



PERFORMANCE STANDARD
for
LIQUID RING VACUUM PUMPS

FOURTH EDITION

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HEAT EXCHANGE INSTITUTE, INC.

PERFORMANCE STANDARD for **LIQUID RING VACUUM PUMPS**

FOURTH EDITION

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FOREWORD

The fourth edition of this Standard has been developed by the Vacuum Technology Section of the Heat Exchange Institute, Inc. The technical information in this Standard combines present industry standards, and provides test methods of factory testing of liquid ring vacuum pumps.

The Performance Standard for Liquid Ring Vacuum Pumps is continually reviewed by the Technical Committee at scheduled meetings under the direction of the Vacuum Technology Section. This Standard primarily covers factory testing, however, it may be used to cover field-testing provided the necessary testing equipment, as outlined in the Standard, is available. This new edition of the standard includes new revised material in Section 5.0, *Test Standards*, as well as a new troubleshooting guide for liquid ring vacuum pumps.

This standard represents the collective experience of the Section members and provides a guide in the performance testing of liquid ring pump vacuum pumps. The methods given in the Standard are the result of a great many years of accumulated experience within the industry and have been verified by tests.

In the preparation of this Standard, consideration has been given to the work of other organizations, such as the American National Standards Institute (ANSI), the American Society of Mechanical Engineers (ASME), European Committee of Manufacturers of Compressors, Vacuum Pumps and Pneumatic Tools (PNEUROP), and others. Credit is hereby given to all those whose Standards may have been helpful in this work.

This publication of the Performance Standard for Liquid Ring Vacuum Pumps represents another step in the Heat Exchange Institute's continuing program to provide Standards, which reflect the latest technological advancements in the field of vacuum technology. Suggestions for improvement of the Standard are welcome and should be sent to the Heat Exchange Institute, Inc., 1300 Sumner Avenue, Cleveland, Ohio 44115, E-mail: hei@heatexchange.org.

1.0 SCOPE

This Test Standard covers routine performance testing of liquid ring vacuum pumps, conducted on dry air as a gas, using water as a service liquid, with the pump discharging to atmospheric pressure.

Non-routine performance testing, basic sizing methods, installation, operational behavior and maintenance are beyond the scope of this Standard. These issues are to be mutually agreed upon between individual manufacturer and user.

Pumps are sized by the manufacturers using proprietary conversion factors to compensate for deviation between field conditions and standard published performance. A list of operating variables and factors affecting pump performance are included in the Appendices of this Standard to provide the user and the manufacturer with a common understanding of the significance of these variables. (Appendices A & D)

2.0 PURPOSE

This test standard provides methods of factory testing of liquid ring vacuum pumps which permit evaluation of test results. The methods given in this Standard are the result of a great many years of accumulated experience within the industry and have been confirmed by tests. They are reliable within the industry and provide both the purchaser and the manufacturer with assurance that all liquid ring vacuum pumps tested in accordance with this Standard will meet the specified performance.

While this Standard primarily covers factory testing, it may be used to cover field testing provided the necessary test equipment, as outlined in this Standard, is available for a field test.

This Standard is not intended to encourage unnecessary testing. In some instances, the manufacturer's methods of manufacture and inspection are such that tests on duplicate units may be eliminated without prejudice to the purchaser.

3.0 DEFINITION OF TERMS

3.1 Units

English units are utilized for ease of interpretation. SI units may be substituted per Appendix E.

3.2 Absolute Temperature

Absolute temperature is the temperature above absolute zero. It is equal to the degrees Fahrenheit plus 460 expressed in degrees Rankine (R).

3.3 Service Liquid

The compressant fluid continuously supplied to the pump to create the liquid ring inside the pump casing.

3.4 Gas Inlet Temperature

Inlet temperature is the temperature of the gas at the inlet of the liquid ring pump, expressed in degrees Fahrenheit.

3.5 Service Liquid Supply Temperature

Service liquid supply temperature is the temperature of service liquid at the liquid ring pump service liquid connection, expressed in degrees Fahrenheit.

3.6 Service Liquid Reference Temperature

The service liquid is usually water and the reference temperature is 60°F.

3.7 Absolute Pressure

Absolute pressure; i.e., absolute vacuum is the pressure measured from absolute zero.

3.8 Vacuum

The subatmospheric pressure differential measured from the barometric pressure.

3.9 Suction Pressure

Suction pressure is the pressure at the inlet of the liquid ring vacuum pump expressed in pounds per square inch or in inches or millimeters of Hg, absolute or vacuum.

3.10 Barometric Pressure

Barometric pressure is the absolute pressure in the surrounding air, expressed in pounds per square inch, inches of Hg, or millimeters of Hg.

3.11 Discharge Pressure

Discharge pressure is the pressure prevailing at the discharge of the liquid ring vacuum pump expressed in pounds per square inch, inches or millimeters of Hg.

3.12 Service Liquid Supply Pressure

Service liquid supply pressure is the pressure at the liquid ring vacuum pump service liquid connection expressed in pounds per square inch absolute.

3.13 Design Point

The required combination of suction pressure and dry air flow rate in ACFM.

3.14 Standard Capacity

Standard capacity is the standardized volume rate of flow of the gas to be handled by the liquid ring vacuum pump measured at a standard pressure (usually 29.92 inches of HgA) and a standard temperature (60°F), expressed in standard cubic feet per minute (SCFM).

3.15 Actual Capacity

Actual capacity is the actual volume flow rate of the gas to be handled by the liquid ring vacuum pump, measured at the pump inlet pressure and temperature expressed in ACFM. Note, the terms "inlet capacity" and "rarified capacity" are synonymous with "actual capacity."

3.16 Dry Air

Atmospheric air at normal room temperature is considered dry air. The very small weight of water vapor contained is insignificant and is ignored. For example, the weight of water vapor in atmospheric air at 50% relative humidity and 60°F temperature is less than 0.0055 lb. per lb. of air.

3.17 Relative Humidity

The ratio between the actual moisture content and the maximum moisture content of a gas at a given pressure and temperature expressed in percent.

3.18 Saturated Air

Air is considered saturated when the relative humidity is 100 percent at the inlet temperature and pressure to the pump.

3.19 Molecular Weight

Molecular weight is the sum of the atomic weights of all atoms in a molecule.

3.20 Mole

Mole is a mass numerically equal to the molecular weight.

3.21 Mole Fraction

Mole fraction of a component in a homogeneous mixture is defined as the number of moles of that component divided by the total number of moles in the mixture.

3.22 Service Liquid Flow

The flow of service liquid required by the liquid ring vacuum pump at a given inlet condition. The unit is gallons per minute (GPM).

3.23 Power Consumption

The power consumed by the liquid ring pump. The unit is brake horsepower (BHP).

3.24 Actual Operating Speed

The speed at which the liquid ring vacuum pump will operate in the field. The unit is revolutions per minute (RPM).

3.25 Test Speed

The speed at which the liquid ring vacuum pump is tested (which may differ from actual operating speed). The unit is revolutions per minute (RPM).

3.26 Correction of Capacity Due to Variation in Service Liquid Temperature

The correction factor required to correct measured capacity to the capacity at the service liquid reference temperature.

3.27 Correction of Capacity Due to Variation in Speed

The correction factor required to correct measured capacity at test speed to the capacity at the actual speed.

3.28 Correction of Power Consumption Due to Variation in Speed

The correction factor required to correct measured power consumption at test speed to the power consumption at the actual speed.

