



**COMPRESSED AIR AND GAS INSTITUTE**

ACCEPTANCE TEST CODE FOR  
**ELECTRICALLY DRIVEN PACKAGED CENTRIFUGAL**  
AIR COMPRESSORS

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## **Acknowledgements**

This test code was formulated by a joint working group of the Compressed Air & Gas Institute (CAGI) and PNEUROP, the European Committee of Manufactures of Compressors, Vacuum Pumps and Pneumatic Toolse.

CAGI and PNEUROP have category A liaison status with ISO.

This publication shall be valid as a joint publication of CAGI and PNEUROP for a 2 year period, from November 5, 2010, until November 5. 2012. The joint working group will review the publication and experiences gained during the period of validity to either revise the document, approve it for another period of use, or progress into ISO TC118 as a future ISO standard or as an annex to an existing standard.

**The use of this test code does not absolve the user from conformity with all appropriate legal obligations.**

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ACCEPTANCE TEST CODE FOR  
**ELECTRICALLY DRIVEN PACKAGED CENTRIFUGAL**  
**AIR COMPRESSORS**

**1. Scope**

1.1 This code applies to any fixed (constant) speed packaged air compressor which incorporates a centrifugal air compressor of any type driven by an electric motor.

The range for this accepted test code is 100-2500 HP (conversion kW) and 60/50 cycle tested at motor nameplate voltage.

1.2 The Code defines and describes acceptance tests for electrically driven packaged air compressors of standard types which are constructed to specifications determined by the manufacturer and which are sold against performance data published in the manufacturer's sales documentation. See section 3.1.

Such compressors are designed to aspire atmospheric air from their immediate surroundings and the performance data offered by the manufacturer usually relates to a normal ambient air inlet pressure.

1.3 The test conditions shall be as close as is reasonably possible to the conditions specified in Table 1:

Relative Humidity	60%
Barometric Pressure	14.5 psia
Inlet Pressure Drop <sup>1</sup>	0.2 psia
Inlet Temperature	95 F
Cooling Water Temperature	85 F
Gas Constant	54.07 ft-lbf/lbm°R

Table 1

<sup>1</sup> When filter is not an integral part of the acceptance test, a test air filter/piping system with this inlet pressure drop specification shall be mounted.

Speed	+/- 0.5%
Absolute ambient pressure	+/- 3%
Inlet temperature	+/- 15 F
Coolant temperature	+/- 15 F
Overall pressure ratio	+/- 2%
External coolant quantity	+/- 5%
Coolant temperature difference	+/- 5 F

Table 2

For multi-stage compressors, the machine must be capable of producing a minimum discharge pressure of 10% greater than the required operating pressure at customer conditions. When it is not feasible to test a compressor within this limitation and the limitations specified in Table 2 it is recommended that the test should be carried out as an individually specified and guaranteed machine in accordance with ISO 5389 or ASME PTC 10.

1.4 The compressor on test will be deemed to be acceptable provided the results obtained do not differ from the specified performance by more than the allowances given in Table 3 below:

Volume Flow Rate	Specific Power Consumption	Unloaded Power Consumption
+/- 4%	+/- 5%	+ 10%

Table 3

## 2. Reference Standards

ISO 5389 – Turbocompressors – Performance Test Code  
ISO 3857/1 – Compressors, pneumatic tools and machines –  
Vocabulary – Part 1: General  
ISO 5167 – Measurement of fluid flow  
ISO 9300 – Measurement of gas flow  
ASME PTC 10 – Test Code on Compressors and Exhausters  
IEC Publication 51  
ASME FLUID METERS

## 3. Definitions

In general terms used in this Code to describe machine and testing features are as defined in ISO 5389. Definitions of particular relevance to this Code are as follows.

### 3.1 Packaged Air Compressor:

An air compressor package includes those components factory mounted to a common baseplate. As a minimum a compressor package shall include:

- Compressor
- Driver
- lube oil system (as required)
- Cooling Water System
- Process piping and cooling
- Inlet guide vane or control valve

A package could also include:

- Unloading control valve
- Control system
- Sound enclosure
- Intake air filter
- Unloading silencer
- and other items when mounted in the factory on the common baseplate.

Items supplied shipped loose for installation at site are not considered to be a part of the compressor package.

### 3.2 Standard Inlet Point:

Unless otherwise indicated by the manufacturer this is the point at which ambient air enters the filter. If filter is not included, refer to table 1.

### 3.3 Standard Discharge Point:

The terminal discharge point of the compressor, typically at the discharge flange of the package.

### 3.4 Ambient Pressure:

Absolute pressure of the atmospheric air measured in the vicinity of the compressor.

### 3.5 Discharge Pressure:

Mean absolute pressure at the standard discharge point.

### 3.6 Inlet Temperature:

Temperature at the standard inlet point of the compressor.

### 3.7 Ambient Temperature:

Temperature of the atmospheric air in the vicinity of the compressor but unaffected by it.

### 3.8 Free Air:

Air at ambient pressure and ambient temperature and humidity.

