INTERNATIONAL STANDARD 1217

INTERNATIONAL ORGANIZATION FOR STANDARDIZATION •МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ПО СТАНДАРТИЗАЦИИ •ORGANISATION INTERNATIONALE DE NORMALISATION

Displacement compressors — Acceptance tests

Compresseurs volumétriques — Essais de réception

First edition — 1975-04-01

UDC 621.51.001.41 **Ref. No. ISO 1217-1975 (E)**

Descriptors : compressors, tests, acceptability, power measurement, capacity, flow measurement, pressure measurement, testing conditions, error, definitions.

Price based on 84 pages

FOREWORD

ISO (the International Organization for Standardization) is a worldwide federation of national standards institutes (ISO Member Bodies). The work of developing International Standards is carried out through ISO Technical Committees. Every Member Body interested in a subject for which a Technical Committee has been set up 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.

Draft International Standards adopted by the Technical Committees are circulated to the Member Bodies for approval before their acceptance as International Standards by the ISO Council.

International Standard ISO 1217 (originally draft No. 1115) was drawn up by Technical Committee ISO/TC 118, *Compressors, pneumatic tools and pneumatic machines.*

Draft No. 1115 (which did not include annexes C, D, E and G) was circulated to the Member Bodies in October 1967. It has been approved by the Member Bodies of the following countries :

Australia	Germany	Sweden
Belgium	Greece	Switzerland
Brazil	Ireland	Thailand
Canada	Israel	Turkey
Chile	Japan	United Kingdom
Czechoslovakia	Netherlands	U.S.S.R.
Egypt, Arab Rep. of	Poland	
France	South Africa, Rep. of	

No Member Body expressed disapproval of the document.

Annexes C, D, E and G of the document were circulated to the Member Bodies in October 1972. They have been approved by the Member Bodies of the following countries :

Belgium	Hungary	South Africa, Rep. of
Bulgaria	India	Sweden
Czechoslovakia	Ireland	Switzerland
Egypt, Arab Rep. of	Japan	Thailand
Finland	Mexico	Turkey
France	Netherlands	United Kingdom
Germany	Romania	U.S.S.R.

No Member Body expressed disapproval of these annexes.

The aim of this code for acceptance tests of displacement compressors is to standardize such tests so that results from different machines and obtained by different supervisors can be compared in a technically correct way, all to promote trade and fair competition in the field. The code can be applied entirely or in part, depending on the technical and economical conditions prevailing for every separate test (see annex C). It is recommended that type testing according to sub-clause C.2.2 be carried out and that in sales literature and tenders, measured performance values be given according to the supervisor's test report.

Printed in Switzerland

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Displacement compressors – Acceptance tests

1 SCOPE AND FIELD OF APPLICATION

Interpretation : A displacement compressor is a machine where a static pressure rise is obtained by allowing successive volumes of gas to be aspired into and exhausted out of a closed space by means of the displacement of a moving member.

This International Standard specifies methods for acceptance tests and technical conditions for the supply of displacement compressors. The absolute intake pressure should exceed approximately 100 Pa (1 mbar), thus including certain types of displacement vacuum pumps.

It gives detailed instructions on the measurement of capacity and power consumption and means of adjusting the measured values to guaranteed conditions.

NOTES

1 The main body of this International Standard gives detailed instruction regarding acceptance tests of displacement compressors. There is, however, also a practical need for somewhat simpler tests. Besides the acceptance test there exist also :

- type test,
- simplified test and
- endurance test.

Instructions for carrying out these latter classes of tests are given in annex C.

2 The International System of units (SI) is used in this International Standard. The fundamental units, metre, kilogram, second, ampere, kelvin (formerly degree Kelvin) and candela, are defined in ISO 1000.

Conversion factors for other unit systems are added to this International Standard, in order to facilitate the use of the International System. (See annex F.)

2 REFERENCES

ISO/R 541, *Measurement of fluid flow by means of orifice plates and nozzles.*

ISO 1000, *SI units and recommendations for the use of their multiples and of certain other units.*

ISO/R 1219, *Graphical symbols for hydraulic and pneumatic equipment and accessories for fluid power transmission.*

IEC Publication 46, *Recommendations for steam turbines – Part 2 : Rules for acceptance tests.*

IEC Publication 51, *Recommendations for indicating electrical instruments and their accessories.*

3 DEFINITIONS

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

3.1 total pressure : The pressure measured at the stagnation point when a moving gas stream is brought to rest and its kinetic energy is converted by an isentropic compression from the flow condition to the stagnation condition. It is the pressure usually measured by a Pitot tube. In a stationary body of gas the static and the total pressures are numerically equal.