3.29 Notation

BHP_c	power consumption – corrected
BHP_t	the power consumption measured during the test
CF_1	capacity correction factor due to variation in service liquid supply temperature
CF_2	capacity correction factor due to variation in speed
CF_3	power consumption correction factor due to variation in speed
CF_4	temperature correction factor for observed barometric pressure
N_s	speed (RPM) specified in the contract
N_t	speed (RPM) measured during the test
P_1	gas inlet pressure, inches HgA
P_2	gas discharge pressure, inches HgA
P_b	barometric pressure, inches HgA
P_{bc}	corrected barometric pressure (corrected to 32°F) inches HgA
P_{dg}	partial vapor pressure of the service water at 60°F, inches HgA
P_{dt}	partial vapor pressure of service water at the actual temperature during the test, inches HgA

P_s	service liquid supply pressure, psia	V_c	corrected inlet volume flow rate, ACFM or SCFM
Q_s	service liquid flow rate, GPM	V_s	standard volume flow rate, standard cubic feet per minute, SCFM
t_a	ambient air temperature, degrees F	V_t	inlet volume flow rate measured during the test, ACFM or SCFM
t_s	service liquid supply temperature, degrees F	W	mass flow rate, pounds per hour
t_1	gas inlet temperature, degrees F		
t_2	service liquid discharge temperature, degrees F		
V_1	rarified inlet volume flow rate, actual cubic feet per minute, ACFM		

4.0 DESCRIPTION OF LIQUID RING VACUUM PUMPS

4.1 Operating Principle

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 the liquid ring as a result of the relative eccentricity between the casing and a rotating multi-bladed impeller.

The eccentricity results in near complete filling then partial emptying of each rotor chamber during each revolution. The partial filling and emptying creates a piston action within each set of rotor or impeller blades. Parts are positioned in such a man-

ner as to admit gas when the rotor chamber is emptying of liquid and allow the gas to discharge once compression is completed. Sealing areas between the inlet and discharge ports are provided to close the rotor areas, separating the inlet and discharge flows.

A portion of the liquid in the casing is continuously discharged with the gas and the cooler service liquid is introduced to remove the heat generated during operation.

Figures 1 and 2 provide typical examples of liquid ring vacuum pumps.

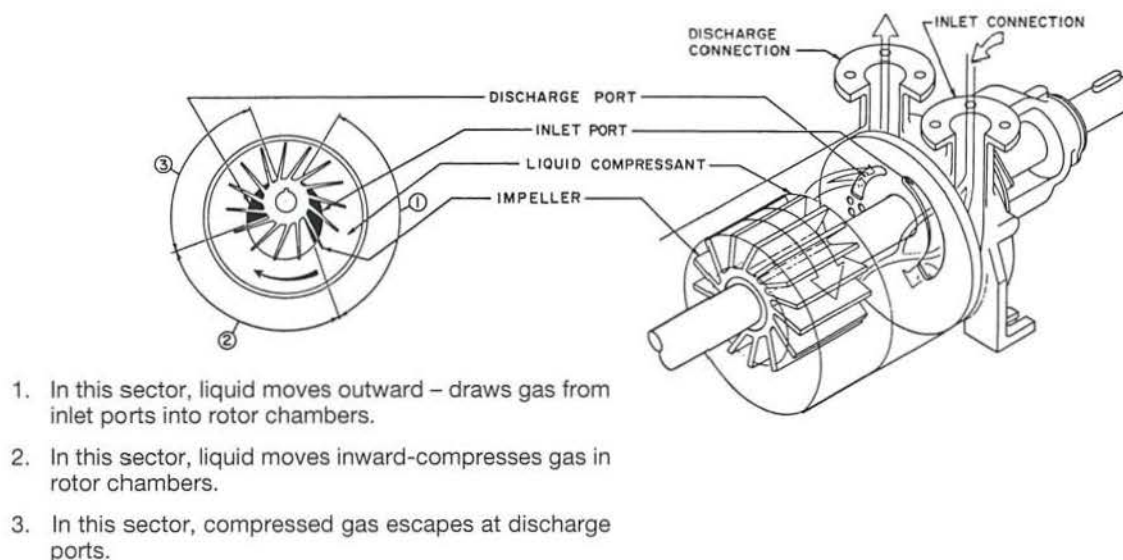


Figure 1
FLAT PORT PLATE

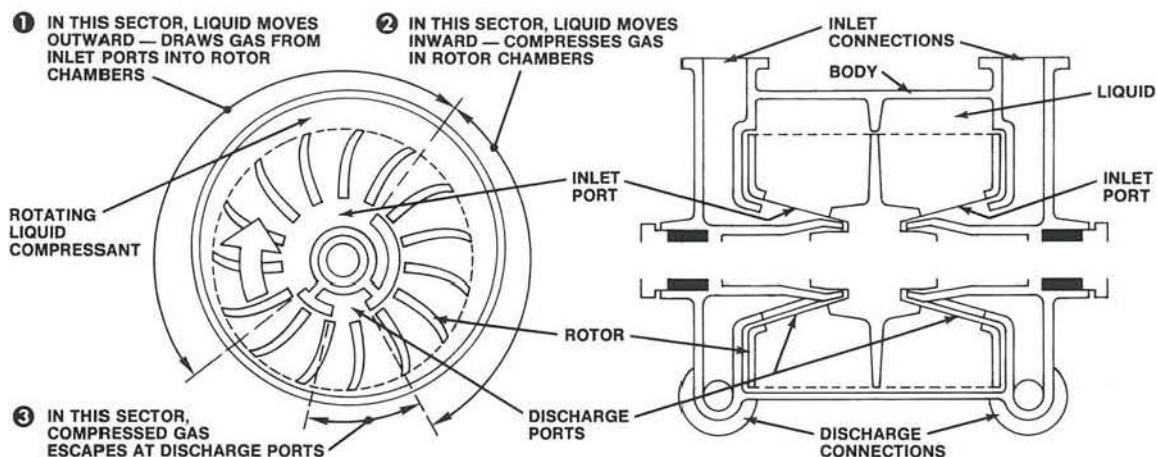


Figure 2
CONICAL PORT

4.2 Types

Common types of liquid ring vacuum pumps are as follows:

- 1) Single stage, flat port plates, Figure 3
- 2) Single stage, conical ports, Figure 4
- 3) Two stage, flat port plates, Figure 5
- 4) Two stage, conical ports, Figure 6

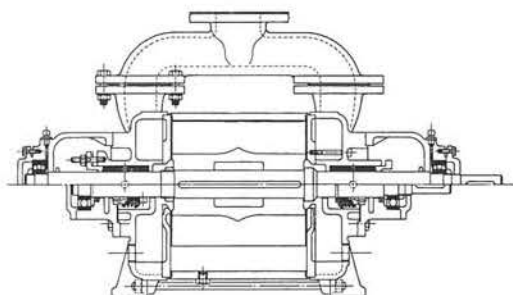


Figure 3
SINGLE STAGE, FLAT PORT PLATES

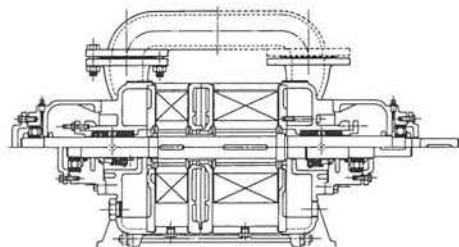


Figure 5
TWO STAGE, FLAT PORT PLATES

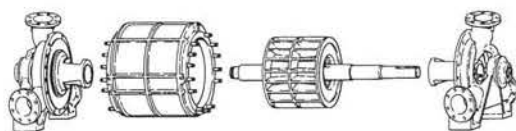


Figure 4
SINGLE STAGE, CONICAL PORTS

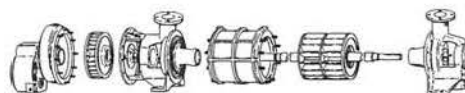


Figure 6
TWO STAGE, CONICAL PORTS

4.3 Nomenclature

Liquid ring vacuum pumps vary in specific design and construction with manufacturer, however, regardless of manufacturer, they consist of the following major components:

- 1) Rotor or Impeller: The device used to impart energy to the liquid ring, enclose the gas during compression and move the gas from the inlet to the discharge port.
- 2) Shaft: To transmit power from a driver to the impeller.
- 3) Bearings: To support the shaft in the casing.
- 4) Stuffing Boxes/Mechanical Seals: To seal the shaft exit from the casing.
- 5) Heads or End Casings: To duct the gas to or from the inlet and discharge ports.
- 6) Port Plate or Cone: To duct the gas from inlet and discharge passage to rotor.
- 7) Impeller Casings: To form and contain the liquid ring and impeller.

