INSTALLING LIQUID-RING VACUUM PUMPS

The first lesson for operating liquid-ring vacuum pumps is installing them properly

The liquid-ring vacuum pump is a specific form of rotary positive-displacement pump utilizing liquid as the principal element in gas compression. The compression is performed by a ring of liquid formed as a result of the relative eccentricity between the pump's casing and a rotating multi-bladed impeller.

The eccentricity results in near-complete filling, and then partial emptying, of each rotor chamber during every revolution. The filling and emptying actions create a piston action within each set of rotor or impeller blades.

The pump's components are positioned in such a manner as to admit gas when the rotor chamber is emptying the liquid, and then allowing the gas to discharge once compression is completed. Sealing areas between the inlet and discharge ports are provided, to close the rotor areas, and to separate the inlet and discharge flows.

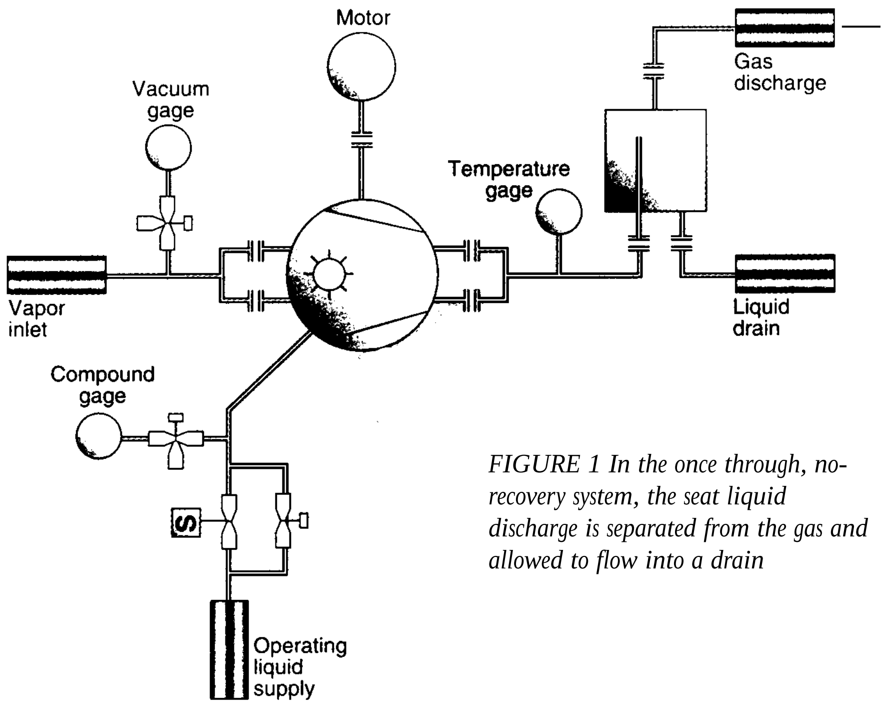

FIGURE 1 In the once through, no-recovery system, the seat liquid discharge is separated from the gas and allowed to flow into a drain

IN THE BEGINNING

The proper installation of a liquid-ring vacuum pump is critical to its subsequent operation and maintenance. The following installation guidelines are general recommendations that apply to nearly all types of liquid-ring vacuum pumps, but users should refer to the specific recommendations of each manufacturer to ensure the best performance.

As with any pump, care should be taken in unpacking the pump so as not to damage or misalign the assembly. For pump and motor units mounted on a baseplate, the unit should be lifted by the base only. Slings or hooks should not be attached to the pump or motor, since this can cause misalignment. Also, the pump should not be run until it is properly installed, nor should it be run without a sealing liquid.

Normally, a pump's components are protected with a water-soluble preservative, which should be flushed from the unit if any fluid other than water is utilized in a closed-loop system. Pumps made of stainless steel or other non-ferrous materials may be shipped without preservative, that is, "dry." Finally, the unit should be stored or installed such that any liquid present will not freeze.

SETTING UP

Liquid-ring vacuum pumps are basically slow-speed, smooth-operating rotating devices. Nonetheless, it is important to ensure that the pump's frame or baseplate is mounted level and firmly anchored.

Pumps that are about 50 hp and above are best placed on a concrete pad. Smaller units may be mounted on existing floors and skids. All joints in piping, whether flanged or screwed, should be free of strain and checked for leaks prior to start-up.