3.2 static pressure : The pressure measured in a gas in such a manner that no effect on measurement is produced by the gas velocity.

3.3 dynamic (velocity) pressure : The total pressure minus the static pressure.

3.4 atmospheric pressure : The absolute pressure of the atmosphere measured at the test place.

3.5 gauge (effective) pressure : The pressure measured above the atmospheric pressure.

3.6 absolute pressure : The pressure measured from absolute zero, i.e. from an absolute vacuum. It equals the algebraic sum of atmospheric pressure and gauge pressure.

3.7 vacuum : The difference between the atmospheric pressure and the absolute pressure of the gas when the latter is the smaller.

3.8 standard inlet point : The inlet point considered representative for each compressor. This point varies with compressor design and type of installation.

NOTES

1 The standard inlet point of a stationary compressor is generally at the inlet flange (see G.2.5).

2 The standard inlet point of a portable air compressor is a point close to the compressor chosen so that the thermometer is unaffected by the compressor operation.

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

NOTES

1 The standard discharge point of a stationary compressor is generally at the compressor discharge flange.

2 The standard discharge point of a portable air compressor is the terminal outlet valve.

3.10 inlet pressure : The average absolute total pressure at the standard inlet point.

NOTE — The absolute total pressure may be replaced by the absolute static pressure provided that the velocity and density of the gas are comparatively low.

3.11 discharge pressure : The average absolute total pressure at the standard discharge point.

NOTE — The absolute total pressure may be replaced by the absolute static pressure provided that the velocity and density of the gas are comparatively low.

3.12 pressure ratio : The ratio of the discharge pressure to the inlet pressure.

NOTES

1 Stage pressure ratio is the pressure ratio for any particular stage in a multi-stage compressor, the discharge pressure being taken before the intercooler.

2 Overall stage pressure ratio is the pressure ratio for any particular stage in a multi-stage compressor, the discharge pressure being taken after the intercooler (including separator).

3.13 total temperature : The 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.

3.14 inlet temperature : The total temperature at the standard inlet point of the compressor.

3.15 discharge temperature : The total temperature at the standard discharge point of the compressor.

3.16 intercooling : The removal of heat from a gas between stages.

NOTE — Ideal intercooling prevails when the temperature of the gas leaving the intercoolers equals the temperature of the gas at the intake of the first stage.

3.17 aftercooling : The removal of heat from the gas after the compression is completed.

3.18 displacement of a compressor : The volume displaced by the compressing elements of the first stage per unit of time.

3.19 clearance volume : The volume inside a compression space, which contains gas trapped at the end of the compression cycle.

3.20 relative clearance volume : The ratio of clearance volume to the volume swept by the compressing element.

3.21 capacity of a compressor : The actual volume rate of flow 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 (see G.2.5).

3.22 capacity of a vacuum pump : The actual volume rate of flow of gas aspired and compressed by the first stage of a vacuum pump and referred to conditions of total temperature, total pressure and composition (e.g. humidity) prevailing at the standard inlet point.

NOTE — It is normally assumed that the final stage of the vacuum pump discharges to a pressure of 1 bar absolute.

3.23 free air : Air at the atmospheric conditions of the site and unaffected by the compressor.

3.24 volumetric efficiency : The ratio of capacity to displacement of a compressor or vacuum pump.

3.25 polytropic process : A compression or expansion process of an ideal gas in which the relation between pressure and volume follows the equation

$$pv^u = \text{constant}$$

The exponent u 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 — In some countries this process is called adiabatic, but to avoid confusion between adiabatic (no heat exchange with the surroundings) and reversible adiabatic (isentropic) processes it is called here isentropic.

3.26 compressibility factor Z : A factor expressing the deviation of the real gas from an ideal gas :

$$Z = \frac{pv}{RT}$$

3.27 shaft speed : The number of revolutions of the compressor drive shaft per unit of time.

3.28 shaft speed irregularity : The 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.

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

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

3.30 isothermal power consumption : The 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.