5.0 TEST STANDARDS

5.1 Basis

The acceptance test is performed on a dry air basis under ambient conditions at the test location. Atmospheric air at normal room temperature is considered dry air. The very small weight of water vapor in it is considered insignificant and is ignored.

For units removing gases other than air, dry air is still used as basis of testing as it would not be possible to maintain sources of all possible combinations of gases for performance testing.

Note, the basis of test is air and service liquid (water) at 60°F.

The following relationship may be used to determine ACFM, knowing SCFM.

$$V_1 = V_s \times \frac{29.92 \text{ inches HgA}}{P_1} \times \frac{(t_1 + 460)^\circ\text{R}}{520^\circ\text{R}}$$

Where:

- P_1 = gas inlet pressure, in. HgA
- t_1 = gas inlet temperature, °F
- V_s = SCFM
- V_1 = ACFM

The following relationship may be used to determine ACFM, knowing mass flow rate in pounds per hour.

$$V_1 = \frac{W}{60} \times \frac{v_s}{mw} \times \frac{29.92 \text{ inches HgA}}{P_1} \times \frac{(t_1 + 460)^\circ\text{R}}{520^\circ\text{R}}$$

Where:

- W = mass flow rate, pounds per hour
- P_1 = gas inlet pressure, in. HgA
- V_1 = ACFM
- t_1 = inlet temperature, °F
- v_s = standard molar specific volume = (379 cu. ft./lb-mole)
- mw = molecular weight test air = 29

5.2 Test Equipment

5.2.1 Flow Measurement

The device employed to measure the flow rate of air handled by the vacuum pump will vary between equipment manufacturers, but the approved flow measurement devices are listed.

5.2.1.1 Orifice Method

HEI, ASME or Square Edge Orifices can be employed. Refer to HEI, "Standards for Steam Jet Vacuum Systems", latest edition. Nozzles should be inspected periodically for damage that might affect performance.

5.2.1.2 Flow Meter Method

Rotary piston, turbine flow meter or mass flow meter can be employed and must be calibrated on a periodic basis and be traceable to the NIST.

5.2.2 Pressure Measurement

Any pressure device capable of a verifiable accuracy within the tolerances specified in this Standard, shall be considered satisfactory for measuring pressures in compliance with this test specification unless otherwise noted in the following paragraphs.

5.2.2.1 General

5.2.2.1.1 Pressure measurements shall be taken at a pressure tap that is not subject to velocity effects and will therefore indicate static pressure.

5.2.2.1.2 Gauge tubes of either barometers or mercury columns shall have an inside bore diameter not less than 0.25 inches and preferably 0.5 inches at the section where the reading is made.

5.2.2.1.3 Gauge tubes shall be clean and free of any visible oxide, dirt, or collected moisture.

5.2.2.1.4 Mercury or other gauge liquid shall be pure, clean and free of dirt and oxide.

5.2.2.1.5 The line connecting the vacuum gauge to the pump shall be purged periodically, by bleeding air through the line, to eliminate moisture.

It shall be tested for leaks by isolating the line and gauge from the pump to see that the gauge reading does not change.

5.2.2.1.6 The line connecting the vacuum gauge to the pump shall have a minimum bore of 1/4 inches. If rubber tubing is used, it shall have a minimum wall thickness of 3/16 inches.

5.2.2.2 Suction Pressure

The following precautions shall apply to all subatmospheric pressure measurements.

5.2.2.2.1 Spring type vacuum gauges shall not be used.

5.2.2.2.2 Absolute Pressure Measurement 4.0 inches to 30 inches of mercury; the verifiable accuracy for this range must be 0.05 inches Hg or better.

5.2.2.2.2.1 Mercury columns or precision aneroid manometers are preferred in this range.

Mercury manometers shall have a scale graduated in 0.1 inches Hg (or 2.54 mm Hg) and readings estimated to 0.05 inches Hg (or to the nearest 2.54 mm Hg, if mm Hg scale is used).

Precision aneroid manometer with a 0-31 inches of HgA range shall have a scale graduation of 0.05 inches Hg maximum and its accuracy must be within 0.05 inches Hg full scale.

5.2.2.2.3 For absolute pressure from 4.0 inches to 0.5 inches of mercury, the verifiable accuracy of the instrument must be 0.02 inches of mercury or better.

5.2.2.2.3.1 Precision aneroid manometer with a 0-4 inches HgA range shall have a scale graduation of 0.05 inches Hg maximum, and its accuracy must be within 0.02 inches Hg full scale. This manometer shall be used for inlet pressures below 4 inches HgA.

5.2.2.2.3.2 An electronic pressure transmitter that can be read within 0.02 inches of Hg can be used. Its accuracy shall be within $\pm 0.25\%$ of full scale.

5.2.2.2.3.3 Mercury columns or manometers, using straight tubes with scales graduated to 0.1 inches (or 2.54 mm Hg) and vernier readings to 0.01 inches (or 0.25 mm Hg) can be used.

5.2.2.3 Barometric Pressure

5.2.2.3.1 A mercury barometer is the preferred instrument for normal barometric pressure measurement. The accuracy of this barometer shall be established by periodic checks against standards as specified in the latest edition of the ASME Power Test Code, "Instruments and Apparatus", 19.2, Pressure Measurement.

5.2.2.3.1.1 When comparing the mercury column readings and barometer readings, both shall be corrected to 32°F in accordance with Appendix B.

5.2.2.3.1.2 Electronic precision manometers can be employed as an alternative if the reading tolerance is a maximum 0.2% of the reading.

5.2.2.3.2 The barometer shall be located near the test apparatus and substantially at the same elevation.

5.2.3 Air Temperature

5.2.3.1 Inlet air temperature shall be measured by calibrated instruments such as thermometers, thermo-electrical instruments or resistance temperature detectors. The reading of the inlet temperature must be accurate within ± 2 degrees F.

5.2.4 Service Water Measurement

5.2.4.1 Service Water Parameters to be measured.

5.2.4.2 Temperature shall be measured with instruments as described in 5.2.3 except the measured reading must be within ± 1 degree F.

5.2.4.3 Water flow rate shall be measured with flow meter, orifice or nozzle. Accuracy shall be within $\pm 5\%$ of total flow rate being measured.

5.2.5 Absorbed Horsepower

The absorbed horsepower requirement may be measured directly with a dynamometer (swivel bearing motor) or torque meter, or indirectly determined by measured electrical input to the driving motor.

5.2.5.1 Dynamometer Method

The dynamometer needs to be periodically calibrated and its accuracy must be within 0.5% full scale.

5.2.5.2 Torque Meter Method

The torque meter's calibration setting must be checked before and after each test. If the calibration setting has drifted from the original value, the test must be repeated. The torque meter shall be periodically calibrated and its accuracy shall be within 0.25% of full scale. The instrument shall not be used for torque readings at the low end of its scale where the accuracy of the reading exceeds $\pm 1.5\%$.

5.2.5.3 Two-Wattmeter Method

The vacuum pump absorbed horsepower can also be obtained by measuring electrical input to a calibrated electric motor. The term "calibrated" indicates the motor has been tested and compared to a known torque, to determine the Efficiency vs. % of Full Load. Multiplying the Watts by the Efficiency and dividing by 746 will equal the absorbed horsepower.

The above formula holds true for single-phase and three-phase motors. When a three-phase motor is being tested, the two-wattmeter method or other method with similar accuracy shall be used. In all cases, the following electrical data shall be recorded: Volts, Amperes, Power Factor, Watts.

NOTE: The power factor need not be recorded if watt readings are taken. Calibrated motors can only be used in the range for which they have been calibrated.

