BSR/ASHRAE Standard 158.1-2012R

Public Review Draft

Methods of Testing Capacity of Refrigerant Solenoid Valves

First Public Review (November 2018)
(Complete Draft for Full Review)

This draft has been recommended for public review by the responsible project committee. To submit a comment on this proposed standard, go to the ASHRAE website at www.ashrae.org/standards-research--technology/public-review-drafts and access the online comment database. The draft is subject to modification until it is approved for publication by the Board of Directors and ANSI. Until this time, the current edition of the standard (as modified by any published addenda on the ASHRAE website) remains in effect. The current edition of any standard may be purchased from the ASHRAE Online Store at www.ashrae.org/bookstore or by calling 404-636-8400 or 1-800-727-4723 (for orders in the U.S. or Canada).

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(This foreword is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

FOREWORD

This standard was written at the request of the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) to provide a standard method of test for the capacity of refrigerant solenoid valves. The intent is to provide a standard that meets American National Standards Institute (ANSI) requirements. ANSI/AHRI Standard 760 (I-P), Performance Rating of Solenoid Valves for Use With Volatile Refrigerants,[1] *and ANSI/AHRI Standard 761 (SI)* Performance Rating of Solenoid Valves for Use With Volatile Refrigerants,[8] *require this standard be used as a method of test for capacity. It is further anticipated that AHRI will continue to maintain Standard 760/761 as it relates to standard methods of rating refrigerant service solenoid valves. AHRI Standard 760/761 may also include information concerning other solenoid valve performance characteristics.*

The basis for the method of testing and the calculation of capacity for flow through solenoid valves is a research project (PRF 5233) performed at Ray W. Herrick Laboratories, Purdue University, West Lafayette, Indiana, and sponsored by AHRI. This research followed a study performed at Herrick Laboratories, under AHRI auspices, by R.T. McKenzie, J.B. Chaddock, and W.E. Fontaine between September 1963 and September 1966.

This standard provides a means of accurately measuring the refrigerant mass flow capacity of solenoid valves. The flow capacity may be expressed in terms of refrigerating effect with various refrigerants by performing simple thermodynamic computations. Examples of the computations necessary to express valve capacity in kW (tons) or other appropriate units are included in Informative Annex B of this standard for the user's convenience.

ANSI/ASHRAE Standard 15, Safety Standard for Refrigeration Systems,[2] *and ANSI/ASHRAE Standard 34,* Designation and Safety Classification of Refrigerants,[3] *list the various refrigerants to which this standard is applicable.*

1. PURPOSE

This standard prescribes a method of testing the capacity of refrigerant solenoid valves for use in refrigerating systems.

2. SCOPE

2.1 This standard is applicable to refrigerant solenoid valves in the following circumstances:

- as defined in Section 3, Definitions;
- for either liquid or vapor refrigerant applications; and

- to be used with refrigerants deemed available and suitable according to ANSI/ASHRAE Standard 15, *Safety Standard for Refrigeration Systems*,[2] and ANSI/ ASHRAE Standard 34, *Designation and Safety Classification of Refrigerants*.[3]

2.2 This standard specifies procedures, apparatus, and instrumentation that will produce accurate capacity data.

2.3 This standard does not do the following:

- specify rating conditions or electrical or mechanical design requirements (rating conditions may be found in ANSI/AHRI Standard 760, *Performance Rating of Solenoid Valves for Use with Volatile Refrigerants*[1] for IP units or ANSI/AHRI Standard 761, *Performance Rating of Solenoid Valves for Use with Volatile Refrigerants*[8] for SI units);
- make recommendations for safety; or
- specify tests for production, specification compliance, or field testing of solenoid valves.

3. DEFINITIONS

capacity: the mass flow rate of a selected refrigerant that will pass through the valve under test at specified conditions.

certified standard instrument: an instrument that is calibrated by the manufacturer or other reliable agency and is certified traceable to the National Institute for Standards and Technology (NIST).

direct-operated solenoid valve: a valve in which the solenoid functions to directly open and close the main valve port, which is the only flow path in the valve.

equilibrium temperature (maximum attained temperature): temperature in the solenoid coil that is reached when the resistance bridge meter reading ceases to rise.

flowmeter: a device for determining the mass flow rate through the valve under test.

pilot-operated solenoid valve: a valve in which the solenoid functions to directly open and close a relatively small (pilot) flow port. Flow through the pilot port parallels the flow path of the main port. Starting or stopping flow through the pilot port creates a pressure imbalance on the main valve member, thereby causing the main valve port to be opened or closed.

refrigerant solenoid valve: a two-way (i.e., one inlet and one outlet), two-position (i.e., open or closed) valve that is actuated by a solenoid and is suitable for use with any of the refrigerant fluids designated in Section 2.1(c). It may be pilot or direct operated.

"shall," "should," "recommended," *and* ***"it is recommended"*** shall be interpreted as follows:

> ***shall*** and ***shall not*** are used to indicate that a provision is mandatory if compliance with the standard is claimed.

should, recommended, *and* ***it is recommended*** are used to indicate provisions that are not mandatory but that are desirable as good practice.

4. INSTRUMENTATION

4.1 General. Instruments shall have the accuracies listed in this standard and shall be certified standard instruments.

4.2 Temperature-Measuring Instruments

4.2.1 Temperature shall be measured with any device meeting the requirements of ANSI/ASHRAE Standard 41.1, *Standard Method of Temperature Measurement.*[4]

4.2.2 The accuracy of temperature-measuring instruments shall be within ±0.28°C (0.5°F).

4.3 Pressure-Measuring Instruments

4.3.1 Pressure shall be measured with any device meeting the requirements of ANSI/ASHRAE Standard 41.3, *Standard Method for Pressure Measurement.*[5]

4.3.2 The accuracy of pressure-measuring instruments shall be within ±1.0% of the pressure reading.

4.4 Fluid Flow-Measuring Instruments[6]

4.4.1 The accuracy of flow-measuring instruments shall be within ±2.0% of the indicated value.

4.4.2 In no case shall the smallest scale division of the measuring instrument exceed 2 1/2 times the specified accuracy.