Normally, pumps that are supplied direct coupled to motors are aligned and test-run in the factory prior to shipment. However, because of unforeseen forces and moments imposed on the pump during shipment and installation, it is necessary to check the coupling's alignment prior to startup. To do this correctly, the guidelines of the coupling manufacturer should be followed as a minimum, and exceeded where possible.

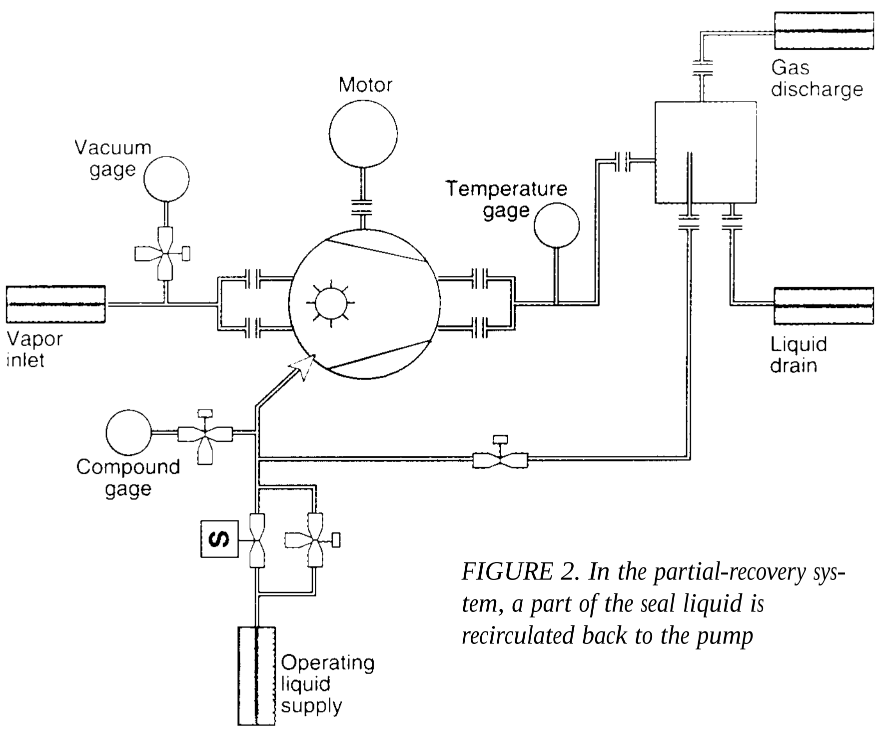

FIGURE 2. In the partial-recovery system, a part of the seal liquid is recirculated back to the pump

For pumps utilizing V-belt drives, it is necessary to ensure that the sheaves are properly installed and aligned before attempting to tension the drive. The V-belts should be placed over the sheaves and in the grooves without forcing them over the sides of the grooves.

When all belts are in their grooves, the centers are adjusted to take up all slack and leave the belts fairly taut. When the pump is operating, the slack side should have a slight bow. After several days of operation, re-tension the belts if necessary. Slipping (squealing) at startup are indications of insufficient tension. Excessive tension can shorten bearing life. If the unit is idle for an extended period of time, the tension on the belts should be removed.

Excessive heat (140°F and higher) should be avoided, since this over-cures the rubber and shortens belt life. The belts should never be mixed or switched from one groove to another on the sheaves, and should be replaced only with a matched set. Belt dressing should never be applied, and the sheaves should remain free of oil and grease.

PIPING THE SEAL LIQUID

The working principle of the liquid-ring pump is dependent upon a continuous supply of clean seal liquid (normally water, but other suitable liquids can also be used). This liquid enters the pump through a connection on the casing and is discharged from the pump, along with the gas.

Three basic piping arrangements for the seal liquid can be used for vacuum pump applications: once through, partial recovery, and closed loop. All these arrangements have four elements:

- A source for the seal liquid (from a water main or reservoir)
- A regulating device, to control the flow of liquid, if required
- A means of stopping the flow when the pump is shut off
- A means of separating the gas-liquid exhaust mixture

Once-through, no recovery. In this design, seal liquid is taken directly from a main and supplied to the pump (Figure 1). The liquid discharge is separated from the gas and wasted to a drain. No recirculation or recovery takes place. This is a common arrangement where conservation or contamination of the seal liquid is not a concern.