5.2.5.4 The test methods described in paragraphs 5.2.5.1, 5.2.5.2, and 5.2.5.3 will yield the most accurate result. Every vacuum pump will be tested to one of these three methods, except for motor mounted pumps; they will be tested in accordance with paragraph 5.2.5.5.

5.2.5.5 The absorbed horsepower for motor mounted pumps will be tested by the two-wattmeter method and the motor efficiency will be based on the motor manufacturer's value, and an actual calibration test of the motor being tested will not be required. All other requirements of the two-wattmeter method shall be met.

5.2.5.6 Electrical instrument accuracy shall be as follows and they must be periodically calibrated.

5.2.5.6.1 Volt meter must be within $\pm 0.5\%$ of full scale.

5.2.5.6.2 Ampere meter must be within $\pm 0.5\%$ of full scale.

5.2.5.6.3 Wattmeter must be within $\pm 0.5\%$ of full scale.

5.2.5.6.4 Power factor meter must be within $\pm 0.5\%$ of full scale.

5.2.6 Pump Shaft Speed

The pump shaft speed can be measured by means of electronic frequency meters, stroboscopes or shaft counters. The accuracy of this type of instrument shall be within $\pm 0.5\%$ full scale.

5.3 Test Set-Up

Figure 7 is a schematic of the test set-up for a liquid ring vacuum pump performance test.

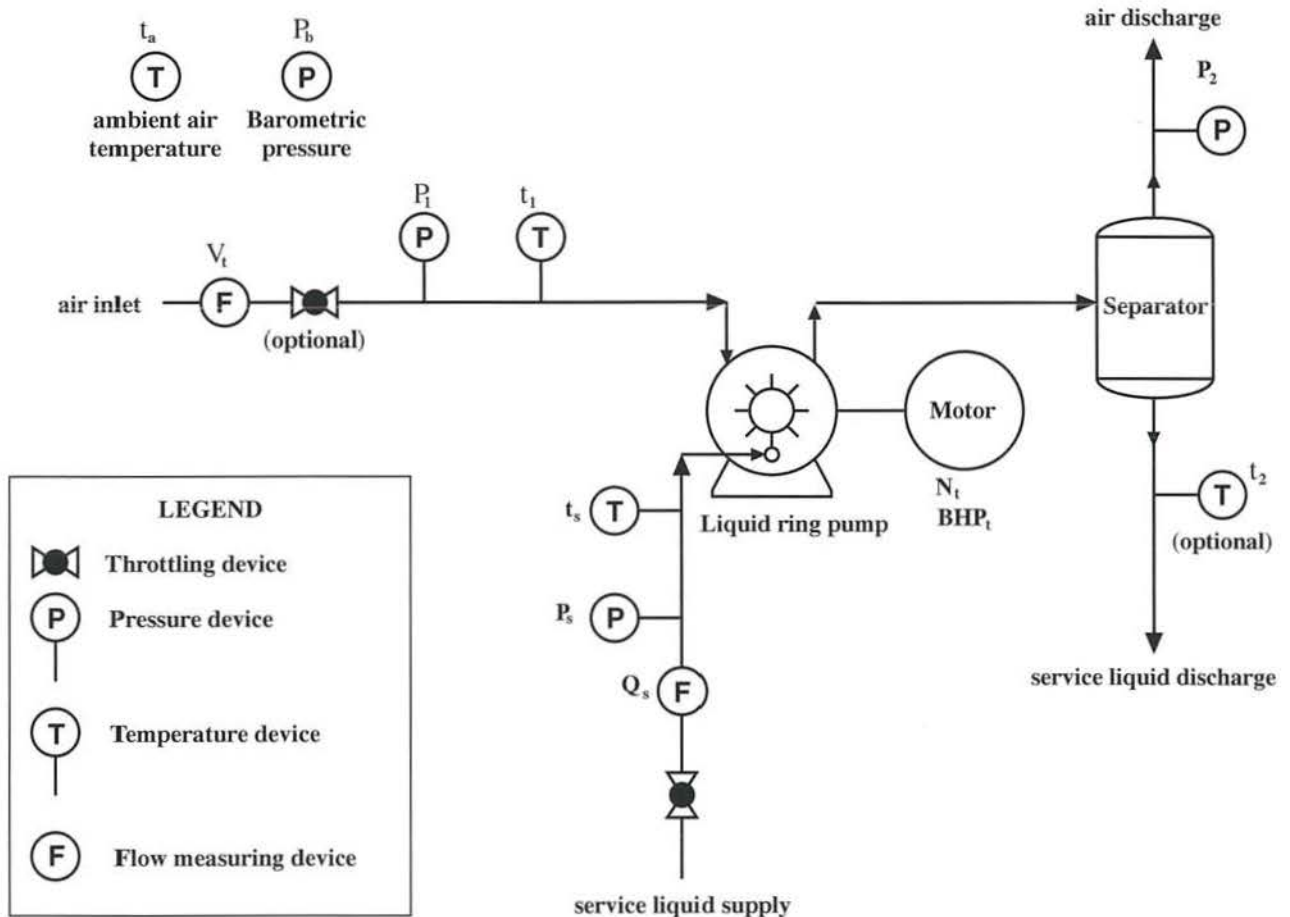


Figure 7
TEST SET-UP

5.4 Test Procedure

5.4.1 General

5.4.1.1 Before performance tests are begun, the vacuum pump shall be examined to ascertain whether it is in suitable condition to conduct a performance test. All external leakage shall be eliminated.

5.4.2 Test Set-Up and Method

5.4.2.1 The vacuum pump to be tested will be set-up with the appropriate pressure and temperature measurement devices as close to the inlet or inlet manifold of the vacuum pump.

5.4.2.2 The instruments used to measure the variables shall be installed and arranged as shown in Section 5.3, Figure 7.

5.4.2.3 A preliminary test shall be run for the purpose of checking instruments. This preliminary test may, by agreement, be considered the acceptance test, provided that all requirements for an acceptance test have been met.

5.4.2.4 Before readings are taken, the vacuum pump shall be run until steady state conditions are reached so that no systemic changes occur in the instrument readings during the test.

5.4.2.5 During the test, all variables listed under Section 5.5 shall be measured and recorded.

5.4.2.6 The measurements shall be carried out by competent persons with measuring equipment according to Section 5.2.

5.4.2.7 The test conditions shall be as close as reasonably possible to the specified conditions, and a minimum of three test points shall be taken during the performance test. These three points must bracket the specified inlet pressure or the points must be as mutually agreed upon between the purchaser and the manufacturer.

5.4.2.8 For each vacuum level, sufficient readings shall be taken to indicate that steady state conditions have been reached.

5.4.2.9 During the test, no adjustments other than those required to maintain the test condition shall be made.

5.4.2.10 After the test, the vacuum pump and the measuring equipment shall be inspected. Should any faults be found that may have affected the test results, then a further test may be run after faults have been corrected.

5.5 Variables To Be Measured During The Test

Variable	Symbol	Unit of Measure
Inlet Pressure	P_1	Inches HgA
Inlet Temperature	t_1	°F
Discharge Pressure	P_2	Inches HgA
Speed	N_1	RPM
Service Water Flow Rate	Q_s	GPM
Service Water Inlet Temperature	t_s	°F
Service Water Discharge Temperature (optional)	t_2	°F
Inlet Volume Flow Rate ¹	V_1	ACFM or SCFM
Absorbed Horsepower	BHP_t	Brake Horsepower
Service Water Pressure	P_s	PSIA
Ambient Temperature	t_a	°F
Barometric Pressure	P_b	Inches HgA

¹This value is obtained by devices listed under paragraph 5.2.1.

5.6 Evaluation of the Measurements

5.6.1 Before the recorded measurements are converted to standard conditions, they are to be checked for conformity to the specified conditions to ensure the measured values do not exceed the limits stated in Section 5.6.2.