4.5 Electrical Measuring Instruments

4.5.1 The accuracy of voltage measuring instruments shall be within ±0.5% of the indicated value.

4.5.2 The accuracy of resistance measuring instruments shall be within ±1.0% of the indicated value.

4.5.3 The accuracy of current measuring instruments shall be within ±1.0% of the indicated value.

4.5.4 In no case shall the smallest scale division of the measuring instrument exceed 2.0 times the specified accuracy.

4.6 Electric Power Source

4.6.1 An electric current source of adequate capacity shall be made available with a stabilized voltage which can be adjusted, using any necessary electrical apparatus, to provide the following:

a. The rated solenoid valve coil voltage.

b. Eighty-five percent (85%) of the rated valve coil voltage.

4.6.1.1 The regulation and ripple of the supplied voltage for direct current solenoids shall be ±1.0%.

4.6.1.2 The alternating current supply shall be a pure sine wave form voltage with total harmonic distortion of 5% maximum.

5. GENERAL PIPING SPECIFICATIONS

5.1 Main Size. The pipe or tubing used for the inlet and outlet connecting mains to the solenoid valve being tested shall be the size and type accommodated by the solenoid valve body connections. The main shall be free from scale, rust, and other obstructions that may cause excessive turbulence.

5.2 Main Length. The inlet and outlet mains connected to the solenoid valve being tested shall be straight for a minimum of 14 internal diameters from the face of the solenoid valve inlet and outlet connections.

5.3 Pressure-Tap Holes. Pressure-tap holes must be located at the appropriate points on the circumference of the main with respect to the adjacent surroundings. With horizontal mains, pressure-tap hole position depends largely on the fluid flowing. With liquids, the pressure-tap holes shall be level with or below the centerline of the main. Pressure-tap holes should not be positioned on the bottom of the main due to possible blockage of the hole by foreign matter. The inner surfaces of the main adjoining holes shall be free of imperfections, such as rivet heads, jogs, and other sources of eddies, to ensure parallel flow. All pressure-tap holes should be located at the same elevation and on the same side of the main. The internal diameter shall be straight and of uniform size for not less than two diameters from the main internal surface. The inner rim of the hole shall be flush with the inner surface of the main and be free of any burrs, excessive chamfers, and jagged edges.

5.3.1 Pressure-tap hole diameters shall be approximately 10% of the main internal diameter with the following exceptions:

a. Mains with an internal diameter of 12 mm (15/32 in.) or less shall have a pressure-tap hole diameter of 0.8 mm (1/32 in.).
b. Mains with internal diameters of 50 mm (2.0 in.) or greater shall have a pressure-tap hole diameter of 5.0 mm (3/16 in.).

5.3.2 Upstream Location. The upstream pressure-tap hole shall be located in the main, two internal main diameters upstream from the face of the inlet connection of the solenoid valve being tested.

5.3.3 Downstream Location. The downstream pressure-tap hole shall be located in the main, ten internal main diameters downstream from the face of the outlet connection of the solenoid valve under test.

5.4 Fluid Temperature Measurement Locations. Measurement of the temperature of the fluid entering the solenoid valve shall be made at a point located not more than 12 internal main diameters upstream from the face of the inlet connection of the solenoid valve under test. If an intrusive temperature-measuring device is used, care should be taken to avoid disturbing flow patterns at the pressure-tap holes.

6. LIQUID FLOW CAPACITY TEST

6.1 Apparatus

6.1.1 The valve shall be tested in a water flow system, as shown in Figure 1, with instrumentation in accordance with Section 4 and piping in accordance with Section 5.

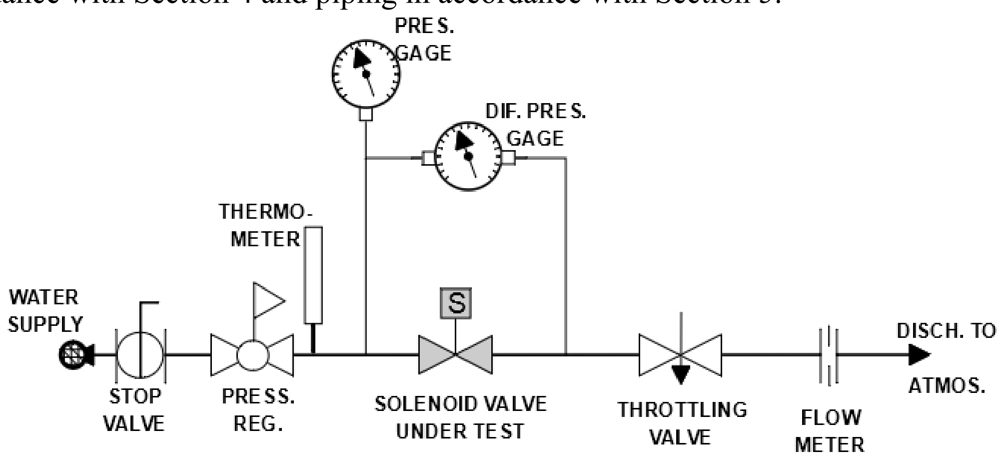

Figure 1 Water flow test system schematic.

6.2 Test Conditions

6.2.1 Compute the $\rho\Delta P$ at the end use rated or specified conditions. Flow through the valve under test shall be measured at the following conditions.

- Water and ambient temperatures suitable for the valve under test.
- Adequate inlet pressure to provide the range of pressure drops at which flow measurements will be made and to ensure that "flashing" (water vapor formation) will not occur within the test system.
- Flow measurements shall be made at five distinct conditions evenly dispersed over the selected range of $\rho\Delta P$ interest. Each condition is defined as density times pressure drop.

