INTERNATIONAL STANDARD

ISO 1217

Third edition
1996-09-15

Displacement compressors — Acceptance tests

Compresseurs volumétriques — Essais de réception

Reference number
ISO 1217:1996(E)

Contents

International Organization for Standardization
Case Postale 56 • CH-1211 Genève 20 • Switzerland

Printed in Switzerland

Annexes

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.

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.

International Standard ISO 1217 was prepared by Technical Committee ISO/TC 118, *Compressors, pneumatic tools and pneumatic machines*.

This third edition cancels and replaces the second edition (ISO 1217:1986), which has been technically revised.

Annexes A to D form an integral part of this International Standard. Annexes E, F and G are for information only.

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 as in annex A.

This International Standard specifies the operating and testing conditions which shall be agreed between the manufacturer and purchaser when a full performance test is specified.

For air compressors manufactured in batches or in continuous production quantities and sold against performance data published in manufacturers' sales, literature tests as described in annexes B, C and D are considered equivalent alternatives.

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. 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 shall be agreed between the manufacturer and purchaser at the contractual stage or certainly prior to the execution of the tests. This International Standard specifies methods for determining the value of such tolerances.

Annex E of this International Standard specifies standard inlet conditions for reference purposes.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 2602:1980, *The interpretation of test results — Estimation of the mean — Confidence interval.*

ISO 2854:1976, *Statistical interpretation of data — Techniques of estimation and tests relating to means and variances.*

ISO 3046-1:1995, *Reciprocating internal combustion engines — Performance — Part 1: Standard reference conditions, declarations of power, fuel and lubricating oil consumptions, and test methods.*

ISO 5167-1:1991, *Measurement of fluid flow by means of pressure differential devices — Part 1: Orifice plates, nozzles and Venturi tubes inserted in circular cross-section conduits running full.*

ISO 5941:1979, *Compressors, pneumatic tools and machines — Preferred pressures.*

ISO 9300:1990, *Measurement of gas flow by means of critical flow Venturi nozzles.*

IEC 46:1962, *Recommendations for steam turbines — Part 2: Rules for acceptance tests (now withdrawn).*

IEC 51-1:1984, *Direct acting indicating analogue electrical measuring instruments and their accessories — Part 1: Definitions and general requirements common to all parts.*

IEC 584-1:1995, *Thermocouples — Part 1: Reference tables.*

IEC 584-2:1982, *Thermocouples — Part 2: Tolerances.*

IEC 584-3:1989, *Thermocouples — Part 3: Extension and compensating cables — Tolerances and identification system.*

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1 General

3.1.1 acceptance test: Performance test carried out in accordance with this International Standard.

3.1.2 displacement compressor: Machine where a static pressure rise is obtained 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.

NOTE 1 For the definition of a liquid-ring compressor, see annex A.

3.1.3 swept volume of a displacement compressor: Volume swept in one revolution by the compressing element(s) of the compressor's first stage.

3.1.4 displacement of a displacement compressor: Volume swept by the compressing element(s) of the compressor's first stage per unit of time.

3.1.5 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.

3.1.6 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.

3.1.7 liquid injected rotary compressors: Rotary compressor in which a liquid is injected into the gas stream before or in the compressor.

3.1.8 packaged compressor: Compressor with prime mover, transmission, fully piped and wired internally which may also include ancillary and auxiliary items of equipment and may be a stationary or mobile (portable) unit.

3.1.9 clearance volume: Volume inside the compression space, which contains gas trapped at the end of the compression cycle.

3.1.10 relative clearance volume: Ratio of clearance volume of the stage under consideration to the swept volume of the compressing element of this stage.

3.1.11 standard inlet point: Inlet point considered representative for each compressor and which varies with compressor design and type of installation.

NOTES

2 The standard inlet point of a bare compressor is generally at the inlet flange.

3 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.

3.1.12 standard inlet condition: Condition of the aspirated gas at the standard inlet point of the compressor.

3.1.13 standard discharge point: Discharge point considered representative for each compressor. This point varies with compressor design and type of installation.

NOTES

4 The standard discharge point of a bare compressor is generally at the compressor discharge flange.

5 The standard discharge point of a packaged air compressor is the terminal outlet.

3.1.14 standard discharge condition: Condition of the compressed gas at the standard discharge point of the compressor.

3.1.15 intercooling: Removal of heat from a gas between stages.

3.1.16 aftercooling: Removal of heat from a gas after the compression is completed.

3.1.17 external coolant: Medium externally supplied to the compressor to which the generated heat is finally rejected; usually ambient air or cooling water.