5.6.2 Comparison of recorded measurements to specified conditions.

5.6.2.1 The recorded absolute inlet pressure must be equal to or below the specified point.

5.6.2.2 The recorded discharge pressure must be equal to or above the specified value, where feasible. It may not be feasible to regulate the discharge pressure for large pumps, such as those that discharge to a trench during testing. If it is not feasible, the manufacturer must show correction on power and capacity to be expected at the design discharge pressure.

5.6.2.3 The vacuum pump shaft speed must be within $\pm 3\%$ of the agreed upon test speed.

5.6.2.4 The service water flow rate shall be within $\pm 10\%$ of manufacturer's recommended quantity.

5.6.2.5 The service water temperature correction factor (CF_1), shall not exceed a value of 1.2, except where agreed upon by manufacturer and purchaser.

5.7 Conversion of Test Results to Standard Conditions

5.7.1 Measurement of Flow Rate

5.7.1.1 Definition of Standard Conditions

The calibrated values given for air flow are based on standard barometric pressure and on free atmospheric air.

- (a) Standard barometric pressure is based on a mercury column of 29.92" Hg at 32°F which is equivalent to the barometric pressure at sea level under normal conditions.
- (b) Free atmospheric air at the vacuum is defined to be: the flow of free atmospheric air at 60°F, 50% relative humidity, from standard barometric pressure at 29.92" HgA to the vacuum level. The density and specific volume of this air at atmospheric conditions are:

Density = 0.07608 lbs./ft.³

Specific Volume = 13.144 ft.³/lb.

5.7.1.2 Flow Measurement Instrument Correction Factor

The intent of this HEI Standard is not to establish a method of air flow measurement, but rather to establish a uniform vacuum pump performance evaluation. Therefore, variables which affect the performance of the vacuum pump will be covered in detail, and variables which affect flow measurement devices, such as orifices and flow meters, will only be listed as information. The purchaser can request from the manufacturer specific flow measurement device details and correction factors.

Variables which may affect flow measurement devices:

- (1) air temperature
- (2) barometric pressure
- (3) density of the gas

5.7.1.3 Volume Flow Rate Correction

- (a) The corrected air flow as measured by the manufacturer's flow measurement device, and corrected as described in Section 5.7.1.2, must be handled by the vacuum pump; therefore, variables which affect the vacuum pump performance need to be corrected.

Inlet pressure corrected to standard barometric pressure and temperature.

The observed barometer and vacuum column readings must be corrected to 32°F when mercury columns are used. This correction factor CF_4 is plotted and shown in Appendix B.

$$P_{bc} = P_b - CF_4$$

- (b) If the service water supply temperature is other than 60°F, the vacuum pump capacity is affected and, therefore, must be corrected. The actual correction factors used by most liquid ring vacuum pump manufacturers are smaller in value than the result of the following formula. This formula should only be used to verify the manufacturer's service water correction factor.

$$CF_1 = \frac{P_1 - P_{dg}}{P_1 - P_{dt}}$$

P_1 = inlet pressure inches HgA

P_{dg} = partial vapor pressure of service water @ 60°F

P_{dt} = partial vapor pressure of service water at actual temperature (t_s) during the test.

- (c) Vacuum pump speed correction factor must be applied if the actual test speed and agreed upon speed differ. It may be assumed that the vacuum pump efficiency remains unchanged for deviations not exceeding $\pm 3\%$ from the agreed upon test speed.

Speed Correction Factor

$$CF_2 = \frac{N_s}{N_t}$$

Where:

N_s = the speed (RPM) specified in the contract

N_t = the speed (RPM) measured during the test

- (d) Relative humidity of free air has a very small effect on the liquid ring vacuum pump performance and, therefore, can be neglected.
- (e) The corrected inlet volume flow rate is described by the following formula:

$$V_c = CF_1 \times CF_2 \times V_t$$

Where: V_t = the inlet volume flow rate measured during the test and corrected as indicated in Paragraph 5.7.1.2.

The rate of flow (V_c) is the corrected performance in CFM (cubic feet per minute). This flow needs to be compared to the manufacturer's specified performance.

5.7.2 Power Correction Factor

The vacuum pump shaft speed is the only variable being considered as affecting measured brake horsepower during the performance test. Other variables which affect power are not being considered because the test described with this standard has been based on air as the gas being handled and water as the service liquid. Therefore, such variables as viscosity, specific gravity, and density have been eliminated. Further, it should be noted that these tests are conducted without back pressure on the vacuum pump, i.e., discharging to atmosphere.

- (a) Power correction factor due to variation in speed is as follows:

$$CF_3 = \left(\frac{N_s}{N_t} \right)^2$$

Where:

N_s = the specified speed in the contract

N_t = the speed measured during the test

NOTE: The exponent "2" is an approximate value which is used in conjunction with limits set forth in Section 5.6.2.

- (b) The power correction calculation will be performed as follows:

$$BHP_c = CF_3 \times BHP_t$$

Where:

BHP_t = the power requirement measured during the test

5.8 Allowable Tolerance on the Agreed Design Point (Measured values corrected to standard conditions)

The test results of this Performance Standard shall be compared to the agreed upon design point and will be found to be acceptable providing they are within the limits shown in Table 1.

TABLE 1
Tolerance Based On Rotor Diameter

Variable	Symbol	Unit of Measure	19.7 inches Diameter & Below	Above 19.7 inches Diameter
Inlet Volume Flow Rate	V_c	ACFM	-10%	-5%
Absorbed Horsepower	BHP_c	HP	+10%	+5%
Service Water Flow Rate	Q_s	GPM	±10%	±10%

6.0 CONVERSION OF STANDARD TEST PERFORMANCE TO SPECIFIED OPERATING CONDITIONS

Since operating conditions with respect to inlet gases, condensable vapors, service liquid, and other field conditions are often different from those of the Standard Test, a conversion must be carried out. Conversions of this kind shall be based upon the manufacturer's standard method and shall be agreed upon beforehand by the parties involved.

A check list of performance variations, Appendix D, will provide the user with a better understanding of the conversions to be made.

It should be noted that a rigorous mathematical solution or conversion is generally not practical. The equipment selection procedure is usually a reiteration of a series of approximations.

The latter are based upon a combination of user and manufacturer field experience, vendor laboratory tests and similarity.

APPENDIX A**DESIGN SPECIFICATIONS (OPERATING VARIABLES)**

In order to properly design a liquid ring vacuum pump system, the following design requirements and operating parameters must be specified. To simplify the information required, a User Specification Sheet is also included.

CAPACITY

- (a) the absolute pressure to be maintained
- (b) the total weight in pounds per hour of the gas to be handled and/or ACFM of the gas
- (c) the temperature of the gas to be handled
- (d) composition of the gas to be handled. The gas analysis specifying each constituent shall be given in pounds per hour.
- (e) if the gas is other than air or water vapor, its physical and chemical properties shall be fully specified.

SERVICE LIQUID

- a) type of service liquid used is to be fully specified
- b) temperature
- c) pressure, minimum and maximum
- d) if water, source and quantity/quality
- e) if other than water, vapor pressure, specific heat, specific gravity, viscosity, other properties of importance

COOLING WATER FOR HEAT EXCHANGER (RECIRCULATED SERVICE LIQUID SYSTEMS)

- (a) maximum and minimum pressure available to the heat exchanger
- (b) maximum temperature available
- (c) maximum and minimum quantity available
- (d) source and quality of water
- (e) maximum allowable pressure drop
- (f) any limitations on the cooling water for the specified capacity

DISCHARGE PRESSURE

- (a) the pressure against which a pump must discharge shall be specified.
- (b) the normal barometric pressure shall be specified.

TYPE OF DRIVER

- (a) the type of driver available shall be specified-i.e. electric motor, steam turbine, gas engine
- (b) the electrical characteristics of the power supply shall be given, i.e. voltage, phase, cycles

OTHER CONSIDERATIONS

- (a) System Volume to be evacuated, air in leakage, evacuation time, and final pressure
- (b) Unusual operating conditions, cycling, etc.

