CAGI VACPUMP-100 -2023

Simplified Acceptance Test for Bare Vane Vacuum Pumps for Mobile Vacuum Systems

Compressed Air & Gas Institute

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Suggestions for improvement of this standard will be welcome. They should be sent to the Compressed Air & Gas Institute.

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1. Introduction

This standard was developed by the Blower and Vacuum Section of the Compressed Air & Gas Institute in response to needs expressed by the industry manufacturers and users of mobile vacuum systems.

This standard provides a simplified performance test method to verify package bare vane vacuum pump performance for mobile package applications. It applies to positive displacement bare vane vacuum pumps for vacuum truck applications that typically deliver a maximum vacuum level of 28" Hg.

2. Scope

2.1 This standard applies to positive displacement bare vane vacuum pumps handling atmospheric air. Such pumps generally only incorporate essential ancillary equipment, e.g., valves needed for testing.

2.2 This standard defines and describes acceptance tests for bare vane vacuum pumps which are constructed to manufacturer's specifications, and which are supplied against performance data published in the manufacturer's sales documentation.

Such vacuum pumps are usually manufactured in batches or in continuous production quantities and the performance guarantee offered by the manufacturer to the purchaser is implicit in the information stated in the relevant sales data.

Such vacuum pumps are designed to use atmospheric air from their immediate surroundings and the performance data offered by the manufacturer usually relates to standard ambient air inlet conditions.

2.3 Only the measurements, as stated in this standard, (flow, vacuum, speed, and temperature differential) shall be taken at a single set of conditions to verify the performance stated in the manufacturer's sales documentation.

2.4 The conditions the vacuum pump is exposed to shall be specified in the customer's specifications. If not specified, the default conditions in Table 1 below will be used.

Measurement	Value/Unit
Ambient temperature	68°F
Relative Humidity	36% RH
Barometric Pressure	14.7 PSIA

Table 1 – Default Conditions

2.5 The bare vane vacuum pump test results will be presented in the following format (Figure 1). Once the test speed is set, the vacuum level is varied based on Figure 1 to measure the volume flow (ICFM) and the horsepower (HP). The objective is to verify the flow accuracy of +/- 5% of the manufacturer's published data. Although there is no specified tolerance for power it still should be recorded as a reference.

Manufacturer Name:						
Rated Capacity (Flow)* at Rated Operating Vacuum:		ICFM				
Rated Operating Vacuum:		"HgV				
Vacuum Pump Rated Speed:		RPM				
Barometric reference conditions (14.7 PSIA, 36% RH, 68°F)						
Manufacturer Series:						
Model Number / Serial Number:						
Date:						
		RPM				
"Hg	Volume Flow (ICFM)	1400	1300	1200	1100	1000
Max Vac (28)	(ICFM)					
	HP					
24 Hg	(ICFM)					
	HP					
18 Hg	(ICFM)					
	HP					
12 Hg	(ICFM)					
	HP					
6 Hg	(ICFM)					
	HP					
0 Hg	(ICFM)					
	HP					

Figure 1 – Data Sheet

3. Reference Standards

The following referenced documents are relevant for the application of this document. The latest edition of the referenced documents (including amendments) will apply:

- ASME MFC-3M-2004 (R2017)
- ISO 1217, Displacement Compressors – Acceptance Tests

4. Definitions

The general terms used in this standard apply to the testing for bare vacuum pumps. Definitions of particular relevance to this standard are as follows:

4.1 Ambient pressure – absolute pressure of the atmospheric air measured in the vicinity of the machine.

4.2 Ambient temperature – temperature of atmospheric air in the vicinity of the vacuum pump, but unaffected by it.

4.3 Bare vane vacuum pump – consists of input drive shaft and the inlet and outlet flanges for the air mover.

4.4 Barometric pressure – absolute pressure of atmospheric air in the vicinity of the vacuum pump, but unaffected by it.

4.5 Blank off (BO) - zero volumetric flow at defined speed.

4.6 Correction factor – a mathematical adjustment to correct the data when standard conditions may not be achieved.

4.7 Discharge pressure – total mean absolute pressure at the standard discharge point

4.8 Free airflow (FA) – pump displacement per revolution multiplied by maximum rpm at zero vacuum.

4.9 ICFM – (inlet cubic feet per minute) –inlet flow conditions at measurement point

4.10 Inlet temperature – total temperature at the standard inlet point of the vacuum pump.

4.11 Standard discharge point – discharge point considered representative of each vacuum pump.

4.12 Standard inlet point – inlet point considered representative of each vacuum pump, and which varies with vacuum pump design and type of installation.

4.13 Shaft power – power required at the vacuum pump driveshaft, equal to the sum of mechanical losses and the internal power, not including losses in external transmissions such as gear drives or belt drives unless part of the scope of supply.

4.14 Steady state – the state in which the difference between inlet and outlet temperatures is within 1.8°F for a period of three minutes or more.

4.15 Vacuum level – measurement of inlet pressure below ambient pressure typically referred to as inches of mercury vacuum ("HgV).
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5. Units and Symbols

The following symbols are to be used unless otherwise defined in the text.

Latin letters Symbol	Meaning	US Customary
n	speed of rotation	RPM
P	power	HP
p	pressure	lbf/in^2
T	thermodynamic temperature	ºR
t	temperature	°F
q_v	volume flow	ft^3/min
Δ	difference	—
η	efficiency	—
π	pressure ratio	—
ρ	density	lb/ft^3
φ_{rel}	relative humidity	—
k	correction factor	—
V	vacuum rating	inHg

Subscripts

Index	Meaning
1	inlet (suction side)
2	outlet (discharge side)
air	dry air
amb	ambient (air, temperature)
co	corrected to guarantee conditions
g	guarantee or reference conditions
te	Test result

6. Measuring Methods

6.1 Methods of Determining Flow Rate

The measurement of flow rate may be made by any one of the established methods in ASME - Fluid Meters – Their Theory and Applications, 6th Edition, Part II, "Flow Measurement" as specified in ASME/ANSI MFC/3M Sub Sonic Venturi.

The manufacturer is responsible for clearly identifying which method it will apply in the sales documentation in which the guaranteed performance of the vacuum pump is stated. The volume flow rate shall always be measured at the standard inlet point of the pump.

6.2 Methods of Determining Shaft Power

Bare vacuum pumps sold against standard sales data will generally be tested by the manufacturer on a fixed test rig using an electric motor (which may be a reaction mounted driver) as a means of providing, and measuring, shaft power. In a test lab power can be measured using a torque meter placed directly at the input/drive shaft.

Alternatively, power measurements may be derived from one of the following methods:

1. by measuring electrical power consumption and factoring in motor and transmissions losses;

2. by measuring discharge temperature and comparing against ideal isentropic temperature to calculate efficiency and derived power.

In the field, estimated power may be derived mathematically. See Section 8. Allowances shall be made for temperature losses from machine housing and oil lubrication system.

6.2.1 Measurement of Shaft Speed

Shaft speed shall be determined by methods having an accuracy of 1 rpm or better at measured value.

6.3 Measurement of Vacuum

Precision vacuum gauges and/or transducers shall have an accuracy of .25% full scale or better.

7. Test Procedure and Report

7.1 Preliminary tests may be performed to determine whether the bare vane vacuum pump is in a suitable condition for the acceptance test to be conducted and to check the measuring instruments.

7.2 During the test, no adjustments shall be made, other than those required to maintain the test conditions and those required for normal operation of the bare vane vacuum pump, as given in the instruction manual.