### 3.9 Volume Flow Rate:

The volume flow rate of air compressed and delivered at the standard discharge point, referred to conditions of inlet temperature, inlet pressure and composition (e.g. humidity) prevailing at the standard inlet point.

### 3.10 Packaged Compressor (electrical) Power Input:

The sum of the electrical power inputs to the prime mover and all other ancillary and auxiliary items included in the standard package at the specified electrical supply conditions (voltage, phase and frequency) stated by the manufacturer in his sales data at loaded test conditions.

### 3.11 Unloaded Power Consumption:

The sum of the electrical power inputs to the prime mover and all other ancillary and auxiliary items included in the standard package at the specified electrical supply conditions (voltage, phase and frequency) stated by the manufacturer in his sales data at unloaded test conditions.

### 3.12 Specific Power Consumption:

Packaged Compressor input power per unit of compressor volume flow rate.

### 3.13 External Coolant:

The medium externally supplied to the compressor to which the compression heat is finally rejected usually through cooling water.

### 3.14 Pressure Ratio:

The discharge pressure divided by the total mean absolute pressure at the standard inlet point.

### 3.15 Test Report:

See Appendix A

## 4. Measuring Methods

### 4.1 Measurement of Volume Flow Rate At Package Discharge

**ISO 5167 - Measurement of fluid flow by means of orifice plates, nozzles and venturi tubes inserted in circular cross section conduits running full.**

**ISO 9300 - Measurement of gas flow by means of critical flow venture nozzles.**

**ASME - Fluid Meters – Their Theory and Applications, 6<sup>th</sup> Edition, Part II, “Flow Measurement”**

### 4.2 Method of Determining Condensate Rate

If the compressor package has no means of condensing moisture from the air being compressed, no correction shall be made for moisture content. If the compressor has means of condensing and ejecting moisture, e.g. intercooler(s), aftercooler(s), etc., correction of the volume flow rate may be made either by collection and measurement of the condensate ejected during the test according to 4.2.1. or entirely by calculation according to 6.1.2.

#### 4.2.1 Collection and Measurement Of Condensate

Before and after the acceptance test, carried out with the compressor running at the specified test conditions, the condensate shall be drained from all ejection positions before the standard discharge point in such a way that the steady state of the compressor's running is not disturbed.

The average mass rate of condensate ejection during the test shall be calculated by dividing the mass of condensate drained after the test by the time between the draining operations.

### 4.3 Measurement of Compressor Power Input

Electrically driven packaged compressors will be assembled as a complete unit in accordance with the manufacturer's specification for their acceptance test. The measurement of the total electrical power supplied to the package will be made when it is running at the specified speed, ambient and discharge air conditions, supply voltage and frequency. In these conditions two basic methods are available to measure the input electrical power:

(i) The double element watt meter method which gives a direct indication of the electrical kW input

and

(ii) a computation based on the separate measurement of voltage, current and power factor of the electrical supply.

### 4.4 Measurement of Shaft Speed

Shaft speed shall be determined by methods having an accuracy of 0.1% or better.

## 5. Test Procedure and Report

**5.1** Preliminary tests may be performed to determine that the package is in suitable condition for the acceptance test to be conducted and to check the measuring instruments.

**5.2** After a preliminary test has been made, this test may, by agreement, be considered the acceptance test, provided all requirements for an acceptance test have been met.

**5.3** During the test no adjustments other than those required to maintain the test conditions and those required for normal operation of the package as given in the instruction manual shall be made.

**5.4** Before readings are taken the package shall be run long enough to assure that steady state conditions are reached.

**5.5** If the test conditions impose an ambient pressure outside the limits of  $\pm 3$  percent, the test may be carried out at the ambient pressure normally existing at the test place provided the specified absolute pressure ratio and speed are maintained.

5.6 The test report shall be short and simple without tolerance calculations and with only the essential corrections cited.

## 6. Computation of Test Results

Test conditions never agree exactly with the specified conditions. Therefore, before test results and specified performance values are compared, corrections shall be applied to the measured values of volume flow rate, specific power consumption, and packaged input power.

### 6.1 Volume Flow Rate Correction

The corrected volume flow rate,  $q_{v\text{corr}}$ , is calculated as follows:

$$q_{v\text{corr}} = K_1 \cdot K_2 \cdot q_{vR}$$

Where  $q_{vR}$  = the measured volume flow rate derived from the observed results of the test.