3.1.18 polytropic process: Compression or expansion process of an ideal gas in which the relation between pressure and volume follows the equation

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

The exponent n can have various values. For example:

$$pV = \text{constant}$$

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

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

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

NOTE 6 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.

3.1.19 ideal multi-stage compression: Process when a perfect gas is isentropically compressed and the gas inlet temperature as well as the amount of work spent is the same for each stage.

3.1.20 shaft rotational speed: Number of revolutions of the compressor drive shaft per unit of time.

3.1.21 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 these two.

$$\text{Shaft-speed irregularity} = 2\frac{n_{\text{max}} - n_{\text{min}}}{n_{\text{max}} + n_{\text{min}}}$$

3.2 Pressures

3.2.1 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.

3.2.2 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.

3.2.3 dynamic (velocity) pressure: Total pressure minus the static pressure.

3.2.4 atmospheric pressure: Absolute pressure of the atmospheric air measured at the test place.

3.2.5 ambient pressure: Absolute pressure of the atmospheric air measured in the vicinity of the compressor.

3.2.6 effective (gauge) pressure: Pressure measured above the atmospheric pressure.

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

3.2.8 inlet pressure: Total mean absolute pressure at the standard inlet point.

3.2.9 discharge pressure: Total mean absolute pressure at the standard discharge point.

NOTE 7 The total absolute pressure may be replaced by the static absolute pressure provided that the dynamic pressure is less than 0,5 % of the static pressure.

3.3 Temperatures

3.3.1 total temperature: Temperature which 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.

3.3.2 inlet temperature: Total temperature at the standard inlet point of the compressor.

3.3.3 discharge temperature: Total temperature at the standard discharge point of the compressor.

3.3.4 ambient temperature: Total temperature of the atmospheric air in the vicinity of the compressor but unaffected by it.

3.4 Flow rates

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 (e.g. humidity) prevailing at the standard inlet point.

NOTE 8 The expression "actual capacity" should be avoided as it may be confusing.

3.4.2 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).

NOTE 9 The expression "standard capacity" should be avoided as it may be confusing.

3.4.3 free air: Air at the ambient conditions of the compressor but unaffected by it.

3.5 Powers

3.5.1 isothermal power: Power which 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.

3.5.2 isentropic power: Power which 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, the theoretical isentropic power required is the sum of the isentropic power required at all the stages.

3.5.3 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.

3.5.4 packaged compressor power input (relates to electrically driven machines only)**:** Sum of the electrical power inputs to the prime mover and any ancillaries and auxiliaries (e.g. oil-pump, cooling fan, integral compressed air dryer, etc.) driven from the compressor shaft or by a separate prime mover at rated supply conditions (e.g. phase, voltage, frequency and ampere capability) including the effect of all equipment included in the package.

3.6 Efficiencies

3.6.1 isothermal efficiency: Ratio of the required isothermal power to shaft power.

3.6.2 isentropic efficiency: Ratio of the required isentropic 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 (or steam) consumption: Fuel (or steam) mass flow per unit of compressor actual volume flow rate.

3.8 Gas properties

3.8.1 compressibility factor: Factor expressing the deviation of the real gas from an ideal gas.

3.8.2 relative vapour pressure: Ratio of the partial pressure of a vapour to its saturation pressure at the same temperature.

3.8.3 absolute humidity: Ratio of mass of moisture contained in the gas to the mass of the dry gas.

4 Symbols

4.1 Symbols and units

Symbol	Term	SI unit	Other practical units
A	Area	m^2	mm^2
b	Specific fuel consumption	kg/m^3	—
c	Velocity	m/s	—
e	Relative clearance volume	1	—
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
K	Correction factor	1	—
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, mbar
P	Power	W	MW, kW
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
$\bar{V}$	Absolute uncertainty	unit of symbol	—
W	Work	J	MJ, kJ, kWh
w_m	Mass specific energy requirement	J/kg	kJ/kg
w_V	Volume specific energy requirement	J/m^3	J/l, kWh/m^3
x	Absolute humidity	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	—

4.2 Subscripts

Subscript	Term	Remarks
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 pressures and temperatures.
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 pressures and temperatures.
d	dynamic	Characterizes the dynamic pressures and properties.
e	effective	
E	full-scale value	
el	electric	
f	flow measuring device	Without condensate.
g	gas	
i	individual measurement in a series of n measurements	
in	internal	
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	packaged	
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	

Subscript	Term	Remarks
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	

5 Measuring equipment, methods and accuracy

5.1 General

The equipment and methods given in this International Standard are not intended to restrict the use of other equipment and methods with the same or better accuracy. Where an International Standard exists, relating to a particular measurement or type of instrument, any measurements made or instruments used shall be in accordance with such a standard.