7.3 Before readings are taken, the vacuum pump shall be run long enough to ensure that steady-state conditions are reached so that no systematic changes occur in the instrument readings during the test. The steady state is defined in Section 4.14. For each load, a sufficient number of readings shall be taken to indicate that the steady-state condition has been reached. The number of readings and the intervals shall be chosen to demonstrate repeatability. Once steady state has occurred, at each load point, five sets of data shall be recorded in ten minutes.

For individual readings, the limits on fluctuations in Table 2 below apply:

Measurement	**Symbol**	**Fluctuation**
Barometric Pressure	Pa	1%
Temperature Difference	ΔT	2°F
Speed (rotational speed)	n	0.7%

Table 2 – Test Conditions

7.4 If the test conditions imposed are outside the limits in Section 2.4, Table 1, corrections will need to apply as illustrated in section 8.

7.5 If the test results reveal that the bare vane vacuum pump does not meet the specified performance then suitable alterations and adjustments shall be made. The test shall be repeated to confirm that the bare vane vacuum pump meets the specified performance.

The corrected values shall be compared to the guaranteed values. If the values are within the limits as defined in this standard, then the vacuum pump passes the test and is accepted. If the values are not within the limits as defined in this standard, then the vacuum pump fails the test.

7.6 The test report shall be concise without tolerance calculations and with only the essential corrections published.

8. Computation of Test Results

Test conditions may not align with specified conditions. Therefore, before test results and specified performance values are compared, corrections shall be applied to the measured values of flow rate.

Bare Vane Vacuum Pump Testing/Verification

Rated Values (guaranteed)

Item	Symbol	Units
Barometric Pressure	p_{ambg}	psia
Inlet Pressure (vacuum level)	$p_{1,g}$	psia
Rated Pressure Ratio	$\pi_g = \frac{p_{amb,g}}{p_{1,g}}$	-
Suction Temp	t_g	°F
Relative Humidity	φ_{relg}	%
Pump Speed	n_g	rpm
Effective Inlet Flow Rate	q_{Vg}	ICFM

Measured Values (test)

Item	Symbol	Units
Barometric Pressure	p_{ambt}	psia
Inlet Pressure (vacuum level)	$p_{1,t}$	psia
Rated Pressure Ratio	$\pi_t = \pi_g = \frac{p_{amb,t}}{p_{1,t}}$	-
Adjusted differential pressure	$p_{1,t} = \frac{P_{ambt,t}}{\pi_g} - p_{1,g}$	psia
Suction Temp	t_t	°F
Relative Humidity	$\emptyset_{rel,t}$	%
Pump Speed	n_t	rpm
Effective Inlet Flow Rate	q_{Vt}	ICFM

Calculated Values (corrections)

Item	Symbol	Units
Correction factor pump speed	$k_1 = k_4 = \frac{n_g}{n_t}$	-
Corrected effective inlet volume flow rate	$q_{V\_corr} = k_1 * q_{Vt}$	ICFM
Effective Flow Rate Deviation	$\Delta q_V = q_{Vcor} - q_{Vg}$	ICFM
	$\frac{\Delta q_{V\_cor}}{q_{Vg}}$	%
Allowable Deviation	$\Delta q_{V_{permitted}}$	%

Power Estimation from Differential Temperature (Paragraph 6.2 - alternate method 2)

Step 1: Efficiency from pressure and temperature

$$\eta = \frac{T_1\left[\left(\frac{p_2}{p_1}\right)^{0.2857} - 1\right]}{(T_2 - T_1)}$$

Step 2: Using the equation for isentropic efficiency, we can calculate isentropic power.

$$P_{isen} = 16.52 \times \left(\left(\frac{p_2}{p_1}\right)^{0.2857} - 1 \right) \div \frac{cfm_{FAD}}{100}$$

Step 3: Utilize efficiency value from temperatures and isentropic power to calculate the estimated power

$$n = \frac{P_{isen}}{P_{est}}$$

Or

$$P_{est} = \frac{P_{isen}}{n} x\ 1.341$$