6.2.2 A total of nine flow measurements shall be made at preselected conditions in either of two ways:

- five measurements at sequentially increasing $\rho\Delta P$s followed by four measurements at sequentially decreasing $\rho\Delta P$s or
- five measurements at sequentially decreasing $\rho\Delta P$s followed by four measurements at sequentially increasing $\rho\Delta P$s.

At least one data point shall be below and one shall be above the end use specified conditions.

6.3 Data to be Reported

6.3.1 The date and observer.

6.3.2 Descriptive information concerning the valve under test, including all of the following that apply: manufacturer's name and address, model, type, serial number, size, connection type, and connection size.

6.3.3 Water flow test data at each test point, including inlet pressure, inlet temperature, pressure drop across the valve under test, mass flow rate through the valve under test, and pertinent remarks.

Note: An example of a suitable data sheet is shown in Figure A-1 in Informative Annex A.

6.3.4 A graph of $(\rho\Delta P)^{1/2}$ versus mass flow rate (*m.*) on a linear scale.

Note: An example of the required graph is shown in Figure A-2 in Informative Annex A.

6.4 Test Procedure

6.4.1 Install the valve to be tested in the test system and energize (or de-energize) the solenoid so that the valve to be tested is in the open position (or ready to open when flow commences). Position the manual operating device (if one is an integral part of the valve under test) to the position at which the test is to be conducted. Close the test-system throttling valve and pressurize the entire test system to the highest pressure expected during testing. Check for pressure tightness.

6.4.2 Open the test-system throttling valve to start water flow through the valve under test and adjust system pressures to the first preselected test condition. Observe and record the measured values as required in Section 6.3.

6.4.3 Sequentially adjust the system pressures to each of the eight additional preselected conditions and record the required data at each test point.

6.5 Flow Capacity Calculations

6.5.1 Calculate the value of $(\rho\Delta P)^{1/2}$ using the pressures, temperatures, and properties of water for each test point, where ρ is the density of water entering the valve under test and ΔP is the pressure drop across the valve under test.

Note: The density of liquid water at various temperatures may be found in *ASHRAE Handbook—Fundamentals*[6] in the chapter entitled "Thermophysical Properties of Refrigerants."

6.5.2 Using the calculated values from Section 6.5.1 and the water flow test data, plot on a linear scale the corresponding values of $(\rho\Delta P)^{1/2}$ on the abscissa versus the measured water mass flow rate (*m.*) on the ordinate for each of the nine test points. Using the least-squares method, fit the best straight line through the plotted points and the origin.

Note: See Figure A-2 in Informative Annex A for an example.

6.6 Determine the Refrigerant Liquid Mass Flow Capacity of the Valve under Test

The mass flow rate of any Newtonian liquid through the valve under test may be predicted, within the range of $\rho\Delta P$s tested with water, by using the following procedure.

6.6.1 Using the liquid refrigerant properties at the point where refrigerant mass flow capacity is desired, compute the value of $(\rho\Delta P)^{1/2}$, where ρ is the density of liquid refrigerant entering the valve under test.

Note: The density of some liquid refrigerants at various temperatures may be found in *ASHRAE Handbook— Fundamentals*[6] in the chapter entitled "Thermophysical Properties of Refrigerants." More extensive properties are available in the NIST Standard Reference Database 23, entitled *NIST Thermodynamic and Transport Properties of Refrigerants and Refrigerant Mixtures—REFPROP9*.[7]

6.6.2 The refrigerant liquid mass flow capacity of the valve tested may be obtained directly from the graph created in Section 6.5.2, $(\rho\Delta P)^{1/2}$ versus , by finding the value of $(\rho\Delta P)^{1/2}$ on the abscissa, projecting vertically to the point of intersection with the curve, and then projecting horizontally to obtain the refrigerant mass flow capacity on the ordinate.

7. VAPOR FLOW CAPACITY TEST

7.1 Apparatus

7.1.1 The valve shall be tested in an airflow system, as shown in Figure 2, with instrumentation in accordance with Section 4 and piping in accordance with Section 5.

7.2 Test Conditions

7.2.1 Flow through the valve under test shall be measured at the following conditions:
- Using working fluid and ambient temperatures suitable for the valve under test.
- Vapor shall be sufficiently dry such that condensation does not occur during testing.
- At adequate inlet pressure to provide the range of pressure drops at which flow measurements will be made.

- At nine distinct pressure drops (ΔPs) evenly dispersed over the selected range of pressure drops of interest. (Pressure drops of interest will provide results that will allow calculations per Section 7.5.5 without extrapolation beyond the measured data.)
- At four pressure drops (ΔPs) with $\Delta P / P_1 < 0.1$ and at five ΔPs with $0.1 \le \Delta P / P_1 \le 0.47$, where ΔP is the pressure drop across the valve under test and P_1 is the absolute inlet pressure to the valve under test.

Note: Table A-1 in Informative Annex A shows an example of acceptable test conditions.

