



PERFORMANCE STANDARD
for
LIQUID RING VACUUM PUMPS

THIRD EDITION



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HEAT EXCHANGE INSTITUTE, INC.

PERFORMANCE STANDARD for **LIQUID RING VACUUM PUMPS**

THIRD EDITION

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FOREWORD

The third 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.



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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.

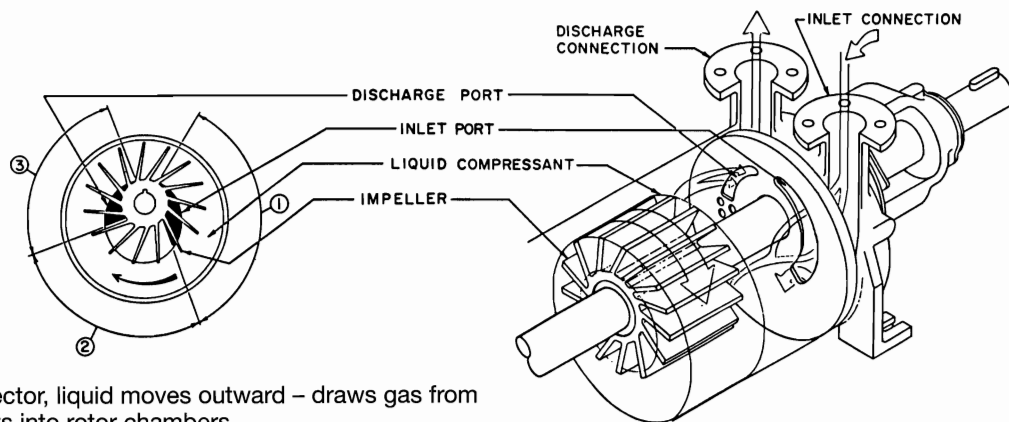
The compression is performed by the liquid ring as a result of the relative eccentricity between the casing and a rotating multi-bladed impeller.

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 manner

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.



1. In this sector, liquid moves outward – draws gas from inlet ports into rotor chambers.
2. In this sector, liquid moves inward-compresses gas in rotor chambers.
3. In this sector, compressed gas escapes at discharge ports.

Figure 1
FLAT PORT PLATE

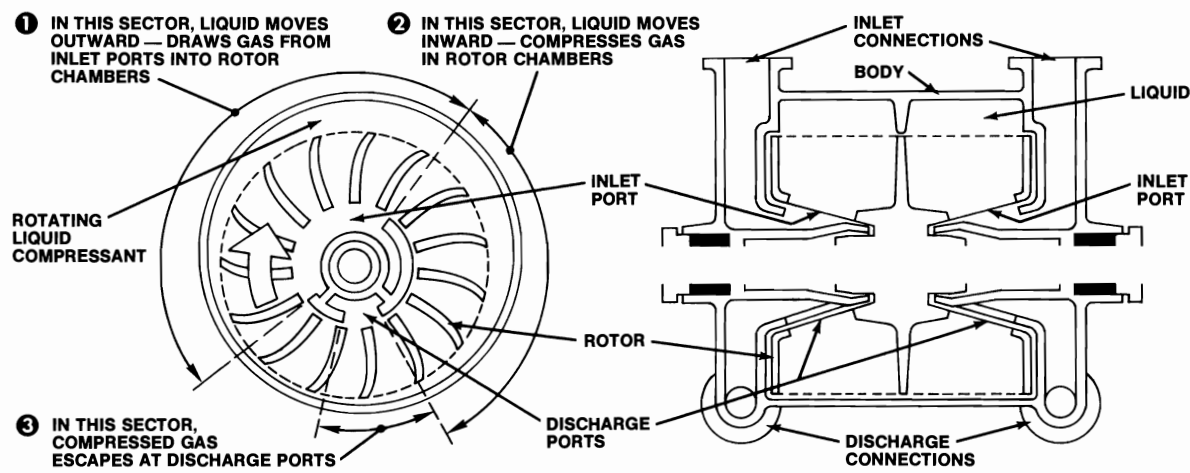


Figure 2
CONICAL PORT

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

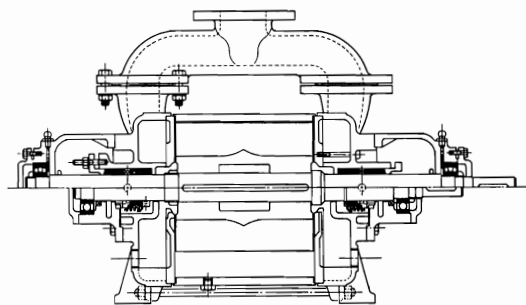


Figure 3
SINGLE STAGE, FLAT PORT PLATES

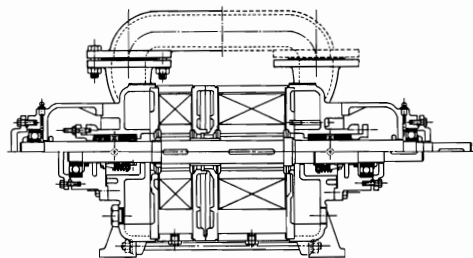


Figure 5
TWO STAGE, FLAT PORT PLATES

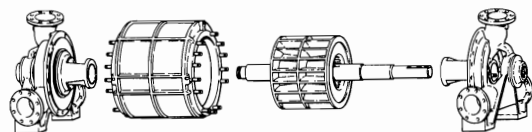


Figure 4
SINGLE STAGE, CONICAL PORTS

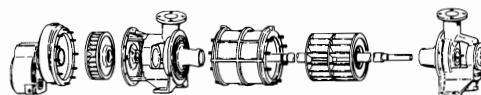


Figure 6
TWO STAGE, CONICAL PORTS