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Displacement compressors — Acceptance tests

Compresseurs volumétriques — Essais de réception

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 1217 was prepared by Technical Committee ISO/TC 118, *Compressors and pneumatic tools, machines and equipment*, Subcommittee SC 6, *Air compressors and compressed air systems*.

This fourth edition cancels and replaces the third edition (ISO 1217:1996), which has been technically revised.

Displacement compressors — Acceptance tests

1 Scope

This International Standard specifies methods for acceptance tests regarding volume rate of flow and power requirements of displacement compressors. It also specifies methods for testing liquid-ring type compressors (see Annex A).

This International Standard specifies the operating and testing conditions which apply when a full performance test is specified.

For compressors manufactured in batches or in continuous production quantities and supplied against specified data, the tests described in Annexes B, C and D are considered equivalent alternatives.

Annex E, which is normative, applies to any electrically driven compressor manufactured in batches or in continuous production quantities and supplied against specified data having variable speed drive (e.g. variable frequency drive, direct current drive and switched reluctance), which incorporates a displacement compressor of any type driven by an electric motor.

Detailed instructions are given for a full performance test, including the measurement of volume flow rate and power requirement, the correction of measured values to specified conditions and means of comparing the corrected values with the guarantee conditions. This International Standard specifies methods for determining the value of the tolerances to be applied to the measurement of flow, power and specific power.

NOTE The tolerances to be applied to the measurement of flow, power, specific power, etc. for all acceptance tests carried out in accordance with this International Standard are agreed on by the manufacturer and the purchaser at the contractual stage or prior to the execution of the tests.

Annex F specifies standard inlet conditions for reference purposes. Annex G, which is normative, indicates the uncertainty of measurement.

This International Standard is not applicable to noise statements, which are identified in ISO 2151.

2 Normative references

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

ISO 3046-1, *Reciprocating internal combustion engines — Performance — Part 1: Declarations of power, fuel and lubricating oil consumptions, and test methods — Additional requirements for engines for general use*

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*

IEC 60584-1, *Thermocouples — Part 1: Reference tables*

IEC 60584-2, *Thermocouples — Part 2: Tolerances*

IEC 60584-3, *Thermocouples — Part 3: Extension and compensating cables — Tolerances and identification system*

IEC 60953-2, *Rules for steam turbine thermal acceptance tests — Part 2: Method B — Wide range of accuracy for various types and sizes of turbines*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1 General

3.1.1
acceptance test
performance test carried out in accordance with this International Standard, i.e. ISO 1217:2009

3.1.2
aftercooling
removal of heat from a gas after the compression is completed

3.1.3
batch
two or more compressors manufactured at the same time in one operation

3.1.4
clearance volume
volume inside the compression space, which contains gas trapped at the end of the compression cycle

3.1.5
displacement compressor
machine that creates a static pressure rise by allowing successive volumes of gas to be aspirated into and exhausted out of a closed space by means of the displacement of a moving member

3.1.6
displacement of a displacement compressor
volume swept by the compressing element(s) of the compressor's first stage per unit of time

3.1.7
external coolant
medium externally supplied to the compressor to which the generated heat is finally rejected

NOTE This is usually ambient air or cooling water.

3.1.8
fuel consumption
total mass of fuel consumed by the engine per unit time while the compressor is running on test at the specified conditions of inlet and discharge pressure and speed, with all engine ancillary equipment such as alternator and water pump connected and operating normally

See Annex D.

3.1.9
ideal multi-stage compression
process by which a perfect gas is isentropically compressed and the gas inlet temperature as well as the amount of work spent are the same for each stage

3.1.10
intercooling
removal of heat from a gas between stages

3.1.11
liquid-injected rotary compressors
rotary compressor in which a liquid is injected into the gas stream before or in the compressor

3.1.12
liquid-ring compressor
machine with a rotating impeller with protruding blades eccentrically mounted in a stationary round housing or centrally mounted in a stationary elliptical housing

See Annex A.

NOTE 1 A working liquid creating a liquid ring rotating together with the bladed impeller creates either one or two crescent-shaped working spaces.