An automatic solenoid valve ensures the flow of the seal liquid in conjunction with the pump-motor's operation (i.e., when the motor stops running, the valve closes to prevent the casing from filling with seal liquid). With a manual seal-liquid shut-off valve, care should be taken to flash *cautions* to open the valve immediately before turning the motor on, and shutting the valve immediately before the motor is stopped.

Partial recovery. Here, the seal liquid enters and leaves the pump in the same manner as with the once-through arrangement (Figure 2). After that, a portion of the seal liquid is recirculated from the separator tank to the pump, and the remainder is discharged from the separator and drained.

Fresh makeup seal liquid is introduced in sufficient quantity to maintain the proper temperature that is essential to good pump performance. This type of arrangement is used where seal-liquid conservation is important (up to 50% reduction in fresh water consumption is possible, and if other than water is utilized, the consumption can be reduced more than 50%, depending upon the fluid vapor pressure and temperature).

Closed loop. This arrangement provides for total recirculation of the seal liquid. A heat exchanger is added to the system to remove the heat of compression and condensation from the seal liquid before it is reintroduced into the pump (Figure 3). For prolonged operation at high suction pressures, and when the system (heat exchanger, piping, valves, and so on) has excessive pressure drop losses, a circulating pump may be necessary.

With partial or total recovery arrangements, the seal-liquid level in the separator-recirculation tank should be at, or slightly below, the centerline of the pump shaft. Provisions may also be made for high-level overflow and low-level makeup on total recovery systems. These level controls help prevent the starting of the pump with the casing full of water, since this could overload the motor and damage the pump.

In fact, liquid-ring vacuum pumps in any piping arrangement should not be started with a full casing of seal liquid. Thus, provisions are normally made to drain the pumps in the event they become flooded. These provisions may vary somewhat from one manufacturer to another.

In general, it is not necessary to drain the pump if the incoming seal liquid is shut off simultaneously. An automatic valve can be used to control this procedure.

Many liquid-ring vacuum pumps that incorporate a standard packing or gland arrangement for shaft sealing are also fitted with lantern rings and a gland connection provided for cooling liquid. A suitable source of cooling liquid must be provided, at around 5 psig above the operating pressure. A common supply for both the seal liquid and the gland cooling is normally used.

If mechanical seals are employed, a supply of cooling and flush liquid is also required. It is recommended that a separate and clean source of seal liquid for mechanical seals is used. Double mechanical seals require a monitoring device to detect a leak on the inboard seal.

PIPING

To begin, the suction and discharge flanges on pumps are normally marked by arrows on the casing. The suction and discharge lines should be the same size as the pump connections.

Ideally, the discharge line from the pump to the separator should be at as low an elevation as possible. However, if it is necessary, a discharge leg can be used with minimum elevation above the pump's discharge flange. Too high an elevation in the discharge line can cause a back pressure on the pump, overloading the motor and affecting the pump's capacity.