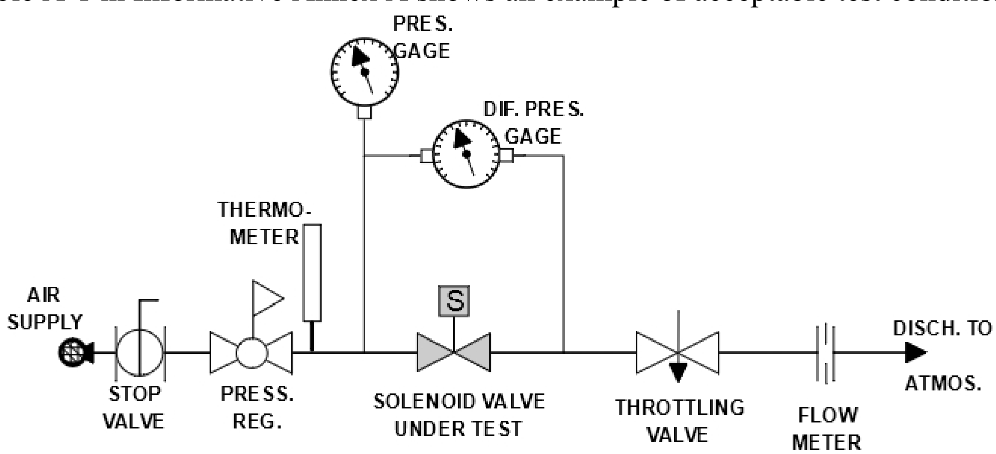

Figure 2 Airflow test system schematic.

7.2.2 A total of seventeen flow measurements shall be made at preselected conditions in either of two ways:

- nine measurements at sequentially increasing ΔPs followed by eight measurements at sequentially decreasing ΔPs or
- nine measurements at sequentially decreasing ΔPs followed by eight measurements at sequentially increasing ΔPs.

7.3 Data to be Reported

7.3.1 The date and observer.

7.3.2 Descriptive information concerning the valve under test, including all of the following that apply: manufacturer's name and address, model, type, serial number, size, connection type, and connection size.

7.3.3 Airflow test data at each test point, including inlet pressure, inlet temperature, pressure drop across the valve under test, mass flow rate through the valve under test, and pertinent remarks.

Note: An example of a suitable data sheet is shown in Figure A-3 in Informative Annex A.

7.3.4 A graph of $(\rho \Delta P)^{1/2}$ versus on a linear scale, as directed in Section 7.5.1.

7.3.5 A graph of A_R versus c on a linear scale, as directed in Section 7.5.4.

Note: Examples of the required graphs are shown in Figures A-2 and A-4 in Informative Annex A.

7.4 Test Procedure

7.4.1 Install the valve to be tested in the test system and energize (or de-energize) the solenoid so that the valve to be tested is in the open position (or ready to open when flow commences). Position the manual operating device (if one is an integral part of the valve under test) to the position at which the test is to be conducted. Close the test-system throttling valve and pressurize the entire test system to the highest pressure expected during testing. Check for pressure tightness.

7.4.2 Open the test-system throttling valve to start airflow through the valve under test and adjust system pressures to the first preselected test condition. Observe and record the measured values, as required in Section 7.3.

7.4.3 Sequentially adjust the system pressures to each of the sixteen additional preselected conditions and record the required data at each test point.

7.5 Flow Capacity Calculations

7.5.1 Calculate the value of $(\rho \Delta P)^{1/2}$ for each test point, where ρ is the density of air entering the valve under test and ΔP is the pressure drop across the valve under test.

7.5.2 Using the calculated values from Section 7.5.1 and the air test data, plot on a linear scale the corresponding values of $(\rho \Delta P)^{1/2}$ on the abscissa versus the measured air mass flow rate, $\dot{m}$, on the ordinate for each test point for which $\Delta P/P_1 \leq 0.1$. For the best results, combine the non-compressible air test data, for which $\Delta P/P_1 \leq 0.1$, and the water test data, Section 6.5.3, on the same plot. Using the least-squares method, fit the best straight line through the plotted points.

Note: See Figure A-2 in Informative Annex A for an example.

7.5.3 Using the airflow test data, the results of Section 7.5.1, and Equation 7-1, calculate the value of c for each test point for which $0.1 \leq \Delta P/P_1 \leq 0.47$.

$c = \dot{m}/(\rho \Delta P)^{1/2}$ (7-1)
where
c = compressible flow coefficient for valve under test
$\dot{m}$= measured mass flow rate

7.5.4 Using the airflow test data and Equation 7-2, calculate the value of A_R for each test point that $0.1 \leq \Delta P/P_1 \leq 0.47$.
$A_R = \Delta P/P_1 k$ (7-2)

where
A_R = acoustic ratio
k = specific heat ratio of fluid flowing (1.4 for air)

7.5.5 Using the calculated values from Sections 7.5.3 and 7.5.4, plot on linear coordinates A_R values on the abscissa versus corresponding c values on the ordinate for each test point for which $0.1 \leq \Delta P/P_1 \leq 0.47$. Fit the best straight line through the plotted points using the least-squares method. Do not extrapolate beyond the measured data.

Note: See Figure A-4 in Informative Annex A for an example.

7.6 Determine the Refrigerant Vapor Mass Flow Capacity of the Valve under Test

The mass flow rate of any gaseous Newtonian fluid through the valve under test may be predicted, within the range of ΔPs and acoustic ratios tested with air, by using the following procedure.

7.6.1 Using the refrigerant properties, pressures, and temperatures for which the predicted flow capacity is desired, compute the values of the following three parameters:

$(\rho\Delta P)^{1/2}$

$\Delta P/P1$

A_R

Note: The density and specific heat ratio of some refrigerant vapors at various saturation temperatures may be found in *ASHRAE Handbook—Fundamentals*[6] in the chapter entitled "Thermophysical Properties of Refrigerants." More extensive properties are available in the NIST Standard Reference Database 23, entitled *NIST Thermodynamic and Transport Properties of Refrigerants and Refrigerant Mixtures— REFPROP9*.[7]

7.6.2 For values of $\Delta P/P1 \leq 0.1$, the mass flow may be obtained directly from the graph of Section 7.5.2, $(\rho\Delta P)^{1/2}$ versus, by finding the new value of $(\rho\Delta P)^{1/2}$ on the abscissa, projecting vertically to the point of intersection with the curve, and then projecting horizontally to obtain the refrigerant mass flow rate ($m.$) on the ordinate.