NOTE 2 The volumes trapped between each pair of blades, the hub and the liquid ring will vary periodically, thereby creating a change in pressure that will generate a flow from the suction to the discharge side of the compressor.

3.1.13
packaged compressor
compressor with prime mover, transmission, fully piped and wired internally, including ancillary and auxiliary items of equipment and being stationary or mobile (portable unit) where these are within the scope of supply

3.1.14
polytropic process
compression or expansion process of an ideal gas, in which the relationship between pressure and volume is:

$$pV^n = \text{constant}$$

NOTE 1 The exponent n can have various values. For example:

$$pV = \text{constant}$$

describes an isothermal process, i.e. the gas temperature remains constant.

$$pV^k = \text{constant}$$

describes an isentropic process, i.e. the gas entropy remains constant.

NOTE 2 Sometimes this process is called adiabatic, but to avoid confusion between adiabatic (no heat exchange with the surroundings) and reversible adiabatic (isentropic) process, the expression isentropic is preferred.

3.1.15
relative clearance volume
ratio of clearance volume of the stage under consideration to the swept volume of the compressing element of this stage

3.1.16
rotary compressor
displacement compressor in which the element is one or more rotors operating in a casing, the displacement being effected by vanes, meshing elements or by displacement of the rotor itself

3.1.17
shaft-driven reciprocating compressor
displacement compressor in which gas intake and compression are achieved by the straightforward alternating movement of a moving element in a space constituting a compression chamber due to a shaft rotation

3.1.18
shaft rotational speed
number of revolutions of the compressor drive shaft per unit of time

3.1.19
shaft-speed irregularity
dimensionless number obtained when the difference between maximum and minimum instantaneous shaft speeds during one period is divided by the arithmetic mean of both

$$\text{Shaft-speed irregularity} = 2\,\frac{N_{\text{max.}} - N_{\text{min.}}}{N_{\text{max.}} + N_{\text{min.}}} \qquad (1)$$

3.1.20
specific fuel consumption
mass per unit time divided by the compressor volume flow rate, both measurements being corrected to standard conditions by the methods given in Annex D

3.1.21
standard discharge condition
condition of the compressed gas at the standard discharge point of the compressor

3.1.22
standard discharge point
discharge point considered representative of each compressor

NOTE This point varies with compressor design and type of installation:

a) for a bare compressor, it is generally at the compressor discharge flange:

1) reciprocating type compressors: discharge flange of the last (or only) stage cylinder or any chamber fitted as standard to that cylinder to reduce pulsations in the delivered compressed gas and so indicated by the manufacturer in the sales data for the particular type of compressor;

2) rotary type compressors: discharge flange of the last (or only) rotor casing;

b) for a packaged compressor, it is the terminal outlet of the package.

3.1.23
standard inlet condition
condition of the aspirated gas at the standard inlet point of the compressor

3.1.24
standard inlet point
inlet point considered representative of each compressor and which varies with compressor design and type of installation

NOTE 1 For a bare compressor, it is generally the inlet flange to the first (or only) stage cylinder or rotor casing, i.e. after any inlet filter or silencing equipment which can normally be used for test purposes, unless otherwise identified.

NOTE 2 The standard inlet point of a packaged air compressor, unless otherwise indicated by the manufacturer, is the point at which ambient air enters the package or, in the case of a non-enclosed package, where air first enters the confines of the machine, probably the air inlet filter.

3.1.25
swept volume of a displacement compressor
volume swept in one revolution by the compressing element(s) of the compressor's first stage

3.1.26
turn-down ratio
ratio expressed in percentage of the difference between maximum and minimum speed divided by the maximum speed of the main driver

3.2 Pressure

3.2.1
absolute pressure
pressure measured from absolute zero, i.e. from an absolute vacuum, equal to the algebraic sum of atmospheric pressure and effective pressure

3.2.2
ambient pressure
absolute pressure of the atmospheric air measured in the vicinity of the compressor

3.2.3
atmospheric pressure
absolute pressure of the atmospheric air measured at the test place

3.2.4
discharge pressure
total mean absolute pressure at the standard discharge point

NOTE The total absolute pressure can be replaced by the static absolute pressure, provided that the dynamic pressure is less than 0,5 % of the static pressure.