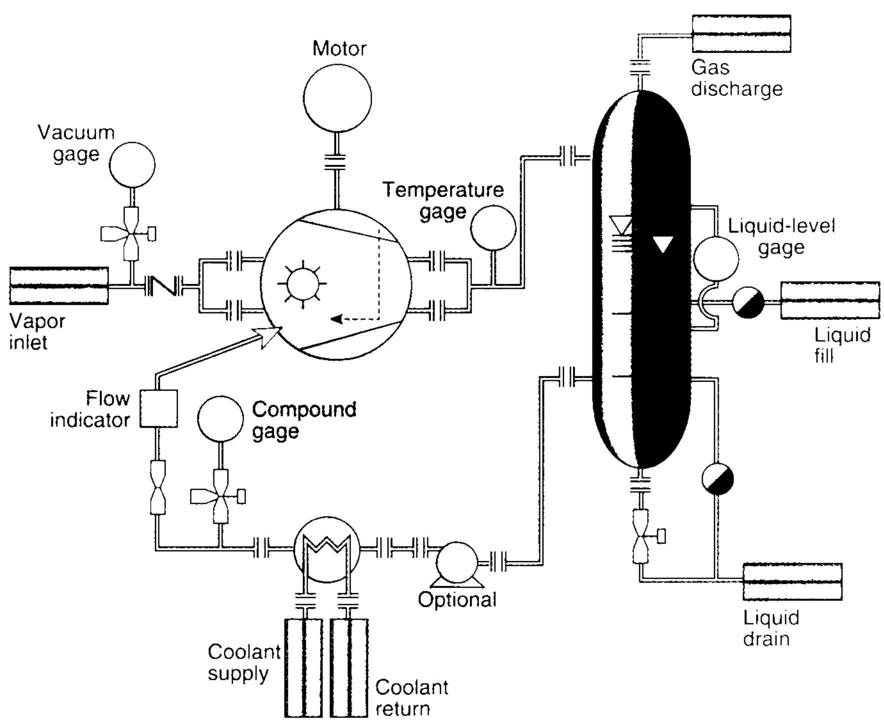

FIGURE 3. In this design, the seal liquid is totally recirculated

The seal-liquid supply piping should be the same size as the connection on the pump. For fully recirculated seal systems that do not use a recirculation pump, a larger pipe size is often used to reduce the pressure drop.

Remove the protective coverings from the pump openings just before connecting the pipe work. Check that all foreign matter, such as welding slag, nuts, bolts, rags and dirt, have been thoroughly cleared out of pipe work before connecting to the pump.

When connecting the pipe work, check that the flanges fit easily without strain, and that the flange holes are in perfect alignment. The flange gaskets must not protrude into the interior bore of the pipe or pump flange. All pipe work must be supported independently on each side of the pump, and must fit easily without transmitting strain to the pump casing. It is recommended that during the first three weeks of operation, a protective mesh be fitted at the pump's suction inlet.

Forces and moments caused by piping connections to the pump should be held to a minimum. Ideally, there should be no forces or moments exerted on the pump casing, which can be achieved by completely supporting the piping. Finally, the line sizes should be at least the same size as the pump connections, to eliminate any unnecessary pressure drops.

ELECTRICAL CONNECTIONS

Standard induction motors are suitable for driving liquid-ring pumps. Starting loads are low, and so across-the-line operation is normally employed.

It is recommended that a motor controller with over-current protection of the heater or fuse be used. The full-load current rating, stamped on the motor nameplate, should be used in making the selection for protection rating. A disconnect switch should also be installed between the motor controller and the power supply.

After the electrical work is completed, the pump should be turned by hand. It may be necessary to slacken the gland rings in order for the shaft to turn freely. The direction of rotation is marked by an arrow on the pump. Prime the system, turn on the seal liquid, bump the motor (turn it on and off) to check the pump's rotation, and turn off the seal liquid. If the direction is wrong, reverse any two of the three motor leads and recheck.

A 115-V, single-phase supply should be used for control circuits. Solenoid valves, vacuum and pressure switches, level controllers, and alarms should be supplied with only 115 V, to comply with electrical-safety-code requirements.

ACCESSORIES

Liquid-ring pumps come with many accessories, supplied by the manufacturer or by other companies in the field. An application's particular requirements, mode of operation, and type of control scheme dictate the necessity of various items. The following covers some of the more commonly used items.

Isolation valves separate the pump from the system whenever it is shut down for extended periods of time or for maintenance procedures. Gate valves or full-port ball valves are recommended for minimizing pressure drops in lines that are 3 inches or above in size. Butterfly valves are a more economical choice.

Inlet check valves prevent the gas and seal liquid from flowing back to the process when the pump is stopped. Swing-check, double flexible-seal, or equal-type valves must be installed horizontally.

