

Displacement compressors — Acceptance tests

ICS 23.140

National foreword

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Displacement compressors — Acceptance tests

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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

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

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 given inlet conditions to a given discharge pressure

Note 1 to entry The term “ideal gas” is used to indicate any gas in a condition or state so that it follows closely the ideal gas law. 

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

isotropic efficiency

ratio of the required isentropic power to measured power for the same specified boundaries with the same gas and the same inlet conditions and outlet pressure

$$\eta_{\text{isen}} = \frac{P_{\text{isen}}}{P_{\text{real}}}$$

Note 1 to entry Examples of specified boundaries may be shaft power of bare compressor or motor power of the package including inlet and discharge losses or total input power of the package.

Note 2 to entry In many turbo compressor textbooks, the adiabatic stage gas power $P_i = \Delta h \cdot q_m = (h_2 - h_1) \cdot q_m$ is taken

as P_{real} . Isentropic efficiency is then defined as $\eta_{\text{isen}} = \frac{P_{\text{isen}}}{\Delta h \cdot q_m} = \frac{\Delta h_{\text{isen}}}{\Delta h}$. In this special case, the most narrow boundaries

are used which are enclosing only the gas volume. In this sense, it corresponds with the formula for isentropic efficiency given in ISO 5389:2005, Formula (E.101). ^(A1)

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	$\text{N}\cdot\text{m}$	—
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	$\text{J}/(\text{kg}\cdot\text{K})$	—
t	Celsius temperature	$^{\circ}\text{C}$	—

T	Thermodynamic temperature	K	—
V	Volume	m ³	L
$\bar{V}$	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	

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 relating to a particular measurement or type of instrument exists, any measurements carried out or instruments used shall be in accordance with such an International 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

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

NOTE For low pressures or high flow velocities, minor irregularities such as burrs can lead to serious error.

Connecting piping shall be leak-free, as short as possible, of sufficient diameter and arranged so 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.

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

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

The total pressure is the sum of the static and the dynamic pressures. It shall 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 should be calculated on the basis of a calculated average velocity.

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 in accordance with the requirements of this International Standard shall not be carried out.

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.

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

Column readings shall be corrected for ambient temperature.

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

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 $\pm 0,15\%$.

5.2.3 Intercooler pressure

Intercooler pressure shall be measured immediately after any intercooler.

5.3 Measurement of temperature

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

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.

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.

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

Precautions shall be taken to ensure that the:

- a) 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) 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) thermometer pocket does not disturb the normal flow.

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. The selection and use of thermocouples shall be in accordance with IEC 60584-1, IEC 60584-2 and IEC 60584-3.

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 $\pm 3\%$ or better.

5.5 Measurement of rotational frequency

Shaft speed shall be determined by using methods that have an accuracy of $\pm 0,5\%$ or better.

5.6 Measurement of flow rate

The actual delivered flow rate of the compressor shall be measured by performing a test as indicated in ISO 5167-1 or ISO 9300.

Measurement of the aspirated volume flow rate may be 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);
- where aspirated air is measured, in which case the measurement device should not restrict the measurement.

The external coolant flow shall be determined by using a measuring method with an accuracy of $\pm 5\%$ of the measured value or better.

5.7 Measurement of power and energy

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.

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

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.

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 60051-1). Factors influencing the measurement, such as voltage drop in supply cables or measurement systems, shall be taken into account.

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.

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

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

For checking purposes, a recently adjusted kWh-meter may be 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 a gas turbine, the mean fuel consumption shall be determined by weighing or 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 in accordance with IEC 60953-2.

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.

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 carried out 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 cause for rejecting the test.

6 Test procedures

6.1 General

Before acceptance tests begin, the compressor shall be examined to ascertain whether or not it is in a suitable condition to undergo an acceptance test. External leakage shall be eliminated as far as possible. In particular, the pipe systems shall be checked for leakage.

All parts likely to accumulate deposits, particularly the coolers, shall be clean both on the gas and coolant sides.

6.2 Test arrangements

Test arrangements are the following.

- a) Preliminary tests may be run for the purposes of, for example
 - checking instruments, and
 - training personnel.
- b) A preliminary test may, by agreement, be considered the acceptance test, provided that all requirements for an acceptance test have been met.
- c) During the test, all measurements having any bearing on the performance shall be carried out. The determination of the flow rate and the power absorbed by the compressor are covered in detail in 6.3 to 6.9.
- d) The test conditions shall be as close as reasonably possible to the conditions of guarantee; deviations from these shall not exceed the limits specified in Table 1. If no inlet conditions have been agreed, then the provisions of Annex F shall apply.
- e) Where it is not feasible to test a machine with the gas intended to be used with the compressor under test or within the limitations specified in Table 1, alternative test conditions or alternative corrections shall be identified.
- f) The governing mechanism shall be maintained in its normal operating condition.
- g) During the test, the lubricant and the rate of feed shall comply with the operating instructions.
- h) During the test, no adjustments other than those required to maintain the test conditions and those required for normal operation, as given in the instruction manual, shall be made.
- i) Before readings are taken, the compressor 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.
- j) However, should the test conditions be such that systematic changes cannot be avoided, or if individual readings are subject to great variations, then the number of readings shall be increased.
- k) For each load, a sufficient number of readings shall be taken to indicate that steady-state conditions have been reached. The number of readings and the intervals shall be chosen to obtain the required accuracy.
- l) After the test, the compressor plant and the measuring equipment shall be inspected. Should any faults be found that could have affected the test results, a further test shall be run after these faults have been corrected.