3.2.5
dynamic pressure
velocity pressure
total pressure minus the static pressure

3.2.6
effective pressure
gauge pressure
pressure measured above the atmospheric pressure

3.2.7
inlet pressure
total mean absolute pressure at the standard inlet point

3.2.8
static pressure
pressure measured in a gas in such a manner that no effect on measurement is produced by the gas velocity and which, in stationary gas, is numerically equal to the total pressure

3.2.9
total pressure
pressure measured at the stagnation point when a gas stream is brought to rest and its kinetic energy is converted by an isentropic compression from the flow condition to the stagnation condition

3.3 Temperature

3.3.1
ambient temperature
total temperature of the atmospheric air in the vicinity of the compressor, but unaffected by it

3.3.2
discharge temperature
total temperature at the standard discharge point of the compressor

3.3.3
inlet temperature
total temperature at the standard inlet point of the compressor

3.3.4
total temperature
temperature that would be measured at the stagnation point if a gas stream were brought to rest and its kinetic energy converted by an isentropic compression from the flow condition to the stagnation condition

3.4 Flow rate

3.4.1
actual volume flow rate of a compressor
actual volume flow rate of gas, compressed and delivered at the standard discharge point, referred to conditions of total temperature, total pressure and composition prevailing at the standard inlet point

NOTE Composition can refer to humidity, for instance.

3.4.2
free air
air at the ambient conditions of the compressor, but unaffected by it

3.4.3
standard volume flow rate
actual volume flow rate of compressed gas as delivered at the standard discharge point but referred to standard inlet conditions (for temperature, pressure and inlet gas composition)

3.5 Power

3.5.1
isentropic power
power that is theoretically required to compress an ideal gas under constant entropy, from a given inlet pressure to a given discharge pressure, in multi-stage compression

NOTE The theoretical isentropic power required is the sum of the isentropic power required at all the stages.

3.5.2
isothermal power
power that is theoretically required to compress an ideal gas under constant temperature, in a compressor free from losses, from a given inlet pressure to a given discharge pressure

3.5.3
packaged compressor power input
⟨electrically driven machines⟩ sum of the electrical power inputs to the prime mover and any ancillaries and auxiliaries driven from the compressor shaft or by a separate prime mover at rated supply conditions, including the effect of all equipment included in the package

NOTE 1 Auxiliaries include oil pump, cooling fan and integral compressed air dryer.

NOTE 2 Rated supply conditions refer to phase, voltage, frequency and ampere capability.

3.5.4
shaft power
power required at the compressor drive-shaft, 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

3.6 Efficiency

3.6.1
isentropic efficiency
ratio of the required isentropic power to shaft power

3.6.2
isothermal efficiency
ratio of the required isothermal power to shaft power

3.6.3
volumetric efficiency
ratio of the actual volume flow rate to the displacement of the compressor

3.7 Specific energy requirements

3.7.1
specific energy requirements of a bare compressor
shaft input power per unit of compressor actual volume flow rate

3.7.2
specific energy requirements of a packaged compressor
packaged compressor power input per unit of compressor actual volume flow rate

3.7.3
specific fuel consumption
specific steam consumption
fuel or steam mass flow per unit of compressor actual volume flow rate

3.8 Gas properties

3.8.1
compressibility factor
expression of the deviation of the real gas from an ideal gas

3.8.2
mixing ratio
ratio of mass of moisture contained in the gas to the mass of the dry gas

3.8.3
relative vapour pressure
ratio of the partial pressure of a vapour to its saturation pressure at the same temperature

4 Symbols

4.1 Symbols and units

Symbol	Term	SI unit	Other practical unit
A	Area	m^2	mm^2
b	Specific fuel consumption	kg/m^3	—
c	Velocity	m/s	—
e_m	Mass-specific energy requirement	J/kg	kJ/kg
e_V	Volume-specific energy requirement	J/m^3	J/l, kWh/m^3
E	Relative clearance volume	—	—
f	Parameter for uncertainty calculations	unit of symbol	—
F	Fuel consumption	kg/s	kg/h, g/s
G	Quality class	%	—
h	Level for liquid column	m	mm
H_1	Absolute inlet humidity	—	—