7.6.3 For values of $0.1 \leq \Delta P/P1 \leq 0.47$, the refrigerant mass flow rate is predicted by Equation 7-3. The value of c for the new condition and/or fluid is obtained from the graph created in Section 7.5.4 (a linear plot of A_R versus c) by finding the new value for A_R on the abscissa, projecting vertically to the point of intersection with the curve, and then projecting horizontally to obtain the corresponding value for c.

$$\dot{m}_R = c(\rho\Delta P)^{½} \quad (7\text{-}3)$$

8. MAXIMUM OPERATING PRESSURE DIFFERENTIAL (MOPD) TEST

8.1 Apparatus

8.1.1 The valve shall be tested in a system as shown in Figure 3 with instrumentation in accordance with Section 4 and piping in accordance with Section 5.

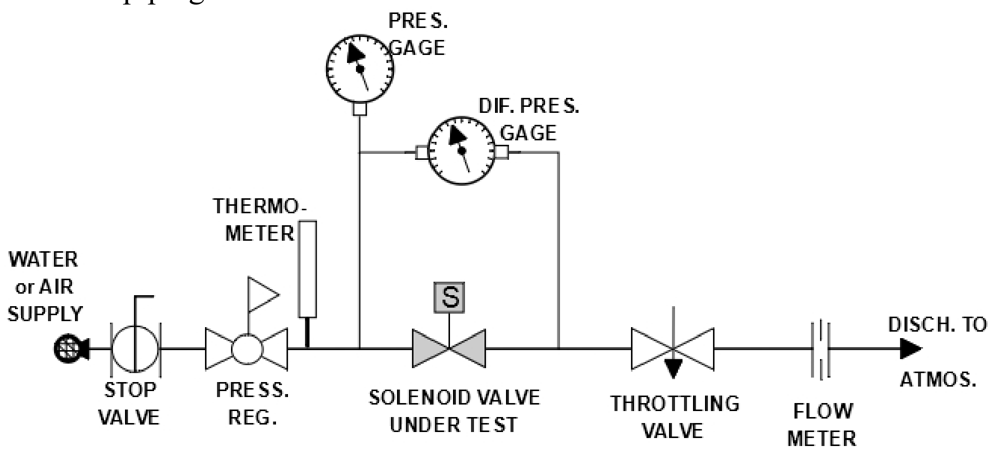

Figure 3 MOPD test system schematic.

8.1.2 Alternating Current. Connect the input side of an adjustable autotransformer to a stabilized alternating current source having the correct voltage, frequency, and adequate capacity. Connect the output side of the autotransformer to the solenoid valve coil with a voltmeter across the coil leads. By adjusting the autotransformer, the voltage applied to the solenoid valve coil can be changed to satisfy the specified conditions and test procedure. A resistance bridge meter is used to measure the DC resistance of the solenoid valve coil (Figure 4).

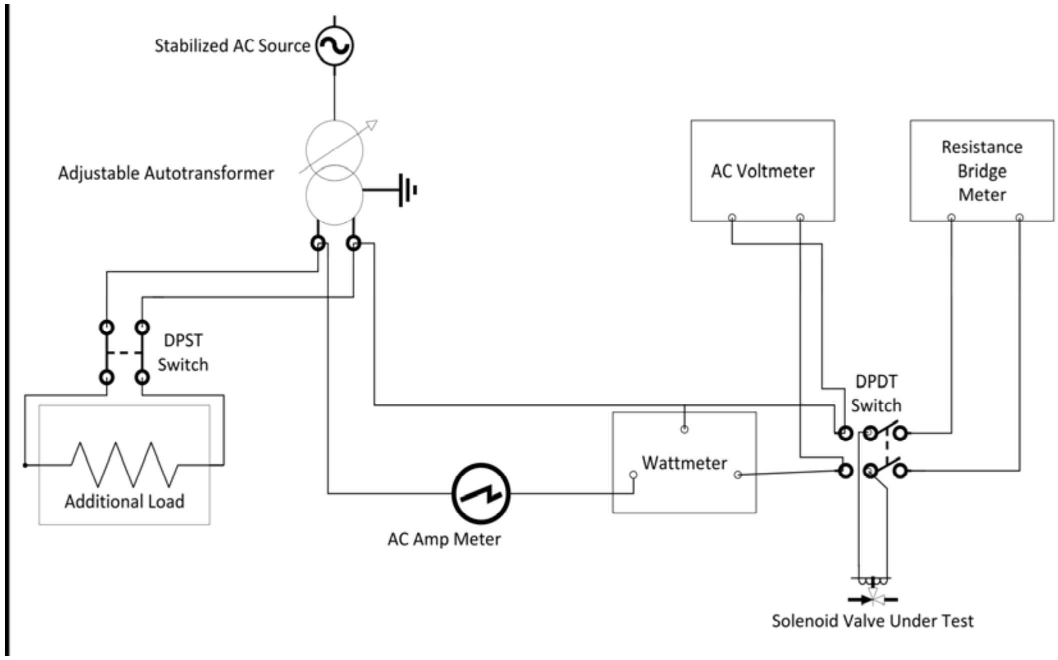

Figure 4: Typical electrical test apparatus for an alternating current solenoid valve

8.1.3 Direct Current. Connect the input side of an adjustable autotransformer to a stabilized alternating current source having the correct voltage, frequency, and adequate capacity. Connect the output side of the autotransformer to the input side of a rectifier. Connect the output side of the rectifier to the solenoid valve coil with the voltmeter across the coil leads and an ammeter in series with the coil. By adjusting the autotransformer which controls the input alternating current voltage to the rectifier, the output direct current voltage or current of the rectifier applied to the solenoid valve coil, can be changed to satisfy the specified conditions and test procedure. The resistance bridge meter is used to measure the DC resistance of the solenoid valve coil (Figure 5).