Table 1 — Maximum deviations from specified values and fluctuations from average readings

Measured variable	Maximum permissible deviations	Maximum permissible fluctuation from average during any set of readings
Inlet pressure, p_1	$\pm 10 \%$	$\pm 1 \%$
Discharge pressure, p_2	Not specified	$\pm 1 \%$
Pressure ratio, r	See 8.3.1	—
Inlet temperature, T_1	Not specified	$\pm 2 \text{ K}$
Absolute inlet humidity, H_1	Not specified	$\pm 5 \%$
Isentropic exponent, κ	$\pm 3 \%$	Not specified

Table 1 (continued)

Measured variable	Maximum permissible deviations	Maximum permissible fluctuation from average during any set of readings
Gas constant $\times$ compressibility factor, $R \times Z$	$\pm 5 \%$	Not specified
Shaft speed, N	$\pm 4 \%$	$\pm 1 \%$
Liquid injection temperature ^a	$\pm 5 \text{ K}$	Not specified
Difference between inlet temperature of external coolant and the gas inlet temperature	$\pm 10 \text{ K}$ For coolant air $\pm 5 \text{ K}$ For coolant liquid	$\pm 2 \text{ K}$ $\pm 2 \text{ K}$
External coolant flow	$\pm 10 \%$	$\pm 10 \%$
Temperature at the nozzle or orifice plate	Not specified	$\pm 2 \text{ K}$
Differential pressure over nozzle or orifice plate	Not specified	$\pm 2 \%$
^a For internally cooled, liquid-injected rotary compressors.		
NOTE 1 The test can be performed if the deviations from the specified conditions are equal to or less than the deviation tolerances.		
NOTE 2 If the deviation from test conditions results in a deviation in absorbed power higher than $\pm 10 \%$, then the test is not within the limits.		
NOTE 3 See 5.2.1.		
NOTE 4 A test at a shaft speed different from the specified value is not accepted if resonant pressure pulsations exceed permitted levels.		
NOTE 5 For the test of a gas compressor with a gas different from that specified, a bigger variation in gas properties often occurs. This is agreed upon by both parties.		
NOTE 6 For liquid-ring compressors, see also Table A.1.		

6.3 Evaluation of readings

Before final calculations are undertaken, the recorded data shall be scrutinized for consistency of operating conditions. The fluctuations of readings during one test shall not exceed the limits given in Table 1.

All accepted readings from any test run shall be consecutive.

Sets of readings showing excessive fluctuation may be discarded, but only at the beginning or end of a test run. All readings in any set shall be taken as near as possible to one another.

The moisture content shall be determined at the standard inlet point, according to 5.4. The moisture content for the different compression stages and at the flow measuring device shall then be determined from condensate measurements.

6.4 Computation of test results

Computation of the test results shall be in accordance with the following.

- Test results, except those for flow measurements, shall be calculated from the arithmetic average values of the accepted readings.
- The mass flow rate shall be determined according to 5.6.
- When the gas being compressed is not dry, the influence of the moisture shall be taken into account by correcting the absorbed power.
- The actual volume flow rate at the inlet is obtained by converting the gas flow measured through the measuring device from the condition there to the condition at the standard inlet point, due consideration being paid to any separated moisture according to 6.5.4 and 6.6.

- e) Some unloading systems exhaust warm gas back to inlet at part load conditions. The inlet temperature thus becomes higher at part load than at full load, whereby the volume flow rate apparently seems to attain a higher value. In such cases, the part load flow rate is calculated with the inlet temperature valid for full load.
- f) Test conditions are never exactly consistent with specified conditions. Therefore, before test results and specified values are compared, corrections shall be applied to volume flow rate and absorbed power.
- g) Within the limits specified in Table 1, this International Standard provides for adjustment of the volume flow rate and the absorbed power when the test conditions deviate from those specified. The volume flow rate shall be adjusted for deviation in shaft speed, isentropic or polytropic exponent, external coolant temperature and discharged condensate. The absorbed power shall be adjusted for deviation in speed, inlet pressure, isentropic or polytropic exponent, humidity effects and external coolant temperature.

NOTE 1 Other corrections, such as correction for gas constant and the compressibility factor, can be made.

- h) Outside the limits specified in Table 1, the influence of the actual operating conditions on the performance of the actual compressor shall be determined by a method of variation so that the size of each correction to the specified operating conditions can be determined by interpolation or, in extreme cases, by extrapolation.

NOTE 2 Such corrections are agreed upon by the parties concerned.

- i) For process compressors where certain amounts of compressed medium are injected or extracted between the stages, the specific energy concept is meaningless and shall be replaced by the power input to the compressor shaft.
- j) If the test is carried out with a gas different from the one specified, a correction shall be made. A change in the gas constant will affect the leakage and hence the volume flow rate.

NOTE 3 Such corrections are agreed upon by the parties concerned.

6.5 Volume flow rate corrections

6.5.1 Correction factor for shaft speed, K_1

The correction factor for shaft speed, K_1 , is calculated using Equation (2):

$$K_1 = \frac{N_C}{N_R} \quad (2)$$

6.5.2 Correction factor for tests where polytropic exponents for specified conditions and test conditions are different, K_2

The correction factor for tests where polytropic exponents for specified conditions and test conditions are different, K_2 , can be neglected, except for when testing single-stage reciprocating compressors. In such machines, a change in the polytropic exponent and in the pressure ratio will influence the volume flow rate as the expansion of the gas trapped in the clearance volume is affected. Since the degree of this influence is not fully known, it is important that the compressor be operated as near to the specified pressure ratio as possible.

For differences within the limits given in Table 1, Equation (3) shall apply:

$$K_2 = \frac{1 - E \left(r_C^{1/n_C} - 1 \right)}{1 - E \left(r_R^{1/n_R} - 1 \right)} \quad (3)$$