$K_1$  = correction factor for influence of speed, temperatures, pressures, and humidity – see 6.1.1

$K_2$  = correction factor for condensed water vapor at the specified free air conditions – see 6.1.2

#### 6.1.1 Influence of speed, temperatures, pressures, humidity

$$K_1 = \frac{N_c}{N_R} + 1 - \frac{r_c T_c \ln(\pi_c)}{r_R T_R \ln(\pi_R)} \left( \frac{N_R}{N_c} \right)^2 \left[ 1 + 0.8 \left[ \left( \frac{T_{wc}/T_c}{T_{wR}/T_R} \right) - 1 \right] \right]$$

Where  $N_c$  = the specified compressor input shaft speed

$N_R$  = the measured compressor input shaft speed

$r_c$  = the specified gas constant

$r_R$  = the measured gas constant

$T_c$  = the specified absolute inlet temperature

$T_R$  = the measured absolute inlet temperature

$\pi_c$  = the specified pressure ratio

$\pi_R$  = the measured pressure ratio

$T_{wc}$  = the specified water inlet temperature

$T_{wR}$  = the measured water inlet temperature

#### 6.1.2 Condensate Formation Correction Factor

When condensate ejected during the test is collected and measured an allowance,  $K_2$ , for this may be calculated as follows:

$$K_2 = 1 + \frac{q_w R_v T_R}{q_{vR} p_R}$$

Where  $q_w$  = average mass rate of condensate ejection during the test

$R_v$  = gas constant of water vapor

$T_R$  = measured absolute ambient temperature

$q_{vR}$  = measured volume flow rate derived from the observed test results

$p_R$  = measured absolute ambient pressure

As an alternative to the collection and measurement of condensate the following method may be used to calculate the correction factor,  $K_2$ :

$$K_2 = \frac{p_R}{p_R - p_{cd} \cdot X \cdot 0.378}$$

Where  $p_{cd}$  = vapor pressure of water at ambient pressure and temperature

$X$  = relative humidity at the obtaining free air conditions

### 6.2 Specific Power Consumption Correction

The packaged specific compressor power input,  $SPC_{pk\text{corr}}$ , is calculated thus:

$$SPC_{pkcorr} = K_4 \cdot K_5 \cdot K_6 \cdot SPC_R$$

Where  $SPC_R$  = the measured specific power consumption

$K_4$  = correction factor for inlet pressure – see 6.2.1

$K_5$  = correction factor for pressure ratio – see 6.2.2

$K_6$  = correction factor for cooling water temperature – see 6.2.3

### 6.2.1 Inlet Pressure Correction

$$K_4 = \frac{P_c}{P_R}$$

Where  $P_c$  = specified absolute inlet pressure  
 $P_R$  = measured inlet pressure

### 6.2.2 Pressure Ratio Correction

$$K_5 = \frac{\ln(\pi_c)}{\ln(\pi_R)}$$

### 6.2.3 Cooling Water Temperature Correction

$$K_6 = 1 + 0.8 \cdot \left[ \left( \frac{T_{wc}/T_c}{T_{wR}/T_R} \right) - 1 \right]$$

## 6.3 Packaged Input Power Correction

The packaged compressor power input,  $P_{pkcorr}$ , is calculated thus:

$$P_{pkcorr} = SPC_{pkcorr} * q_{vcorr}$$

**Appendix A**  
**CAGI ACCEPTANCE TEST REPORT**

**Manufacturer** \_\_\_\_\_  
**Model Number** \_\_\_\_\_  
**Serial Number** \_\_\_\_\_

**Air Cooled**      **Water Cooled**      **Packaged (Mounted) Inlet Filter<sup>4</sup>**      **Packaged (Mounted) Aftercooler**  
**Packaged (Mounted) Unloading Silencer**      **Packaged (Mounted) Unit Control Panel**  
**Packaged (Mounted) Unloaded Control Valve**

Test Conditions	Units	CAGI	CAGI Tolerance <sup>1</sup>		CAGI Range <sup>1</sup>		Actual Value	Result <sup>3</sup>	
		Value	Neg	Pos	Min	Max			
Ambient Temperature	F	95	-15	15	80	110		F	
Absolute Ambient Pressure	PSIA	14.5	-3%	3%	14.07	14.94	14.3	P	
Inlet Pressure drop if applicable <sup>4</sup>	PSIA	0.2							
Coolant Temperature	F	85	-15	15	100	100		F	
Overall Pressure Ratio	%	0.00	-2%	2%			0.0		
Relative Humidity	%	60%							
External Coolant Quantity	GPM		-5%	5%	0	0		F	
Test Results	Units	CAGI Value	CAGI Tolerance <sup>1</sup>		CAGI Range <sup>1</sup>		Tested Value	Corrected Value	Result <sup>3</sup>
Rated capacity at full load operating pressure	acfm		-4%	4%	0	0			F
Full load operating pressure	psig								
Maximum pressure <sup>5</sup>	psig		0%		0			<b>Note 2</b>	F
Total package input power at rated capacity and full load operating pressure	kW								
Specific package input power at rated capacity and full load operating pressure	kW/100cfm		-5%	5%	0	0			F
Total package input power in unloaded state	kW		NA	10%		0		<b>Note 2</b>	F

**NOTES:**

- 1 Reference tables 2 and 3.
- 2 These values are not corrected
- 3 P = Passed / F = Failed
- 4 If inlet air filter is not package mounted, a test air filter / piping system shall be substituted. The pressure drop of this system shall be measured at full load conditions and stated in this report.
- 5 For multi-stage compressors, the machine must be capable of producing a minimum discharge pressure of 10% greater than the required operating pressure at customer conditions.

5/8/2009