MATERIALS OF CONSTRUCTION

HEI USER SPECIFICATION SHEET

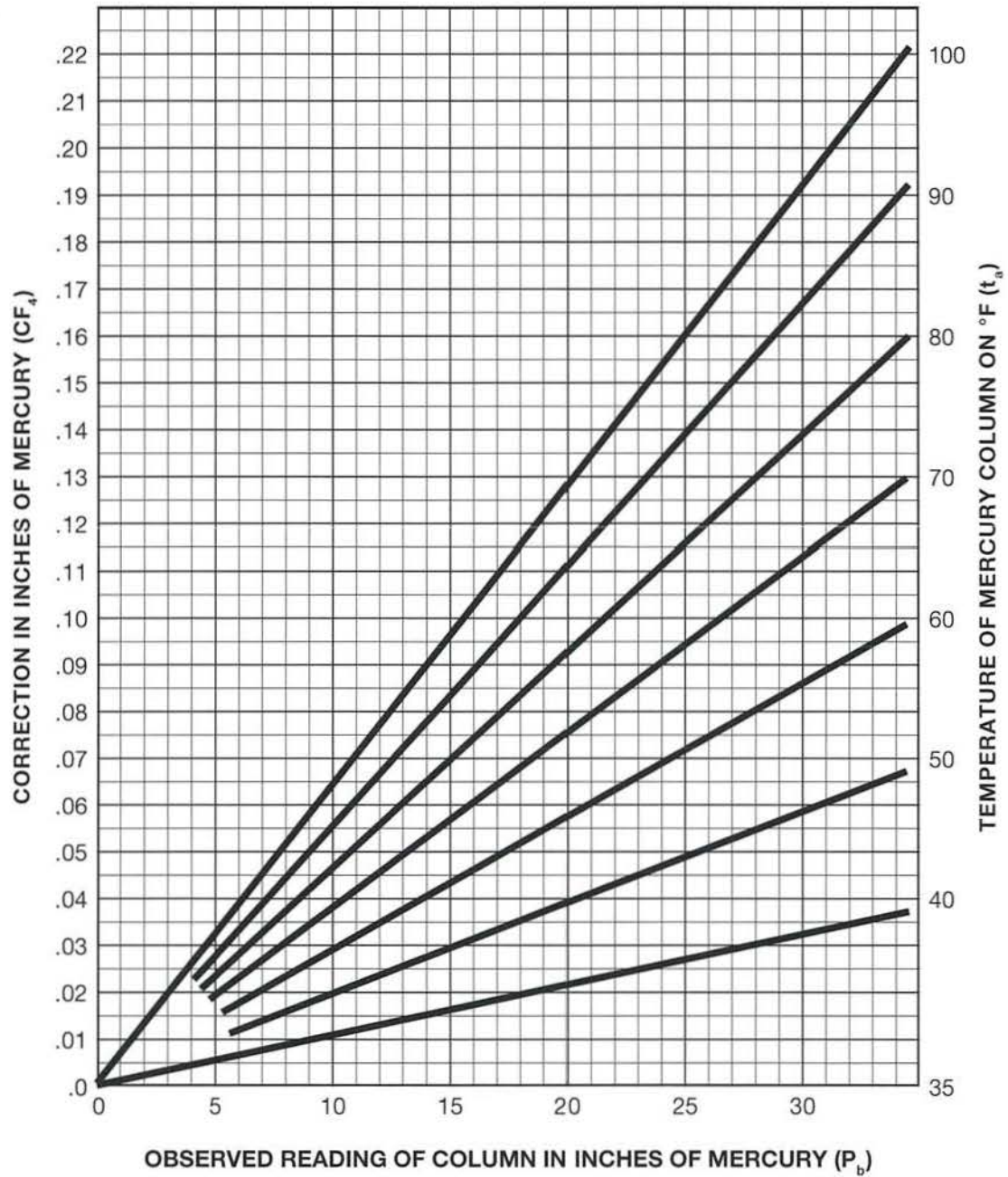
1	INLET GAS LOAD				
2	Pressure	Inches HgA	Temperature	°F	
3	NON CONDENSIBLE GASES				
4	Component	Lb/Hr	MW		
5	G ₁ =				
6	G ₂ =				
7	Etc.				
8	CONDENSIBLE VAPORS				
9	Component	Lb/Hr	MW	*Vapor Pressure (in HgA @ °F)	Latent Heat (BTU/lb)
10	C ₁ =				
11	C ₂ =				
12	Etc.				
13	*Specify minimum 2 points for vapor pressure of each gas				
14	Inlet ACFM				
15	SERVICE LIQUID (S₁, S₂, etc.)				
16	Pressure Available Minimum	psig	Maximum	psig	
17	Temperature	°F	Maximum Allowable Outlet Temperature	°F	
18	S ₁ =	SG ₁ =	SH ₁ =	BTU/lb -°F	VP ₁ = Inches Hg @ °F
19	S ₂ =	SG ₂ =	SH ₂ =	BTU/lb -°F	VP ₂ = Inches Hg @ °F
20	Etc.				
21	Viscosity	Centipoise @	°F and	Centipoise @	°F (2 points)
22	Solubility of Gases in Service Liquid	lb/lb @	°F and	Inches HgA	
23	Miscibility of Vapors in Service Liquid	lb/lb @	°F and	°F (2 points)	
24	COOLING WATER FOR HEAT EXCHANGER (Recirculated Service Liquid Systems)				
25	Pressure Available	Maximum	psig	Minimum	psig
26	Temperature	Maximum	°F	Minimum	°F
27	Quantity Available	Maximum	GPM		
28	Source	Quality			
29	Maximum Allowable Pressure Drop	psi			
30	DISCHARGE CONDITIONS				
31	Discharge Pressure	psia / Inches HgA			
32	Maximum Allowable discharge temperature	°F			
33	DRIVER				
34	Type:	Electric	Steam Turbine	Engine	
35	a)	Voltage			
36	b)	Phase			
37	c)	Cycles			
38	OTHER CONSIDERATIONS				
39	System Volume to be evacuated	ft ³	Air in-leakage	lbs/hr	
40	Evacuation Time	minutes	Final Pressure	Inches HgA	
41	MATERIALS OF CONSTRUCTION				
42	Liquid Ring Pumps – System Components				
43	Casing	Discharge Separator			
44	Impeller	Recirculation Pump			
45	Shaft	Heat Exchanger			
46	Shaft Sleeves	Piping			
47	Port Plates/Cones				
48	Mechanical Seals				
49	Packing Glands				

APPENDIX B

CORRECTION FACTORS

TEMPERATURE CORRECTIONS FOR BAROMETER AND
VACUUM COLUMN READINGS TO STANDARD 32°F BASIS.

Note: – Subtract correction from observed reading.
This corrects for thermal expansion of
mercury and brass scale from 32°F.



*For other scale materials, use appropriate chart.

APPENDIX C

HEI TEST REPORT FOR LIQUID RING VACUUM PUMPS

Customer Name: _____ Manufacturer: _____

Pump Model _____ Test/Serial No. _____

Order No. _____ Test Date _____ By _____

Test Method Square Edged Orifice HEI/ASME Orifice Flow Meter

Motor (V/PH/HZ): _____ / _____ / _____

TEST DATA

Barometer: (P_b) _____ Temp: (t_a) _____

	Test Points						
	1	2	3	4	5	6	7
Inlet Pressure (P_1)	_____	_____	_____	_____	_____	_____	_____
Inlet Temperature (t_1)	_____	_____	_____	_____	_____	_____	_____
Orifice Diameter	_____	_____	_____	_____	_____	_____	_____
Orifice ΔP (if sub critical)	_____	_____	_____	_____	_____	_____	_____
Orifice Quantity	_____	_____	_____	_____	_____	_____	_____
Flow Meter Reading (V_t)	_____	_____	_____	_____	_____	_____	_____
Service Water Temperature in (t_s)	_____	_____	_____	_____	_____	_____	_____
Service Water Temperature Out (t_2)	_____	_____	_____	_____	_____	_____	_____
Service Water Pressure (P_s)	_____	_____	_____	_____	_____	_____	_____
Service Water Flow (Q_s)	_____	_____	_____	_____	_____	_____	_____
Absorbed Horsepower (BHP_t)	_____	_____	_____	_____	_____	_____	_____
Motor Amperes	_____	_____	_____	_____	_____	_____	_____
Volts	_____	_____	_____	_____	_____	_____	_____
Pump Speed (N_t)	_____	_____	_____	_____	_____	_____	_____

CORRECTED DATA:

Barometer: (P_{bc}) _____Capacity-ACFM (V_c) _____Power-HP (BHP_c) _____

Certified By: _____ Title: _____

APPENDIX D**FACTORS AFFECTING VACUUM PUMP PERFORMANCE**

The following is a list of factors that may affect performance of a vacuum pump.

