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Turbocompressors — Performance test code — Simplified acceptance test

Turbocompresseurs — Code d'essais des performances — Essai de réception simplifié

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Foreword

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 118, *Compressors and pneumatic tools, machines and equipment*, Subcommittee SC 6, *Air compressors and compressed air systems*.

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Introduction

ISO 5389 is the primary International Standard for performance statements of dynamic compressors of all types.

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, ISO 5389 provides for demanding conditions to be met for such standard packages.

To allow performance statements to be made for standard types, this simplified code has been developed where the performance statement can be given based on specified test conditions (see Table 1), where the key measured variables are maintained within identified test limitations (see Table 2).

The performance statement is valid, provided it is within the identified acceptance allowances (see Table 3) for volume flow rate, specific power consumption, and unloaded power consumption.

Whereas ISO 5389 addresses any type of dynamic compressor, this simplified International Standard addresses centrifugal compressors only which are of the fixed speed type and are electrically driven packaged air compressors. It is envisaged that at a later date, variable speed types will also be included.

This International Standard will ultimately become an annex of ISO 5389 once sufficient experience has been gained from its use in the field. In its current form, it complements ISO 5389 for standard packages, but where acceptance tests are required to demonstrate fulfilment of the order conditions and guarantees specified by the client in a supply contract, then ISO 5389 is still the primary reference International Standard.

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Turbocompressors — Performance test code — Simplified acceptance test

1 Scope

This International Standard applies to any fixed (constant) speed, liquid cooled, packaged centrifugal air compressor which incorporates a centrifugal compression element of any type driven by an electric motor.

This International Standard 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.

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

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

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 1217, *Displacement compressors — Acceptance tests*

ISO 3857-1, *Compressors, pneumatic tools and machines — Vocabulary — Part 1: General*

ISO 3857-2, *Compressors, pneumatic tools and machines — Vocabulary — Part 2: Compressors*

ISO 5167-1, *Measurement of fluid flow by means of pressure differential devices inserted in circular cross-section conduits running full — Part 1: General principles and requirements*

ISO 9300, *Measurement of gas flow by means of critical flow Venturi nozzles*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 3857-1, ISO 3857-2, ISO 1217 and the following apply.

3.1
ambient pressure
absolute pressure of the atmospheric air measured in the vicinity of the compressor

3.2
ambient temperature
total temperature of the atmospheric air in the vicinity of the compressor but unaffected by it

3.3
centrifugal air compressor
comprise machines in which inlet, compression, and discharge are continuous flow processes

Note 1 to entry: The gas is conveyed and compressed in impellers and decelerated with further increase in pressure in fixed vaned or vaneless stators.

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3.4
external coolant
liquid medium externally supplied to the compressor to which the compression heat is finally rejected

3.5
packaged compressor
compressor unit, fully piped and wired and generally includes all ancillary items necessary for their effective operation as a complete self-contained air compressor installation

3.6
packaged compressor (electrical) power input
sum of the electrical power inputs to the prime mover and all other ancillary and auxiliary items included in the standard package

Note 1 to entry: The total given is at the specified electrical supply conditions (voltage, phase and frequency) stated by the manufacturer in his sales data at loaded test conditions.

3.7
pressure ratio
discharge pressure divided by the inlet pressure

3.8
specific power consumption
packaged compressor input power (3.6) per unit of compressor actual *volume flow rate* (3.12)

3.9
standard discharge point (package)
terminal discharge point of the compressor, typically at the discharge flange of the package

3.10
standard inlet point (package)
point at which ambient air enters the package

Note 1 to entry: Unless otherwise indicated by the manufacturer.

Note 2 to entry: If filter is not included, refer to Table 1.

[SOURCE: ISO 1217:2009, 3.1.24, Note 2 to entry — modified]

3.11
unloaded power consumption
sum of the electrical power inputs to the prime mover and all other ancillary and auxiliary items included in the standard package

Note 1 to entry: The total given is at the specified electrical supply conditions (voltage, phase, and frequency) stated by the manufacturer in his sales data at unloaded test conditions.