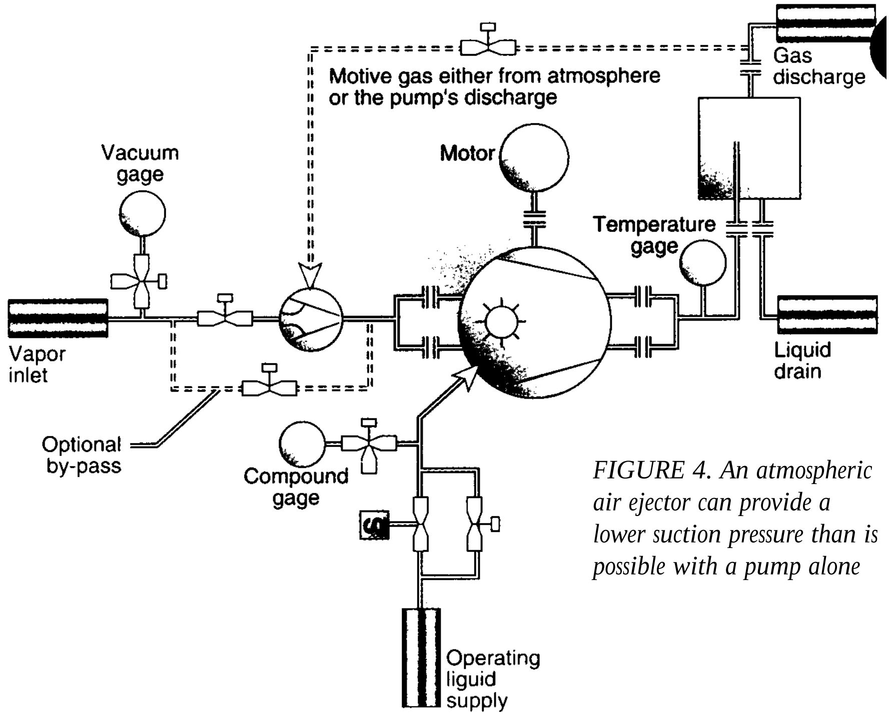

FIGURE 4. An atmospheric air ejector can provide a lower suction pressure than is possible with a pump alone

Inlet vacuum relief valves protect the pump from cavitation. When the pump's suction pressure is below the setting of a vacuum-relief valve, the valve will open and bleed in atmospheric air or process gas (if connected back to the pump's discharge side). Most inexpensive vacuum-relief valves are based on atmospheric pressure and need to be calibrated periodically.

Flexible connectors are used to correct for slight misalignments between a pump and a process, or if a minimal amount of expansion is anticipated.

Inlet vacuum control valves are used to control the system's vacuum level by bleeding in atmospheric air or process gas (recirculated back from pump discharge). Pneumatically operated diaphragms mounted on globe valves are required to achieve a fine degree of control.

Inlet vacuum gages measure the pressure at a vacuum pump's inlet. Normally, they are mounted directly ahead of pump suction.

Seal liquid shut-off valves are used to manually stop the flow of the seal liquid to pump.

Strainers filter out solid particles from the seal liquid.

Seal liquid flow-control valves are used to control the seal liquid's flowrate to the pump. A globe valve is a commonly used design.

Compound pressure gages are used to indicate the pressure at the inlet connection of the seal liquid piping to the pump. Approximate flowrates can be established, by maintaining the pressure properly at the connection point.

Discharge separator tanks separate the seal liquid from the discharged gas stream coming out of pump. These separator tanks can be either mounted on the floor, mounted on a baseplate with the pump (and used for partial and total recovery systems), or supported by the discharge piping (used on once-through systems).

Solenoid valves are used to automatically stop or start the flow of seal liquid to the pump.

Circulating pumps recirculate the seal liquid in total recovery systems. The pumps are required when the pump operates for prolonged periods at high absolute suction pressures or when excessive pressure drops occur due to heat exchangers, piping and valves, or both.

Heat exchangers remove heat from the recirculated seal liquid.

Atmospheric air ejectors provide suction pressures lower than that the liquid-ring pumps are capable of when operating alone (Figure 4). The ejectors may be added to a pump, to provide an inlet pressure as low as 3 torr.

The operation of air ejectors is similar to that of steam ejectors. Atmospheric air or recycled gas from separator discharge is used as the motive force for compressing the process gas from the system's design pressure up to that of the inlet pressure of the liquid-ring pump. To enhance pumping capacity above 30 torr, a motive air shut-off valve can be added. To achieve full pump capacity above 30 turF, a bypass can also be added.

Edited by Jayadev Chowdhury

TROUBLESHOOTING LIQUID-RING VACUUM PUMPS

Like the proper installing of vacuum pumps, troubleshooting them is critical to their continued operation and maintenance. As a result, it is important that only qualified personnel, using proper equipment, be authorized to perform testing,

There are many factors that can influence the performance of a vacuum system. First, it is always good practice to inspect the equipment when it arrives at site, and then to make sure that the equipment is properly installed, and that all valves and flow switches are in correct direction as per the installation drawings. Verify that the pump rotates freely and in the proper direction, and that the system is properly primed before start-up. All these preliminary checks make troubleshooting of the system easier.