The combination of the autotransformer and the rectifier used for a source of direct current in Figure 5 can be replaced by one of the following:

a. A direct current generator having adequate capacity, a regulated voltage output, and a means of adjustment to provide the specified test voltage requirements.

b. One or more batteries of adequate capacity wired together in series and/or parallel, having one of the supply terminals connected between cells, when necessary, to provide the specified test voltage requirements.

An adjustable resistor placed in one of the lines, to which the valve under test is connected, will permit making small adjustments in the voltage to meet the specified test voltage requirements.

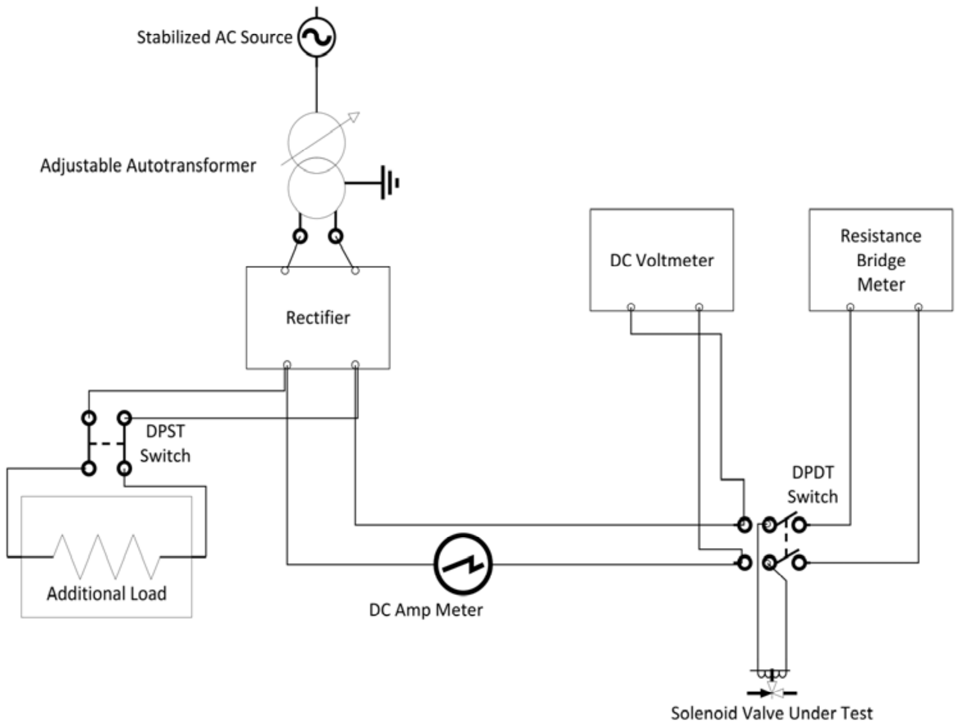

Figure 5: Typical electrical test apparatus for a direct current solenoid valve.

8.2 Test Conditions

8.2.1 MOPD of the valve shall be measured using a working fluid and ambient temperature(s) suitable for the valve under test.

8.3 Data to be Reported

8.3.1 The date and observer.

8.3.2 Descriptive information concerning the valve under test, including all of the following that apply: manufacturer's name and address, model, type, serial number, size, connection type, connection size, and electrical characteristics.

8.3.3 Test fluid, ambient temperature, inlet pressure, inlet temperature, pressure drop across the valve under test, electrical characteristics, MOPD, and pertinent remarks.

Note: An example of a suitable data sheet is shown in Figure A-1 in Informative Annex A.

8.4 Test Procedure

8.4.1 Install the valve to be tested in the test system and energize the solenoid using the rated voltage until the equilibrium temperature is reached. Do not apply pressure to the valve at this time.

8.4.2 Close the valve to be tested and apply pressure to the inlet by opening the stop valve. Testing shall start with an inlet pressure less than the anticipated MOPD.

8.4.3 Apply 85% (±0.25%) of the rated coil voltage to the solenoid. If preferred, 85% of the equilibrium current may be used for direct current solenoid valves.

8.4.4 If the valve opens, the MOPD has not been reached. De-energize the solenoid and increase the inlet pressure. Continue energizing and de-energizing the solenoid at increasing pressures until the valve no longer opens. The highest pressure at which the valve consistently opens is the MOPD.

9. REFERENCES

1. AHRI. 2014. ANSI/AHRI Standard 760- (I-P/2014), *Performance Rating of Solenoid Valves for Use with Volatile Refrigerants.* Arlington, VA: Air-Conditioning, Heating, and Refrigeration Institute.

2. ASHRAE. 2016. ANSI/ASHRAE Standard 15-2016, *Safety Standard for Refrigeration Systems*. Atlanta: American Society of Heating, Refrigerating and Air- Conditioning Engineers, Inc.

3. ASHRAE. 2016. ANSI/ASHRAE Standard 34-2016, *Designation and Safety Classification of Refrigerants*. Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
4. ASHRAE. 2013. ANSI/ASHRAE Standard 41.1-2013, *Standard Method of Temperature Measurement.* Atlanta: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

5. ASHRAE. 2014. ANSI/ASHRAE Standard 41.3-2014, *Standard Method for Pressure Measurement*. Atlanta: American Society of Heating, Refrigerating and Air- Conditioning Engineers, Inc.

6. ASHRAE. 2017. *ASHRAE Handbook—Fundamentals*, "Thermophysical Properties of Refrigerants." Atlanta: American Society of Heating, Refrigerating and Air- Conditioning Engineers, Inc.

7. NIST. 2013. NIST Standard Reference Database 23, Version 9.1 *NIST Thermodynamic and Transport Properties of Refrigerants and Refrigerants and Refrigerant Mixtures—REFPROP9*. Gaithersburg, MD: National Institute of Standards and Technology.