3.31 isentropic power consumption : The 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 consumption is calculated assuming ideal conditions.

3.32 shaft input (absorbed power) : The power required at the compressor drive shaft. Losses in external transmissions such as gears and belt drives are not included.

3.33 indicated power : The power calculated from indicator diagrams.

3.34 mechanical efficiency : The ratio of the indicated power to shaft input.

3.35 specific energy consumption : The shaft input per unit of compressor capacity.

3.36 isothermal efficiency : The ratio of the isothermal power consumption to shaft input.

3.37 isentropic efficiency : The ratio of the real gas isentropic power consumption to shaft input.

3.38 fuel (or steam) consumption : The mass flow rate of fuel (or steam) consumed by the prime mover.

3.29 specific fuel (or steam) consumption : The ratio of fuel (or steam) consumption to compressor capacity.

3.40 temperature-rise ratio : The ratio of the isentropic temperature rise to the measured total temperature rise during compression.

4 SYMBOLS AND ABBREVIATIONS

The use of the following letter symbols is recommended. The list is formulated in line with the following seven principles.

a) The same symbols shall be used for the same quantities regardless of the system of units.

b) For any one quantity a single symbol shall be used with subscripts to indicate readings other than the primary one.

c) The same symbols shall be used for a given concept regardless of the number of special values which occur.

d) Letter subscripts shall be used to denote values under special conditions.

e) Numerical subscripts shall be used to denote values at different points of a cycle.

f) Symbols shall be confined if possible to roman letters.

g) Where possible, capital letters shall be used for absolute quantities.

4.1 Roman letters

Symbol	Quantity	Units
A	area	m^2
c	specific heat capacity	J/(kg·K)
c	relative clearance volume	–
d	orifice diameter of the measuring device at operating condition	m, mm
d	relative density	–
D	internal diameter of measuring pipe at operating condition	m, mm
e	efficiency	–
f	frequency	Hz
F	specific fuel consumption	g/m^3
g	local gravitational acceleration	m/s^2
Ho	Hodgson's number	–
i	number of compression stages	–
j	degree of interruption	–

k	absolute roughness	mm
K	correction factor	–
m	area ratio	–
M	molecular mass	–
n	rotational frequency	rev/s, rev/min
p	pressure	Pa, bar
P	power	W, kW
q	volume rate of flow	l/s, m^3/s, m^3/h
Q	mass rate of flow	kg/s, kg/h
r	pressure ratio	–
R	gas constant	J/(kg·K)
Re	Reynolds number	–
t	temperature	°C
t	time	s, h
T	thermodynamic temperature, absolute temperature	K
u	exponent for polytropic process	–
U	reading	arbitrary
v	velocity	m/s
V	volume of conduit system between the compressor and the flow measuring device	l
x	absolute humidity	kg/kg dry gas
w	specific energy consumption	J/l
W	work	J
Z	compressibility factor	–

4.2 Greek letters

α	total flow coefficient	–
β	diameter ratio	–
ϵ	expansion factor	–
η	dynamic viscosity	Pa·s
κ	isentropic exponent NOTE – For ideal gases the ratio of specific heats and the isentropic exponent have the same value.	–
ν	kinematic viscosity	m^2/s
ρ	mass density	kg/m^3
τ	tolerance	–
φ	relative humidity	–
φ	phase angle	deg

4.3 Subscripts

0	ambient conditions
1	condition at standard inlet point
2	condition at standard discharge point
3	condition upstream of measuring device
4	condition downstream of measuring device
a	air (dry)
av	average value
B	barometric
c	contract
corr	corrected
D	diameter
fuel	fuel
g	gas
i	current
m	measured
max	maximum
min	minimum
p	pressure
r	reading
Re	Reynolds number
u	voltage
v	vapour
V	volume
w	water
w	wattmeter
wet	wet

Subscripts 1, 2, 3, I, II, III, etc., and a, b, c, etc. are further used to discriminate between different quantities of the same kind, as will appear from the following clauses.

5 MEASURING EQUIPMENT AND METHODS

The equipment and methods listed in this clause are only descriptive and not intended to restrict the use of other equipment with the same or better accuracy.

5.1 Measurement of temperature

5.1.1 Temperature shall be measured by certified or calibrated instruments such as thermometers, thermoelectric instruments, resistance thermometers or thermistors inserted into the pipe or into wells.