3.12
volume flow rate
3.12.1
measured
volume flow rate of air, compressed and delivered at the *standard discharge point* (3.9), referred to conditions of total temperature, total pressure and composition prevailing at the standard inlet point

3.12.2
corrected
volume flow rate of air, compressed and delivered at the *standard discharge point* (3.9), corrected for machine behaviour at specified test conditions

Note 1 to entry: The specified test conditions are given in Table 1.

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4 Symbols

4.1 Symbols and units

Symbol	Term	SI unit	Other practical units
f	Correction factor	—	—
f_1	Correction factor for influence of speed, temperatures, pressures, and humidity	—	—
f_2	Correction factor for condensed water vapour at the specified free air condition	—	—
f_4	Correction factor for inlet pressure	—	—
f_5	Correction factor for pressure ratio	—	—
f_6	Correction factor for cooling water temperature	—	—
$\dot{m}$	Mass flow	kg/s	—
N	Rotational frequency (shaft speed)	s^{-1}	min^{-1}
p	Pressure	Pa	MPa, bar, mbar
P	Power	W	MW, kW
Π	Pressure ratio	1	—
R	Specified gas constant	J/(kg·K)	—
SPC	Specific power consumption	—	—
T	Thermodynamic temperature	K	—
$\dot{V}$	Volume flow	m^3/s	m^3/h, m^3/min, L/s

4.2 Subscripts

Subscript	Term	Remarks
a	Absolute	
amb	Ambient	Air, temperature
cond	Condensate	
corr	Corrected	
g	Guarantee	
m	Mass	Characterizes the mass specific rates of flow, energies, and volumes
pk	Package	
R	Reading	Indicates the quantities read during the test or predetermined as test conditions
vap	Vapour	
W	Coolant	

5 Test conditions, limitations and allowances

5.1 General

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

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Table 1 — Specified test conditions

Quantity	Unit	Value	
		Option A	Option B
Relative humidity	%	0	60
Absolute ambient pressure	bara	1	1
Inlet pressure drop	bara	0,01	0,01
Inlet temperature	°C	20	35
Coolant temperature	°C	20	30
Gas constant	J/(kg·K)	287	291
When an inlet 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.			

The option chosen shall be identified in published literature.

The test limitations apply to either of the options in Table 1 that have been selected for the chosen specified test conditions and shall not exceed those given in Table 2.

Table 2 — Test limitations

Measured variable	Maximum permissible deviations
Speed	±0,5 %
Absolute ambient pressure	±5 %
Inlet temperature	±8,5 °C
Coolant temperature	±8,5 °C
Overall pressure ratio	±2 %
External coolant flow rate	±5 %

5.2 Multi-stage compressor — Operational limitations

For multi-stage compressors, the machine should 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.

5.3 Performance acceptance allowances

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.

Table 3 — Performance acceptance allowances

Volume flow rate	Specific power consumption	Unloaded power consumption
±4 %	+5 %	+10 %

6 Measuring methods

6.1 Measurement of volume flow rate at standard discharge point (package)

The measurement of the volume flow rate at the standard discharge point (package) shall be done using ISO 5167-1 or ISO 9300.

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6.2 Method of determining condensate rate

6.2.1 Condensate correction

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 6.2.2 or entirely by calculation according to 8.2.3.

6.2.2 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.

6.2.3 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:

a) the double element watt meter method, which gives a direct indication of the electrical kW input;

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

6.3 Measurement of shaft speed

Shaft speed shall be determined by methods having an accuracy of 0,1 % or better.

7 Test procedure and report

7.1 Preliminary tests

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.

7.2 Preliminary test and acceptance test

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.

7.3 Adjustments

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.

7.4 Readings

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

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7.5 Test report

The test report shall be short and simple without tolerance calculations and with only the essential corrections cited. An example test report is given in Annex A. Those items included in the test shall be indicated from the listing given in Annex A.

8 Computation of test results

8.1 General

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.