8. AHRI. 2014. ANSI/AHRI Standard 761 (SI/2014), *Performance Rating of Solenoid Valves for Use with Volatile Refrigerants.* Arlington, VA: Air-Conditioning, Heating, and Refrigeration Institute.

(This annex is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process.)

INFORMATIVE ANNEX A—EXAMPLES OF TEST CONDITIONS, DATA SHEETS, AND GRAPHS

TABLE A-1 Example of Preselected Gas Flow Test Conditions

Inlet psia	Outlet psia	ΔP psi	$\Delta P/P_1$	A_R (for air)
60	58	2	0.033	
60	57	3	0.050	
60	56	4	0.067	
60	55	5	0.083	
60	54	6	0.1	0.071
60	48	12	0.2	0.143
60	42	18	0.3	0.214
60	36	24	0.4	0.286
60	31.6	28.4	0.47	0.338

Data Sheet
Solenoid Valve Water Flow Capacity

VALVE UNDER TEST ______________________________ **DATE** ____________

MANUFACTURER ______________________ **ADDRESS** ______________________

MODEL __________ **SIZE** __________ **TYPE** __________ **SER. NO.** __________

CONNECTIONS: TYPE __________ **SIZE** __________ **REMARKS** ______________________

LINE NO	INLET CONDITIONS			ΔP*	$(\rho\Delta P)^{1/2}$	FLOW RATE*	REMARKS
	PRES	TEMP	ρ*				
1				2			
2				4			
3				6			
4				8			
5				10			
6				8			
7				6			
8				4			
9				2			

OBSERVER ______________________________________

***NOTE:** *Dimensions must be consistent and may be Inch-Pound (I-P) or Standard International Metric (SI). Flow rates are typically reported as pounds per minute (lb/min) in the I-P system and kilogram per second (kg/s) in the SI system of units.*

Figure A-1 Example of a data sheet for water flow testing.

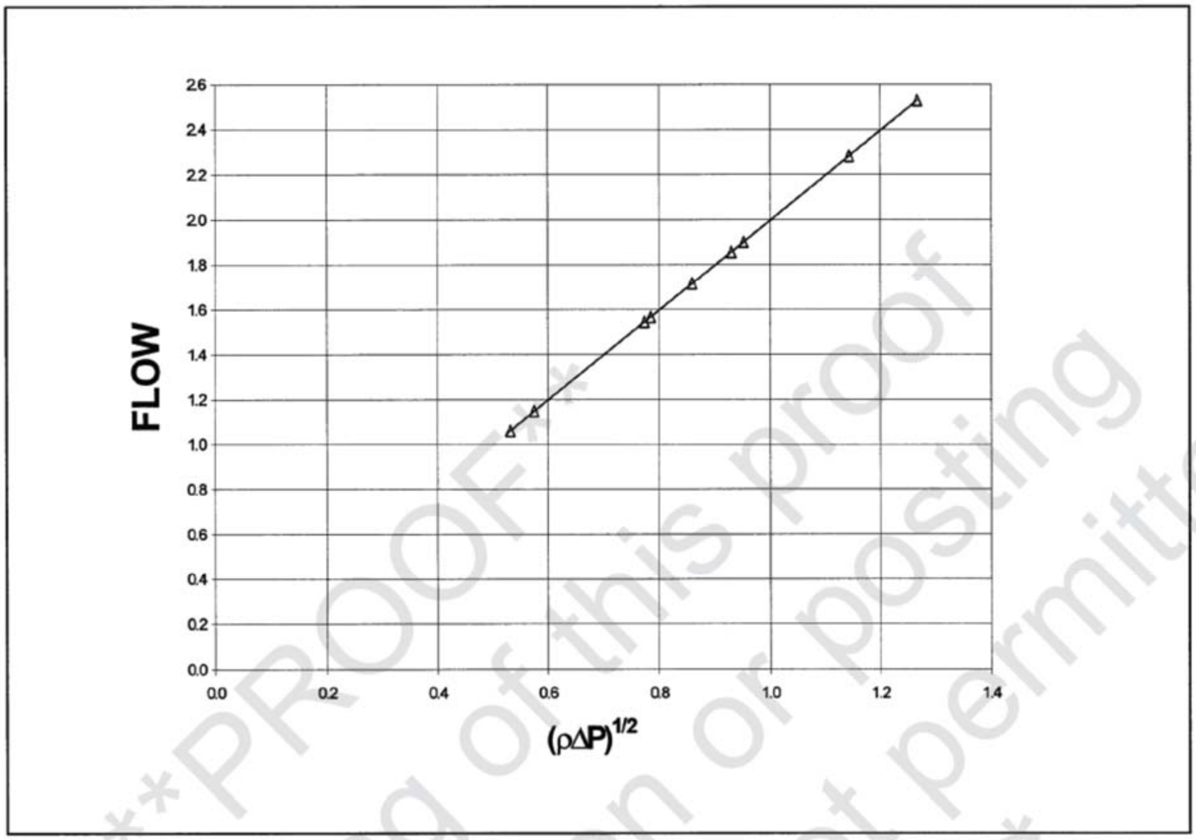

Figure A-2 Example of linear plot of incompressible flow data.

Data Sheet
Solenoid Valve Air Flow Capacity

VALVE UNDER TEST ____________________ DATE __________

MANUFACTURER ____________________ ADDRESS ____________________

MODEL __________ SIZE __________ TYPE __________ SER. NO. ________

CONNECTIONS; TYPE ________ SIZE ________ REMARKS ____________________

LINE NO	INLET CONDITIONS			ΔP*	$(\rho\Delta P)^{1/2}$	A_R	FLOW RATE *		C*	REMARKS
	PRES	TEMP	ρ*				INCREAS-ING ΔP	DECREAS-ING ΔP		
1	60			2						
2	60			3						
3	60			4						
4	60			5						
5	60			6		0.071				
6	60			12		0.143				
7	60			18		0.214				
8	60			24		0.286				
9	60			28.4		0.338				

OBSERVER ____

***NOTE:** *Dimensions must be consistent and may be Inch-Pound (I-P) or Standard International Metric (SI). Flow rates are typically reported as pounds per minute (lb/min) in the I-P system and kilogram per second (kg/s) in the SI system of units.*

Figure A-3 Example of a data sheet for gas flow testing.