5.1.2 Mercury-in-glass thermometers shall have an etched stem.

5.1.3 The readings of the inlet temperature of the gas and the coolant must be with an error not exceeding ± 0,2 K.

Commercial or industrial metal-encased thermometers shall not be used for temperatures that will influence the fulfilment of the guarantee.

5.1.4 The inlet gas temperature shall be measured near the cylinder inlet flange or connection, but sufficiently distant to avoid radiation and conduction errors from cold or hot surfaces, as well as emission of hot gas from the suction valves.

5.1.5 Thermometer wells shall be as thin, and their diameters as small, as is practical, with their outside surface substantially free from corrosion or oxide. The well shall be partially filled with a suitable fluid.

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

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

5.1.8 The thermometer reading shall be corrected for the emergent stem according to the following formula :

$$t = t_r + l\,\gamma\,(t_r - t_{av})$$

where

t is the true temperature;

t_r is the actual temperature reading;

t_{av} is the average temperature of the emergent fluid column;

l is the length of the emerging fluid column, expressed in kelvins;

γ is the apparent expansion coefficient of the thermometer fluid (for mercury-in-glass, $\gamma = 1/6300$).

5.1.9 Precautions shall be taken to ensure

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

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

c) that the average gas velocity does not exceed 30 m/s at the point of measurement;

d) that the thermometer well does not disturb the normal flow.

5.1.10 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 materials suitable for the temperature and the gas being measured. The electromotive force of the thermocouple shall be indicated by a potentiometer-type instrument. The cold junction shall be established by a reference temperature bath.

If thermocouples are used with thermometer wells the hot junction of the couple shall, where possible, be welded to the bottom of the well.

5.2 Measurement of pressure

5.2.1 *General*

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

NOTE — For small pressures or high flow velocities it should be noted that minor irregularities such as burrs can give serious errors.

b) Connecting piping to gauges shall be as short as possible.

Tightness shall be tested (for example with soap solution), and all leaks eliminated.

c) Connecting piping to gauges shall be not less than 6 mm bore for pressure gauges and not less than 10 mm bore for vacuum gauges to minimize capillary effect in the piping.

Connecting piping shall also be so arranged that there are no traps where water can condense.

d) Instruments shall be mounted in a position free from harmful vibrations.

e) The diameter of the scale and the arrangement of the graduations shall permit accurate readings within ± 0,5 % of the pressure measurement. Dead-weight gauges shall have adjustable weights suitable for ± 0,2 % accuracy. Diaphragm gauges shall not be employed.

f) 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 shall be calculated on the basis of a calculated average velocity.

g) If pressure wave amplitudes measured 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 pressure waves exceed 10 % of the specified average inlet or discharge pressures, a test shall not be undertaken under the rules of this International Standard unless agreed to in writing by the parties to the test.

h) Gauges having Bourdon tubes shall be calibrated under pressure and temperature conditions similar to those prevailing during the test, using dead-weight test gauges before and after the tests.

i) Dead-weight gauges shall be examined to ensure that the piston moves freely. The diameter of the piston shall be measured and the weights shall be compared with authentic standards.

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

k) Column readings shall be corrected for the ambient temperature.

l) In cases of pulsating flow, a receiver with an inlet throttling hole shall be provided between the pressure tap and the manometer.

m) Oscillations of gauges shall not be reduced by throttling with a valve.

5.2.2 *Low pressure*

a) The atmospheric pressure shall be measured with a mercury barometer, which shall be read to the nearest 0,5 mm.

The temperature for correcting the barometer reading shall be read with an accuracy of 1 K.

A boiling manometer or a precision aneroid barometer may also be used but the accuracy shall be checked.

If a reliable barometer is not available, an approximation shall be obtained by using records of the nearest meteorological station, and correcting for the difference in altitude between the station and the compressor.

b) For sloping-limb and other amplifying instruments, the relation between the scale readings and the true water column length shall be determined previously by calibration against an absolute manometer of suitable sensitivity.

The inclination to the horizontal and the density of the manometer liquid shall be the same as for the calibration.

c) For all pressures of 0,2 MPa absolute, or below, manometers, columns or vacuum gauges shall be employed.

Closed mercury columns known as absolute vacuum gauges shall not be used.