Malfunction of the vacuum system could be due to utility or process conditions, or both, or the equipment, and it is important to determine the cause. A malfunction due to external influences can be determined as follows:

1. The first step is to compare the original design conditions, especially gas composition and cooling water temperature to the existing condition.

   Any change in the design conditions and the gas's composition may have an effect on the vacuum system. For example, an increase in the condensable load will raise the effective seal-liquid temperature and effect the vacuum system. A change in the condensable or non-condensable gas composition may effect the seal-liquid composition and the vacuum. High seal-liquid temperatures will also affect the vacuum level.

2. Make sure that there is no excessive air leakage. Air leakage can be determined by a drop test per Heat Exchange Institute Standards for Steam Jet Vacuum Systems.

3. Back pressure on the system should be as per design conditions. Excessive back pressure increases the brake horsepower, and may have an effect on the capacity of the vacuum pump.

If it is determined that the malfunction is not due to external influences, troubleshooting of the equipment can be made as follows:

1. Check the seal liquid's temperature rise across the pump. This should be as per design. Even if cooling water temperature and gas composition meet design standards, a reduced seal could be due to a plugged strainer or partially closed valve in the recirculation line. Also, check the recirculating pump's performance (if furnished) and the recirculating heat exchanger for any fouling. Any of these factors could have an effect on the performance of the vacuum system.

2. Check pump speed with a tachometer to make sure it meets design specifications. If the vacuum pump is V-belt driven, check the tension to ensure that the belts are not slipping.

3. Test the vacuum pump per the Heat Exchange Institute's Performance Standards for Liquid Ring Vacuum Pumps, and compare with the manufacturer's performance curve. Internal clearances may have to be readjusted to meet the performance curve.

A regular maintenance program is important even if the desired vacuum is achieved. The following items should be checked:

1. If the vacuum pump is furnished with packing, it is supposed to drip. However, excessive leakage of packing is due to improper adjustment. The packing should be re-adjusted, and the dripping checked to provide proper cooling. Pumps furnished with mechanical seals should not leak. Make sure that the seals are flushed with clean liquid that is compatible with material used.

2. Check for excessive bearing temperatures. The normal temperature is around 140°F. Higher temperatures could be due to misaligned couplings, excessive piping stress, over greasing or contaminated lubricant.

3. Check for excessive noise and vibration of the vacuum pump. This could be caused by coupling misalignment, high seal-water flow, high discharge pressure, an improperly anchored pump, bearing failure, water-filled casing during startup, or a lack of air flow to the vacuum pump.

4. Check the motor's amperage. A high amperage could be due to high discharge pressure, excessive seal-liquid flow, or motor malfunction.

AUTHORS

John Aglitz is chief engineer at NItech, Inc. (64 Horse Hill Rd., Cedar Knolls, NJ 07297; Tel: 201-538-1940), which manufactures vacuum systems. Mr. Aglitz holds a B.S. in chemical engineering from New Jersey Institute of Technology (Newark), and has 20 years of experience in vacuum system design and construction. He is a member of AIChE.

Rajender K. Bhatnagar is a project manager at Nash Kinema, Inc. (700 Glassport-Elizabeth Rd., Elizabeth, PA 15037-1864; Tel: 412-384-3610). He holds a B. Tech degree in chemical engineering from Osmania University (Hyderabad, India). Mr. Bhatnagar has 17 years of experience in engineering, design, manufacturing and production. He is currently involved in engineering, design, troubleshooting and testing of ejector systems, ejector hybrid systems and booster hybrid systems.

Donald E. Bolt is manager of the engineering heat transfer department at Foster Wheeler Energy Corp. (Perryville Corporate Park, Clinton, NJ 08809-4000; Tel: 908-730-4000). He holds a B.S. in mechanical engineering from Syracuse University, and an M.S. degree in mechanical engineering from Polytechnic University. Mr. Bolt is a P.E. in New York, and is a member of Pi Tau Sigma National Mechanical Honorary Soc.

Thomas L. Butzbach is manager of applications engineering for Graham Manufacturing Inc. (P.O. Box 719, Batavia, NY 14021-0719; Tel: 716-343-2216). He holds an A.S. degree in mechanical technology from the State University of New York, and has 35 years of experience in the design and development of vacuum systems. Mr. Butzbach is chairman of the Heat Exchange Institute's Vacuum Technology Technical Committee.