design with the maximum performance.

Another limitation of experimental testing is that the true and often severe operating conditions encountered during actual operation can not always be simulated in test facilities. The behavior of the internal flow field, too, is difficult to visualize during testing and, consequently, the design engineer is unable to easily identify problem areas and their causes. In addition to these limitations, other difficulties often encountered in experimental tests include inaccurate model scaling and data measurements.

The limitations of the design approach described above can be eliminated with the use of CFD. In this computer simulation method, the mathematical equations governing the fundamental conservation laws of fluid dynamics are solved simultaneously on a mesh covering the flow region of interest. (See Figure 1.) Since the complete flow-governing equations are solved, solutions to complex problems with complicated geometry and non-linear flow physics can be computed. Any physical flow parameters can be specified and controlled such that all true operating conditions can be simulated. The effects of geometric characteristics on the performance of the design can be quickly modeled and evaluated on the computer without having to build and test prototypes, therefore reducing design time and cost. In addition, the flow field at any instance in time can be captured and visualized on the computer screen to provide insight into the flow structures and conditions at any point within the flow field. (See Figure 2.) This capability allows flow regions responsible for losses such as wake, separation, recirculation, and choked regions to be quickly identified and corrected.

On the other hand, CFD also has limitations including computer storage and speed. Other limitations arise due to the current inability to understand and, therefore, mathematically model certain complex flow phenomena such as turbulence. However, none of these limitations are insurmountable in principle, and recent trends in computer and...
numerical algorithm developments show reasons for optimism about the role of CFD in the future. Note that CFD does not completely eliminate the roles of analytical analysis and experimental testing from the design process. Analytical analysis is still used to produce an initial design which is then improved using CFD. Experimental testing is used to validate the final design and to provide test data for calibrating complex numerical models such as those used to simulate the effects of turbulence.

Several different modules will be held in stock and continuously replaced. Inquiries should be directed to Cryogenic Industries member company CryoCanada, Inc.

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Inglewood, Ontario LON 1K0 Canada
Tel: 1 905-838-0328

Cosmodyne, Inc., world leader in the design and manufacture of portable air separation plants, boasts an impressive headquarters in Torrance, CA, USA. The 121,900 ft² facility, shown here, sits on nearly 14 acres, is adjacent to a rail spur and within 15 miles of the Port of Los Angeles. A unique part of the complex is an extensive, outdoor testing pad, where each air separation plant is completely assembled and cryogenically tested before it is shipped. This testing procedure duplicates real life conditions and makes possible the shipping and commissioning of a fully operational plant.

ACD

Until recently, the use of CFD has been limited to academia and government labs, mainly due to the high cost of computers. However, with the availability of more powerful and affordable computers, CFD has become a practical design tool. It is increasingly being used in a wide variety of applications including external aerodynamics for aircraft design, chemical vapor deposition for semiconductor manufacturing, and internal aerodynamics for turbomachinery design. Recognizing the benefits and future potential of CFD, ACD has recently begun to implement a CFD design capability with the ultimate goal of increasing the efficiency of the company’s compressor and expander designs. Presently, finite-element analysis (FEA) is used extensively at ACD to analyze the mechanical design for stress, strain, and natural frequencies. The combined use of CFD and FEA will further improve both the reliability and efficiency of the company’s products.

For more information, contact Hoang Vinh at ACD, Inc.
A reciprocating pump primer

Cryogenic reciprocating pump theory and design are examined

High pressure cryogenic pumps used in the industrial gas industry today are generally the single cylinder, single acting positive displacement reciprocating piston type. Two and three cylinder pumps are employed when higher flows are necessary. These standard pumps range in capacity from 0.2 gpm to over 120 gpm, with design capabilities of 3,000 psig to 30,000 psig. Each element of a multiple cylinder pump is identical to each element operating in parallel to it on a common drive shaft. Each is capable of delivering the full pressure rise. Other types of positive displacement pumps, such as gear and sliding vane, have not been developed for commercial cryogenic applications due to the difficulties of sealing the relatively large sliding surfaces and the high pressures required. Multi-stage centrifugal pumps are also not suitable due mainly to the heat input to relatively low flow rates and the high pressure rise required for most of the industry’s high pressure pumping applications.

The single acting, single cylinder reciprocating pump which delivers discharge flow only on the forward stroke of the piston is the preferred configuration. A double acting piston would be a logical approach for higher flow rates except for the complexity of the valving and sealing of the pressures involved during the flow from the pumping chamber on the reverse stroke of the pump.

Displacement Pumping

A positive displacement pump is one where the liquid entering the pumping chamber through the suction valve during the intake stroke is physically displaced from the cylinder by the movement of the piston to the closed end of the cylinder. This is the discharge stroke; liquid is forced through the discharge valve and into the discharge system. The term “positive displacement” refers to the fact that if the liquid can not be displaced from the cylinder, the pressure will either “stall” the pump, force the pressure relief

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The NOVA is presently available in four piston diameters: 32 mm, 36 mm, 40 mm and 45 mm. The pump is designed for 400 barg (6000 psig) maximum discharge pressure in the first three sizes; 300 barg (4500 psig) maximum discharge pressure for the 45 mm size. Flows range up to 19 liters/minute (5 gpm) at 400 barg and up to 24 liters/minute (6.3 gpm) at 300 barg. All NOVA cold ends are made of oxygen-compatible materials, so that they may be used interchangeably for pumping oxygen or inert gases. There is no need to segregate and specially identify cold ends and spare parts to avoid using certain items in oxygen service. The pump is available with either a grease-lubricated or an oil-lubricated drive end.

The NOVA’s low mass results in faster cool-down. The flow-through design permits the pump to stand idle for extended periods without the need to relieve pressure build-up. In addition, the NOVA is an extremely quiet pump, well suited to the noise level restrictions becoming common in many parts of the world.

For more information, contact Gary Steres at Cryopump.

PUMP PRIMER

Valves

The pump inlet and discharge valves are pressure/flow actuated. The reduced pressure in the cylinder created by the intake stroke causes the higher relative liquid pressure against the intake valve to open the valve and flow into the cylinder. At the end of the stroke, when flow through the valve stops, gravity, a spring, or the reverse flow of liquid cause the valve to close. The valves are simply check valves but fitted very closely to the cylinder to minimize the volume of liquid remaining in the cylinder at the end of the stroke. It should be noted that the term “suction” has been avoided, as flow is not generated by “pulling,” but by “pushing.”

Seals

Pistons are also fitted with non-metallic piston rings with overlapping ends to seal the high pressure generated during the discharge stroke from the low pressure side of the system. Low friction shaft seals prevent loss of product at the warm end of the pump and also prevent contamination of the storage system by sealing against atmospheric air.

Two Stage Pump

One of the more recent developments in the reciprocating pump field is a two stage, double piston pump capable of pumping mixed flow product (gas and saturated liquid). This pump was developed for storage systems that can not always supply liquid at conditions adequate to supply the conventional “low NPSH” pumps. This patented SZ pump utilizes a preliminary chamber to fully charge the main high pressure chamber on the suction stroke enabling the pump to deliver full volumetric efficiency under almost all standard tank operation conditions.

See related FrostByte articles in the March 1995 and September 1996 issues. Additional discussions reviewing basic pump applications and design will appear in future issues of FrostByte.

For more information, contact Harold Rich, ACD Inc.
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