Manometers or columns for low pressure measurements shall comprise glass tubing of not less than 10 mm bore for the single-limb type and not less than 6 mm bore for the double-limb U-type, with a scale clearly graduated to allow the column to be read to within 1 mm water column.

The manometers shall be filled with stable liquids of known mass density.

5.2.3 *Normal and high pressure*

For pressures above 0,2 MPa absolute, calibrated gauges with Bourdon tubes or dead-weight gauges, mercury manometers or their equivalent shall be employed.

5.2.4 *Inlet pressure*

The inlet pressure of an air compressor operating without intake pipe shall be measured by a barometer.

If an intake pipe is provided, the pressure shall be measured by a suitable instrument. The intake pipe used must be identical with that of the actual installation.

In cases of pulsating flow, a receiver volume with inlet throttling shall be provided between the manometer and the intake pipe (see also 5.2.1 l) and m)).

Vacuum pump inlet pressure may be determined by means of columns or manometers and shall be measured in a straight length of pipe as close as possible to the inlet flange of the machine.

5.2.5 *Intercooler pressure*

The intercooler pressure shall be measured after the intercooler. However, ± 1 % accuracy is sufficient.

5.2.6 *Discharge pressure*

The pressure tap shall be placed close to the standard discharge point of the compressor, if necessary on a pulsation damper with a throttling device connected before the manometer.

5.2.7 *Differential pressure*

The difference in pressure over the flow measuring device shall be measured with a fluid manometer. It shall be read with an accuracy of ± 0,2 %. The manometer tube shall normally have an inner diameter of at least 10 mm. For high operating pressures this dimension may, however, be diminished.

5.3 Measurement of delivered flow

If possible, the capacity shall be calculated from a measurement of the delivered flow. The best and most reliable method for this is given below.

The test shall be performed as indicated in ISO/R 541. It is necessary to ensure that all the requirements set forth in ISO/R 541 are completely fulfilled during the period of measurement. (For measurements when the flow is pulsating see annex A, clause A.1.)

5.4 Measurement of aspired flow

One object of a vacuum pump test is to determine the aspired volume. If possible, the capacity shall be calculated from a direct measurement. The best and most reliable method for this is given below.

For testing the capacity of a compressor, measurement of the aspired volume shall be used if measurement of the delivered volume is not practical and if the leakage losses can be measured separately.

Measurement of the aspired flow shall be performed as indicated in ISO/R 541. It is necessary to ensure that all the requirements set forth in ISO/R 541 are completely fulfilled during the period of measurement. (For measurements when the flow is pulsating, see annex A, clause A.5.)

5.5 Measurement of power

5.5.1 The measurement of the output of the prime mover or of the energy consumption shall be made according to existing test codes.

5.5.2 The power input shall, if possible, be measured by cradled electric dynamometers.

5.5.3 Cradled electric dynamometers shall not be used below one-tenth of their rated torque.

5.5.4 Torsion dynamometers 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. The calibration shall be conducted with the indicating means in place. Indicator 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 dynamometer is unsatisfactory.

5.5.5 In electrically driven compressors, the shaft input shall be determined by measuring the electrical power supplied and multiplying by the motor efficiency. Only precision instruments shall be used. Power as well as 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 must be used, the voltage drop shall be determined separately and taken into consideration. (See IEC Publication 51.)

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

5.5.7 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.

5.5.8 As a basis for the efficiency of the transmission, the following figures shall be used unless other reliable information is available :

— for properly lubricated precision gears	98 % for each step
— for flat belt drive	97 %
— for Vee-rope drive	95 %

5.6 Internal combustion engines

The relevant national standard of the home country of the compressor manufacturer shall be used.

5.7 Measurement of rotational speed

If possible, the total number of compressor revolutions during the test run shall be recorded with a revolution counter free from slip and the time shall simultaneously be accurately measured.

Stroboscopes and speedometers are normally not sufficiently accurate, but may be used to ensure that the shaft speed is constant.

If a synchronous motor is used, a synchronous clock may replace the revolution counter.

If an asynchronous motor is used, the net frequency and the slip may be measured.

5.8 Miscellaneous measurements

5.8.1 *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.

5.8.2 *Humidity*

If the compressed gas contains moisture, the relative humidity shall be checked during the test.