- a) Inlet mixture may be cooled in pump increasing net capacity.
- b) Inlet mixture may or may not be saturated with condensible vapors.
- c) Inlet condensibles may be miscible or immiscible with each other or with service liquid.
- d) Inlet condensibles may be partially condensed in pump increasing net capacity.
- e) Lower service liquid temperature will increase net capacity by lowering the effective vapor pressure of the service liquid and cooling the inlet gas.
- f) Condensing vapors will increase service liquid temperature rise and increase heat load to optional heat exchanger.
- g) Service liquid specific heat lower than water will increase temperature rise.
- h) Service liquid specific gravity lower than water may effect performance.
- i) Service liquid viscosity lower than water may decrease BHP and, in turn, reduce service liquid temperature rise.
- j) Solubility of inlet gas in service liquid may reduce net capacity.
- k) Inlet vapors may condense and contaminate the service liquid modifying its characteristics. Miscible condensibles may accumulate in service liquid and become a dominant factor in determining net effective vapor pressure. Immiscible condensibles with lower specific gravity than service liquid may collect at gas/liquid interface and become dominant factor in determining net effective vapor pressure.
- l) Net performance is generally determined by vapor pressure at effective service liquid temperature. For two stage pumps, the latter is the interstage temperature.
- m) Higher service liquid rate may reduce temperature rise and increase net capacity at rated conditions.
- n) Service liquid type may determine effective service liquid temperature and performance.

Once-thru generally provides lowest service liquid temperature with highest service liquid consumption.

Partial recirculation provides lower service liquid consumption with higher effective service liquid temperature.

Full recirculation permits use of separate coolant medium-generally with higher effective service liquid temperature. A minimal service liquid purge flow may be used to control service liquid characteristics.

- o) Back pressures other than standard will affect performance.

APPENDIX E REFERENCE DATA

METRIC CONVERSION FACTORS
NOMENCLATURE

NAME		SYMBOL	OTHER UNITS
inch/inches		in	
foot/feet		ft	
meter	(SI)	m	
millimeter		mm	
square inch		in ²	
square foot		ft ²	
square meter	(SI)	m ²	
square centimeter		cm ²	
square millimeter		mm ²	
cubic inch		in ³	
cubic foot		ft ³	
gallon (US liquid)		gal	
cubic meter	(SI)	m ³	
liter		L	
pound mass (avoirdupois)		lbm	
kilogram	(SI)	kg	
pound force (avoirdupois)		lbf	
kilogram force		kgf	
newton	(SI)	N	m · kg/s ²
degree Fahrenheit		°F	
kelvin	(SI)	K	
degree Celsius	(SI)	°C	
British thermal unit (International Table)		Btu	
kilocalorie (International Table)		kcal	
joule	(SI)	J	N · m, m ² · kg/s ²
kilojoule		kJ	
second (customary)		sec	
second	(SI)	s	
minute		min	
hour (customary)		hr	
hour (metric)		h	
watt	(SI)	W	J/s, N · m/s, m ² · kg/s ³
pound force/square inch		psi	lbf/in ²
inches of mercury		in Hg	
feet of water		ft H ₂ O	
pascal	(SI)	Pa	N/m ² , kg/(m · s ²)
kilopascal		kPa	
bar		bar	
millimeter of mercury		mmHg	
torr		torr	
centipoise		cp	

Notes:

1. (SI) Denotes an "International System of Units" unit.
2. Pressure should always be designated as gage or absolute.
3. The acceleration of gravity, *g*, is taken as 9.80665 m/s².
4. One gallon (U S liquid) equals 231 in³.

PREFIXES DENOTING DECIMAL MULTIPLES OR SUBMULTIPLES

PREFIX	SYMBOL	MULTIPLICATION FACTOR
micro	μ	$0.000\ 001 = 10^{-6}$
milli	m	$0.001 = 10^{-3}$
centi	c	$0.01 = 10^{-2}$
deci	d	$0.1 = 10^{-1}$
deca	da	$10 = 10^1$
hecto	h	$100 = 10^2$
kilo	k	$1\ 000 = 10^3$
mega	M	$1\ 000\ 000 = 10^6$
giga	G	$1\ 000\ 000\ 000 = 10^9$

CONVERSION FACTORS

LENGTH

MULTIPLY	BY	TO OBTAIN
in	2.540×10^{-2}	m (SI)
in	2.540×10^1	mm
ft	3.048×10^{-1}	m (SI)
ft	2.540×10^2	mm

AREA

MULTIPLY	BY	TO OBTAIN
in ²	6.451600×10^{-4}	m ² (SI)
in ²	6.451600×10^2	mm ²
ft ²	9.290304×10^{-2}	m ² (SI)
ft ²	9.290304×10^4	mm ²

VOLUME

MULTIPLY	BY	TO OBTAIN
in ³	1.638706×10^{-5}	m ³ (SI)
in ³	1.638706×10^{-2}	L
ft ³	2.831685×10^{-2}	m ³ (SI)
ft ³	2.831685×10^1	L
gal	3.785412×10^{-3}	m ³ (SI)
gal	3.785412	L

MASS

MULTIPLY	BY	TO OBTAIN
lbm	4.535924×10^{-1}	kg (SI)

FORCE

MULTIPLY	BY	TO OBTAIN
lbf	4.448222	N (SI)
lbf	4.535924×10^{-1}	kgf
kgf	9.806650	N (SI)

TEMPERATURE

K = (°F + 459.67)/1.8	(SI)
°C = (°F - 32)/1.8	(SI)
°F = 1.8 °C + 32	
°F = 1.8 K - 459.67	

ENERGY, WORK OR QUANTITY OF HEAT

MULTIPLY	BY	TO OBTAIN
Btu	1.055056×10^3	J (SI)
Btu	2.519958×10^{-1}	kcal
ft·lbf	1.355818	J (SI)
ft·lbf	3.238316×10^{-4}	kcal

APPENDIX E – Continued

POWER (ENERGY/TIME)			
MULTIPLY	BY	TO OBTAIN	
Btu/hr	2.930711×10^{-1}	W	(SI)

PRESSURE OR STRESS (FORCE/AREA)			
MULTIPLY	BY	TO OBTAIN	
psi	6.894757×10^3	Pa	(SI)
psi	6.894757	kPa	
psi	6.894757×10^{-2}	bar	
psi	7.030696×10^{-2}	kgf/cm ²	
lbf/ft ²	4.788026×10^1	Pa	(SI)
lbf/ft ²	4.788026×10^{-2}	kPa	
lbf/ft ²	4.882428	kgf/m ²	
inHg (32°F)	3.38638×10^3	Pa	(SI)
inHg (32°F)	3.38638	kPa	
inHg (32°F)	3.38638×10^{-2}	bar	
inHg (32°F)	3.45315×10^{-2}	kgf/cm ²	
inHg (32°F)	2.540×10^1	mmHg	
torr (0°C)	1.33322×10^2	Pa	(SI)
torr (0°C)	1.0	mmHg	
ftH ₂ O (39.2°F)	2.98898×10^3	Pa	(SI)
ftH ₂ O (39.2°F)	2.98898	kPa	
ftH ₂ O (39.2°F)	3.047915×10^2	kgf/m ²	