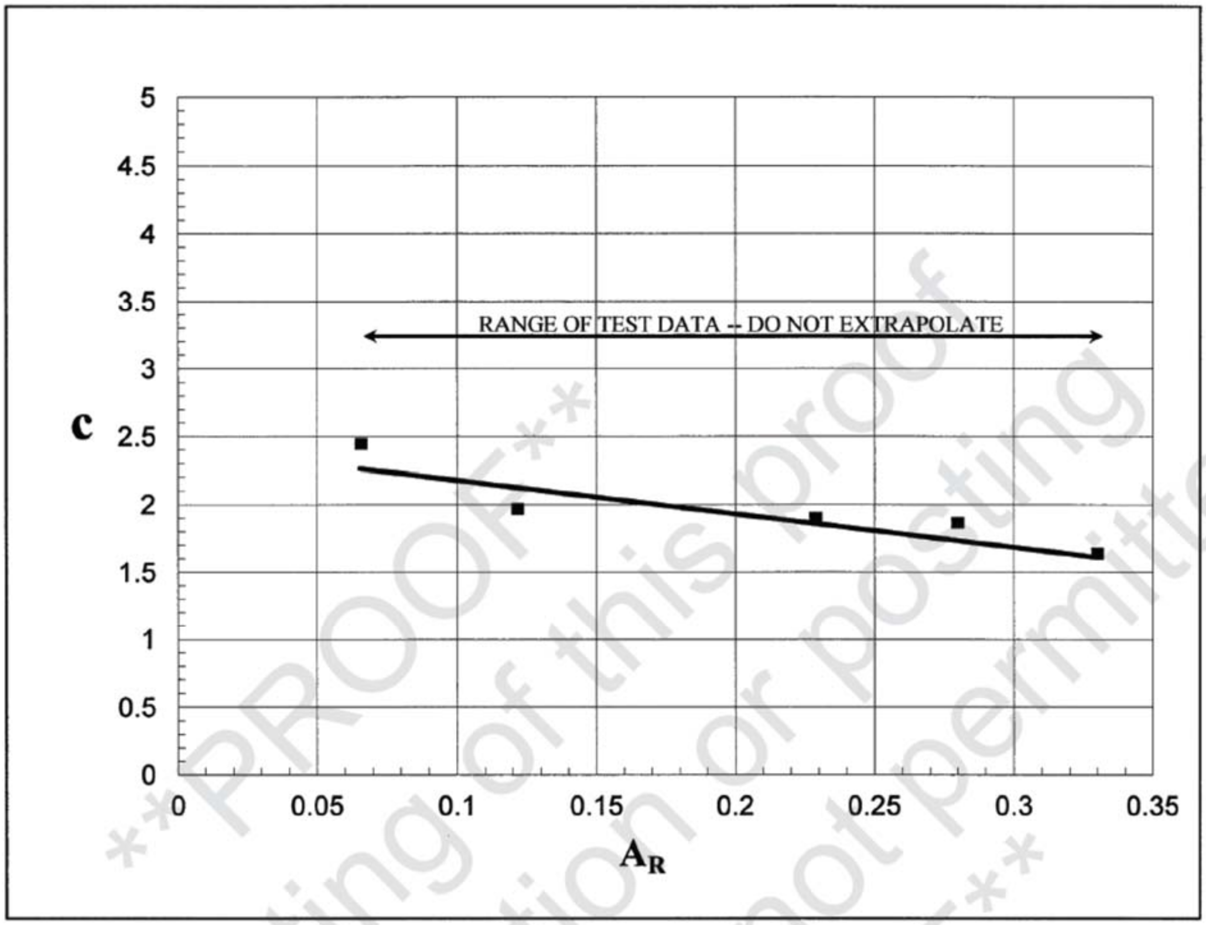

Figure A-4 Example of linear plot of acoustic ratio versus compressible flow coefficient.

(This annex is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE ANNEX B— EXAMPLE OF COMPUTATION TO EXPRESSVALVE CAPACITY IN TERMS OFREFRIGERATING EFFECT

This standard facilitates the measurement and prediction of the refrigerant mass flow rate capacity of solenoid valves intended for use in refrigeration systems.

The following thermodynamic equation relates the heat energy equivalent refrigerating effect to the mass flow rates of various refrigerants. Assuming the refrigerant absorbs the heat associated with the saturated liquid to saturated vapor phase change at the same rate as the mass flow rate through the solenoid valve, it may be used to express refrigerant solenoid valve capacity in terms of refrigerating effect.

$$Q^* = \dot{m}(h_g - h_f)$$

where
Q^* = heat absorbed in the evaporator of the refrigerating system by the refrigerant flowing through the solenoid valve
$\dot{m}$= mass flow rate of refrigerant through the solenoid valve
h_g = specific enthalpy of the saturated refrigerant vapor exiting the evaporator
h_f= specific enthalpy of the refrigerant liquid entering the expansion device

Note: Units must be consistent and may be Inch-Pound (I-P) or Standard International (SI) metric. Refrigeration capacities are typically reported as tons of refrigeration (TR) in the I-P system and as watts (W) in the SI system.

(This annex is not part of this standard. It is merely informative and does not contain requirements necessary for conformance to the standard. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE ANNEX C

INFORMATIVE BIBLIOGRAPY

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