8.2 Volume flow rate

8.2.1 Volume flow rate correction

The corrected volume flow rate, $\dot{V}_{corr}$, is calculated as follows.

$$\dot{V}_{corr} = f_1 \, f_2 \, \dot{V}_R \tag{1}$$

where

$\dot{V}_R$ is the measured volume flow rate derived from the observed results of the test;

f_1 is the correction factor for influence of speed, temperatures, pressures, and humidity, see 8.2.2;

f_2 is the correction factor for condensed water vapour at the specified free air conditions, see 8.2.3.

8.2.2 Influence of speed, temperatures, pressures, humidity

$$f_1 = \frac{N_g}{N_R} + 1 - \frac{R_g \, T_g \, ln\left(\Pi_g\right)}{R_R \, T_R \, ln\left(\Pi_R\right)} \left(\frac{N_R}{N_g}\right)^2 \left[1 + 0{,}8 \left[\left(\frac{T_{Wg} / T_g}{T_{WR} / T_R}\right) - 1\right]\right] \tag{2}$$

where

N_g is the specified compressor input shaft speed in s^{-1};

N_R is the measured compressor input shaft speed in s^{-1};

R_g is the specified gas constant for air in J/(kg·K);

R_R is the calculated gas constant for air at measured conditions in J/(kg·K);

T_g is the specified absolute inlet temperature in K;

T_R is the measured absolute inlet temperature in K;

Π_g is the specified pressure ratio;

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Π_R is the measured pressure ratio;

T_{Wg} is the specified coolant inlet temperature in K;

T_{WR} is the measured coolant inlet temperature in K.

8.2.3 Condensate formation correction factor

When condensate ejected during the test is collected and measured an allowance, f_2, for this may be calculated as follows.

$$f_2 = 1 + \frac{\dot{m}_{cond}\ R_{vap}\ T_R}{\dot{V}_R\ p_{a,ambR}} \tag{3}$$

where

$\dot{m}_{cond}$ is the average mass rate of condensate ejection during the test in kg/s;

R_{vap} is the gas constant of water vapour in J/(kg·K);

$\dot{V}_R$ is the measured volume flow rate derived from the observed test results in m^3/s;

$p_{a,ambR}$ is the measured absolute ambient pressure in Pa.

As an alternative to the collection and measurement of condensate, Formula (4) may be used to calculate the correction factor, f_2:

$$f_2 = \frac{p_R}{p_R - p_{vap,R} \times X_R \times 0{,}378} - \frac{p_g}{p_g - p_{vap,g} \times X_g \times 0{,}378} + 1 \tag{4}$$

where

$p_{vap,R}$ is the vapour pressure of water in Pa at measured test conditions;

$p_{vap,g}$ is the vapour pressure of water in Pa at specified test conditions;

p_g is the specified absolute ambient pressure in Pa;

X_R is the measured relative humidity at the obtaining free air conditions;

X_g is the specified relative humidity at the specified free air conditions.

8.3 Specific power consumption correction

The packaged specific compressor power input, $SPC_{pk,corr}$, is calculated as follows.

$$SPC_{pk,corr} = f_4\ f_5\ f_6\ SPC_R \tag{5}$$

where

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SPC_R is the $P_R / \dot{V}_R$, the measured specific power consumption;

f_4 is the correction factor for inlet pressure, see 8.3.1;

f_5 is the correction factor for pressure ratio, see 8.3.2;

f_6 is the correction factor for cooling water temperature, see 8.3.3.

8.3.1 Inlet pressure correction

$$f_4 = \frac{p_{ag}}{p_R} \tag{6}$$

where

p_{ag} is the specified absolute inlet pressure in Pa;

p_R is the measured absolute inlet pressure in Pa.

8.3.2 Pressure ratio correction

$$f_5 = \frac{ln\left(\Pi_g\right)}{ln\left(\Pi_R\right)} \tag{7}$$

8.3.3 Cooling water temperature correction

$$f_6 = 1 + 0{,}8 \cdot \left[\left(\frac{T_{Wg} / T_g}{T_{WR} / T_R} \right) - 1 \right] \tag{8}$$

8.4 Packaged compressor power input

The packaged compressor power input, $P_{pk,corr}$, is calculated as follows.

$$P_{pkcorr} = SPC_{pk,corr}\, \dot{V}_{corr} \tag{9}$$

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