K	Correction factor	—	—
K_1	Correction factor for shaft speed		
K_2	Correction factor for tests where polytropic exponents for specified conditions and test conditions are different		
K_3	Correction factor for external coolant temperature		
K_4	Correction factor for shaft speed ($= K_1$)		
K_5	Correction factor for inlet pressure, polytropic exponent and pressure ratio		
K_6	Correction factor for isentropic exponent		
K_7	Correction factor for humidity in multi-stage compressors		
K_8	Correction factor for external coolant inlet temperature		
K_9	Correction factor for pressure ratio		
K_{10}	Correction factor for working liquid temperature		
K_{11}	Correction factor for gas inlet temperature		
K_{12}	Correction factor for shaft speed		
K_{13}	Correction factor for condensate formation		
m	Manufacturing tolerance		
M	Torque	N·m	—
n	Exponent for polytropic process in pV diagram	1	—
N	Rotational frequency (shaft speed)	s^{-1}	min^{-1}
p	Pressure	Pa	MPa (bar[a], mbar)
P	Power	W	MW, kW
q	Rate of flow	kg/s or m^3/s	kg/h or m^3/h, m^3/min, L/s
q_m	Mass rate of flow	kg/s	kg/h
q_V	Volume rate of flow	m^3/s	m^3/h, m^3/min, L/s
r	Pressure ratio	1	—
R	Gas constant	J/(kg·K)	—
t	Celsius temperature	°C	—
T	Thermodynamic temperature	K	—
V	Volume	m^3	L
$\overline{V}$	Absolute uncertainty	unit of symbol	—
W	Work	J	MJ, kJ, kWh
x	Mixing ratio	kg/kg	g/kg
z	Number of stages	1	—
Z	Compressibility factor	1	—
Δ	Difference of quantity		—
η	Efficiency	1	—
κ	Isentropic exponent	1	—
μ	Dynamic viscosity	Pa·s	kg/(m·s)
ρ	Mass density	kg/m^3	kg/L
τ	Relative uncertainty	1	—
φ	Relative vapour pressure	1	—
ω	Angular velocity	rad/s	—

[a] 1 bar = 0,1 MPa = 0,1 N/mm^2 = 10^5 N/m^2.

4.2 Subscripts

Subscript	Term	Remark
0	ambient condition	
1	inlet	Indicates the quantities measured at the standard inlet point of the compressor
2	discharge	Indicates the quantities measured at the standard discharge point of the compressor
a	absolute	
ab	absorbed	
ap	approximate	
av	average	
air	dry air	
b	atmospheric	Characterizes the atmospheric pressure and temperature
C	contractual	Indicates the quantities specified in the contract
cd	condensate	
co	coupling	
comb	combination	
corr	corrected	
corr, C	corrected to contractual requirements	
cr	critical	Characterizes the critical pressure and temperature
d	dynamic	Characterizes the dynamic pressure and properties
e	effective	
E	full-scale value	
el	electric	
f	flow measuring device	Without condensate
g	dry gas	
i	individual measurement in a series of n measurements	
in	internal	
int	intercooler temperature	Absolute temperature of air or gas leaving the intercooler under observation
L	working liquid	
m	mass	Characterizes the mass-specific rates of flow, energies and volumes
me	mechanical	
M	motor	
n	number of measurements in the series	
N	normal	
P	package	
pol	polytropic	Characterizes a polytropic process
r	reduced	Characterizes the reduced pressures and temperatures
R	reading	Indicates the quantities read during the test or predetermined as test conditions
res	resulting	
s	saturated	
S	isentropic	Characterizes an isentropic process
t	total	
T	isothermal	Characterizes an isothermal process
th	theoretical	
v	vapour	
V	volume	Characterizes the volume-specific rates of flow and energy
w	coolant	