All inspection, measuring, test equipment and devices that can affect the test shall be calibrated and adjusted at prescribed intervals, or prior to use, against certified equipment having a known valid relationship to nationally recognized standards.

5.2 Measurement of pressure

5.2.1 General

5.2.1.1 Pressure taps in the pipe or receiver shall be normal to, and flush with, the inside wall.

NOTE 10 For low pressures or high flow velocities, it should be noted that minor irregularities such as burrs can lead to serious errors.

5.2.1.2 Connecting piping to gauges shall be as short as possible. Tightness shall be tested and all leaks eliminated.

5.2.1.3 Connecting piping shall be leak-free, as short as possible, and of sufficient diameter and so arranged as to avoid blockage by dirt or condensed liquid. For measurement of liquid pressure or pressure of liquid-gas mixtures, the instrument shall be mounted at the same height as the measuring point and the connecting piping shall be arranged so that the height of liquid columns in the piping exerts no influence. Otherwise account shall be taken of the difference in height. Tightness shall be tested and all leaks eliminated.

5.2.1.4 Instruments shall be mounted so that they are not susceptible to disturbing vibrations.

5.2.1.5 The measuring instrument (analogue or digital) shall have an accuracy of ± 1 % at the measured value.

5.2.1.6 The total pressure is the sum of the static and the dynamic pressures. It can be measured with a Pitot tube having the axis parallel to the flow. When the dynamic pressure is less than 5 % of the total pressure, it can be calculated on the basis of a calculated average velocity.

5.2.1.7 If the amplitudes of low frequency (< 1 Hz) pressure waves in the inlet pipe or the discharge pipe are found to exceed 10 % of the prevailing average absolute pressure, the piping installation shall be corrected before proceeding with the test.

Where the amplitudes of such pressure waves exceed 10 % of the specified average inlet or discharge pressures, a test shall not be undertaken under the requirements of this International Standard unless agreed to in writing by the parties to the test.

5.2.1.8 Transmitters and gauges shall be calibrated under pressure and temperature conditions similar to those prevailing during the test, using dead-weight or electrical testing equipment of an equivalent accuracy.

5.2.1.9 Column readings and dead-weight gauges shall be corrected for the gravitational acceleration at the location of the instrument.

5.2.1.10 Column readings shall be corrected for ambient temperature.

5.2.1.11 In case of low frequency (< 1 Hz) flow pulsations, a receiver with inlet throttling shall be provided between the pressure tap and the instrument.

5.2.1.12 Oscillations of gauges shall not be reduced by throttling with a valve placed before the instrument. However, a restricting orifice may be used.

5.2.2 Atmospheric pressure

The atmospheric pressure shall be measured with a barometer having an accuracy better than ± 0,15 %.

5.2.3 Intercooler pressure

Intercooler pressure shall be measured immediately after any intercooler.

5.3 Measurement of temperature

5.3.1 Temperature shall be measured by certified or calibrated instruments such as thermometers, thermoelectrical instruments, resistance thermometers or thermistors having an accuracy of ± 1 K inserted into the pipe or into pockets.

5.3.2 Thermometer pockets shall be as thin, and their diameters as small as is practical, with their outside surface substantially free from corrosion or oxide. The pocket shall be partially filled with a suitable liquid.

5.3.3 The thermometers or the pockets shall extend into the pipe to a distance of 100 mm, or one-third the diameter of the pipe, whichever is less.

5.3.4 When taking readings, the thermometer shall not be lifted out of the medium being measured nor out of the pocket when such is used.

5.3.5 Precautions shall be taken to ensure

a) that the immediate vicinity of the insertion point and the projecting parts of the connection are well insulated so that the pocket is virtually at the same temperature as the medium being observed;

b) that the sensor of any temperature measuring device or thermometer pocket is well swept by the medium (the sensor or thermometer pocket shall point against the gas stream; in extreme cases a position perpendicular to the gas stream may be used);

c) that the thermometer pocket does not disturb the normal flow.

5.3.6 Thermocouples shall have a welded hot junction and shall be calibrated together with their wires for the anticipated operating range. They shall be made of material suitable for the temperature and the gas being measured. If thermocouples are used with thermometer pockets, the hot junction of the couple shall, where possible, be welded to the bottom of the pocket. For further information on the selection and use of thermocouples reference should be made to publications IEC 584-1, IEC 584-2 and IEC 584-3.