VELOCITY (LENGTH/TIME)			
MULTIPLY	BY	TO OBTAIN	
ft/sec	3.048000×10^{-1}	m/s	(SI)
ft/min	5.080000×10^{-3}	m/s	(SI)

MASS FLOW RATE (MASS/TIME)			
MULTIPLY	BY	TO OBTAIN	
lbm/hr	1.259979×10^{-4}	kg/s	(SI)
lbm/hr	4.535924×10^{-1}	kg/h	

VOLUME FLOW RATE (VOLUME/TIME)			
MULTIPLY	BY	TO OBTAIN	
ft ³ /min	4.719474×10^{-4}	m ³ /s	(SI)
ft ³ /min	1.699011	m ³ /h	
gal/min	6.309020×10^{-5}	m ³ /s	(SI)
gal/min	2.271247×10^{-1}	m ³ /h	
gal/min	3.785412	L/min	

MASS VELOCITY (MASS/TIME-AREA)			
MULTIPLY	BY	TO OBTAIN	
lbm/(hr · ft ²)	1.35623×10^{-3}	kg/(s · m ²)	(SI)
lbm/(hr · ft ²)	4.882428	kg/(h · m ²)	
lbm/(sec · ft ²)	4.882428	kg/(s · m ²)	(SI)

SPECIFIC VOLUME (VOLUME/MASS)			
MULTIPLY	BY	TO OBTAIN	
ft ³ /lbm	6.242797×10^{-2}	m ³ /kg	(SI)
ft ³ /lbm	6.242797×10^1	L/kg	
gal/lbm	8.345406×10^{-3}	m ³ /kg	(SI)
gal/lbm	8.345406 kg/L	L/kg	

APPENDIX E - Continued

DENSITY (MASS/VOLUME)			
MULTIPLY	BY	TO OBTAIN	
lbm/in ³	2.767990×10^4	kg/m ³	(SI)
lbm/in ³	2.767990×10^1	kg/L	
lbm/ft ³	1.601846×10^1	kg/m ³	(SI)
lbm/ft ³	1.601846×10^{-2}	kg/L	
lbm/gal	1.198264×10^2	kg/m ³	(SI)
lbm/gal	1.198264×10^{-1}	kg/L	

ENTHALPY (ENERGY/MASS)			
MULTIPLY	BY	TO OBTAIN	
Btu/lbm	2.326000×10^3	J/kg	(SI)
Btu/lbm	2.326000	kJ/kg	
Btu/lbm	5.555556×10^{-1}	kcal/kg	

HEAT CAPACITY AND ENTROPY (ENERGY/MASS-TEMPERATURE)			
MULTIPLY	BY	TO OBTAIN	
Btu/(lbm · °F)	4.186800×10^3	J/(kg · K)	(SI)
Btu/(lbm · °F)	4.186800	kJ/(kg · K)	
Btu/(lbm · °F)	1.000000	kcal/(kg · °C)	

THERMAL CONDUCTIVITY (ENERGY-LENGTH/TIME-AREA-TEMPERATURE)			
MULTIPLY	BY	TO OBTAIN	
Btu · in/(hr · ft ² · °F)	1.442279×10^{-1}	W/(m · K)	(SI)
Btu · in/(hr · ft ² · °F)	1.240137×10^{-1}	kcal · m/(h · m ² · K)	
Btu · ft/(hr · ft ² · °F)	1.730735	W/(m · K)	(SI)
Btu · ft/(hr · ft ² · °F)	1.488164	kcal · m/(h · m ² · K)	

DYNAMIC VISCOSITY (MASS/TIME-LENGTH OR FORCE-TIME/AREA)			
MULTIPLY	BY	TO OBTAIN	
cp	1.000000×10^{-3}	Pa · s	(SI)
lbm/(hr · ft)	4.133789×10^{-4}	Pa · s	(SI)
lbm/(hr · ft)	4.133789×10^{-1}	cp	
lbm/(sec · ft)	1.488164	Pa · s	(SI)
lbm/(sec · ft)	1.488164×10^3	cp	
lbf · sec/ft ²	4.788026×10^1	Pa · s	(SI)
lbf · sec/ft ²	4.788026×10^4	cp	

HEAT FLUX DENSITY (ENERGY/TIME-AREA)			
MULTIPLY	BY	TO OBTAIN	
Btu/(hr · °ft ²)	3.154591	W/m ²	(SI)
Btu/(hr · °ft ²)	2.712460	kcal/(h · m ²)	

HEAT TRANSFER COEFFICIENT (ENERGY/TIME-AREA-TEMPERATURE)			
MULTIPLY	BY	TO OBTAIN	
Btu/(hr · ft ² · °F)	5.678263	W/(m ² · K)	(SI)
Btu/(hr · ft ² · °F)	4.882428	kcal/(h · m ² · K)	

FOULING RESISTANCE (TIME-AREA-TEMPERATURE/ENERGY)			
MULTIPLY	BY	TO OBTAIN	
hr · ft ² · °F/Btu	1.761102×10^{-1}	m ² · K/W	(SI)
hr · ft ² · °F/Btu	2.048161×10^{-1}	h · m ² · K/kcal	

APPENDIX F

TROUBLESHOOTING GUIDE

This troubleshooting guide has been prepared to assist operators of liquid ring vacuum pumps. The guide provides general guidance, and operators are advised to consult with the manufacturer when necessary for specific instructions regarding their equipment. Many of the items listed below are not in the scope of the liquid ring vacuum pump manufacturer; however, these items do affect operation and must be considered by operators.

Please submit all questions and inquiries to the HEI at hei@heatexchange.org, or visit the HEI website at www.heatexchange.org.

Symptoms	Possible Causes	Possible Solutions
Poor Vacuum	Excessive air leakage	If leakage is high, all piping connections and valve packing under vacuum must be checked.
	Operating temperature too hot	Confirm that the seal water flow and temperature are at rated values. If gas flow includes steam or other condensable gas, check inlet temperature and seal liquid in and out temperatures and confirm they do not exceed rated values.
	Incorrect Rotation	Confirm pump is rotating in direction noted on casing.
	Incorrect Speed	Confirm pump is operating at rated speed.
	Restrictions Upstream of Vacuum Pump	Confirm that there are no restrictions in piping and valves upstream of the vacuum pump. Liquids can collect in low areas of piping and create restrictions.
	Excessive Discharge Pressure	Decrease discharge pressure.
Excessive Pump Noise	Cavitation (insufficient air flow to pump inlet)	Lower service liquid temperature and/or bleed in air (if permissible to process). This may increase suction pressure (decrease vacuum).
	Foreign objects	Shut down pump immediately and remove debris.
Excessive Horse Power	Service liquid flow rate too high	Adjust service liquid flow accordingly.
	Excessive discharge pressure	Decrease discharge pressure and contact manufacturer for additional information.
	Overtight packing	Loosen packing gland so packing is not holding shaft as tightly.

APPENDIX F - Continued
TROUBLESHOOTING GUIDE

Symptoms	Possible Causes	Possible Solutions
Excessive Vibration	Improper pump installation	Check manual and contact the manufacturer.
	Improper shaft alignment	Align shafts as directed by vacuum pump manufacturer.
	Worn bearing	Inspect and lubricate bearing if necessary, replace if needed.
	Excessive pressure differential	Reduce pressure differential across the pump.
	Pump is full of liquid	Drain pump. Prime to proper level.
Pump will not run or is locked up	Rust build up between moving parts	Refer to instruction manual and/or contact manufacturer.
Excessive pump leakage around shaft	Faulty mechanical seal	Repair or replace mechanical seal according to manufacturer's recommendations.
	Packing is worn	Replace packing and/or lantern gland.
	Packing gland is too loose	Tighten gland.
	Too much pressure to gland flush	Reduce flow/pressure of flush to packing.

NOTES

NOTES

NOTES

Heat Exchange Institute, Inc.

PUBLICATION LIST

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