5.4 Measurement of humidity

If the gas contains moisture, the humidity shall be checked during the test. The humidity shall be measured at the standard inlet point with an instrument having an accuracy of ± 3 % or better.

5.5 Measurement of rotational frequency

Shaft speed shall be determined by the use of methods having an accuracy of ± 0,5 % or better.

5.6 Measurement of flow rate

5.6.1 The actual delivered flow rate of the compressor shall be measured by performance of a test as indicated in ISO 5167 or ISO 9300.

Measurement of the aspirated volume flow rate may by used:

— when measurement of delivered volume flow rate is not practical;

— if leakage flows can be measured separately and are then deducted from the aspirated volume flow rate;

— where it can be confirmed that there is no external leakage of compressed gas from the compressor as is the case with liquid-injected rotary compressors;

— where effects of condensation of components of intake gas give rise to possible inaccuracy of measurement of delivered volume flow rate (see 6.5.5 and 6.6).

NOTE 11 For a volume flow rate below the range of ISO 5167 and ISO 9300 an alternative method may be agreed between manufacturer and customer.

5.6.2 The external coolant flow shall be determined by a measuring method with an accuracy of ± 5 % of the measured value or better.

5.7 Measurement of power and energy

5.7.1 The power input to the compressor shall be measured directly by reaction mounted drivers, or a torque meter, or indirectly determined from measurements of electrical input to a calibrated driving motor or from the certified performance characteristics of a driving prime mover.

5.7.2 The measurement of the shaft power of the prime mover shall be made according to a recognized test code.

5.7.3 Precision torque meters shall not be used below one-third of their rated torque. They shall be calibrated after the test with the torsion member at the same temperature as during the test. Readings shall be made with a series of increasing loads with the precaution that, during the taking of readings with increasing loads, the load shall at no time be decreased.

Similarly, when readings are made with decreasing loads, the load shall at no time be increased. The calculation of output shall be based on the average of the increasing and decreasing loads as determined by the calibration. If the torque difference between increasing and decreasing loads exceeds 1 %, the torque meter is unsatisfactory.

5.7.4 The shaft power of an electrically driven compressor shall be determined by measuring the electrical power supplied and multiplying by the motor efficiency value obtained from the certified calibration of the motor. Only precision instruments shall be used. Power, voltage and current shall be measured.

The voltage coils of the instruments shall be connected immediately before the terminals of the motor, so that voltage drop in cables will not affect the measurement. If remote instruments are used, the voltage drop shall be determined separately and taken into consideration (see IEC Publication 51). Factors influencing the measurement such as voltage drop in supply cables or measurement systems shall be taken into account.

5.7.5 Electric power of the machine shall be referred to the electrical input terminals. Factors influencing the measurement such as voltage drop in supply cables or measurement systems shall be taken into account.

5.7.6 For three-phase motors, the two-wattmeter method or some other method with similar accuracy shall be used.

5.7.7 Current and voltage transformers shall be chosen to operate as near their rated load as possible so that their ratio error will be minimized.

For checking purposes it may be convenient to have a recently adjusted kWh-meter connected to the circuit during the test.

5.8 Miscellaneous measurements

5.8.1 Fuel consumption

If the compressor is driven by an internal combustion engine or gas turbine, the mean fuel consumption shall be determined by weighing or by measuring the volume of the fuel consumed per unit of time while running at the constant conditions of a particular test point (see ISO 3046-1).

5.8.2 Steam consumption

If the compressor is driven by a steam engine or turbine, the steam rate shall be determined by a recognized code (see IEC Publication 46).

5.8.3 Gas composition

When tests are performed with gases other than air, the chemical composition and the physical properties of the gas entering the compressor during the tests shall be determined and if necessary checked at regular intervals.

5.8.4 Condensation rate

The condensate collected in aftercoolers, receivers and other places after the discharge flange, but before the flow measuring device, shall be measured.

Before and after every test, the condensate shall be drained from the intercoolers and their separators in such a way that the steady state of the compressor is not disturbed. The separated quantities shall be weighed for every cooler and divided by the time since the preceding draining operation.

NOTE 12 Any oil carried over with the condensate should be separated from the condensate before the mass of the latter is measured.

5.9 Calibration of instruments

Calibration records of the instruments shall be available prior to the test.

Recalibration after the test shall be made for those instruments of primary importance which are liable to variation in their calibration as a result of use during the test.

Any change in the instrument calibrations which will create a variation exceeding the class of accuracy of the instrument may be a cause for rejecting the test.