For tests with an open system, the dry and wet bulb temperatures shall be measured with a psychromoter of the Assman type or another instrument with similar accuracy. The humidity content is then found from psychrometric tables or from an enthalpy/humidity chart.

For tests with a closed system, the humidity shall be measured with a dew point instrument or a psychrometer of the Assman type or another instrument with similar accuracy.

The humidity shall, if possible, be measured at the standard inlet point. If this is not possible the humidity shall be estimated.

5.8.3 *Coolant flow*

The coolant flow is best determined with the aid of a vessel of known volume and a stop-watch or with a calibrated flow meter. The measurement may also be made with an orifice or nozzle according to ISO/R 541.

5.8.4 *Condensation rate*

Before and after every test, the condensate shall be drained form the intercoolers and their separators. The separated quantitites shall be weighed for every cooler and divided by the time between the draining operations, which shall be carried out carefully, so that the steady state of the compressor in other respects will not be disturbed.

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

If water separators are provided, the efficiency of separation shall be determined.

The condensate collected in aftercoolers, receivers and other places after the discharge flange shall be measured and the total amount and time shall be noted.

5.8.5 *Fuel consumption*

If the compressor is driven by a combustion type engine, the fuel consumption shall be determined by weighing or by measuring the volume of the fuel consumed during the test.

5.8.6 *Steam consumption*

If the compressor is driven by a steam engine or turbine, the non-bleeding water rate shall be determined. (See IEC Publication 46 Part 2.)

6 PREPARATION OF THE MACHINE AND THE TESTING EQUIPMENT

6.1 General remarks

6.1.1 Before acceptance tests are begun, the compressor shall be examined in order to ascertain whether it is in suitable condition to conduct an acceptance test. All external leakage shall be eliminated; in particular the pipe system shall be checked for leakage.

6.1.2 All unused pipe connections from the compressor discharge shall be blanked. If this is not possible, the connections shall be broken at suitable points to allow constant observation of the outlets. To ensure correct test results an intake pipe shall not serve more than one compressor.

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

6.2 Installation of testing equipment

The installation of the measuring devices is specified in the respective sub-clauses of clause 5. Detailed instructions are given

– in 5.1 for temperature and

– in 5.2 for pressure.

6.3 Calibration of instruments

Initial 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 the instrument may be a cause for rejecting the test.

7 THE TEST

7.1 General rules for conducting the test

Preliminary tests shall be run for the purpose of

a) determining whether the compressor and associated system is in a suitable condition to conduct an acceptance test;

b) checking instruments;

c) training personnel.

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

7.1.1 During the test, all such measurements as have any bearing on the performance shall be made. In the following sub-clauses the determination of the capacity and the power consumption of the compressor are treated in detail.

7.1.2 The measurements shall be carried out by competent persons with measuring equipment according to clause 5.

7.1.3 The test conditions shall be as close as is reasonably possible to the guarantee conditions; deviations from these shall not exceed the limits specified in 9.1.6.

Where it is not feasible to test a machine either with the gas required by the purchaser or within the limitations specified in 9.1.6, special conditions of test or special corrections shall be agreed upon between purchaser and manufacturer.

7.1.4 The governing mechanism shall be maintained in its normal working position.

7.1.5 During the test, the lubricant, the adjustment of lubricating pumps, lubricators, or other lubricating means, shall comply with the operating instructions.

7.1.6 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.

7.1.7 Before readings begin, 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.

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 and due regard paid to this in the calculation of the tolerances.

7.1.8 For each load two tests shall be made, each of them comprising sufficient readings to indicate that steady state conditions have been reached. The number of readings and the intervals shall be chosen to obtain sufficient accuracy.

7.1.9 After the test, the compressor plant and the measuring equipment shall be inspected. Should any faults be found that may have affected the test results, then a further test shall be run after these faults have been corrected.

7.2 Evaluation of the readings

Before final calculations are undertaken, the recorded data shall be scrutinized for consistency of the operating conditions. The fluctuations of readings during one test shall not exceed the limits given in 9.1.6.

7.2.1 All accepted readings from any test run shall be consecutive.

7.2.2 Sets of readings showing excessive fluctuation may be discarded but only at the beginning or the end of a test run. All readings in any set shall be taken as nearly as possible simultaneously.

7.2.3 The moisture content shall be determined from psychrometer readings at the standard inlet point, according to 5.8.2.

The moisture content for the different compression stages and at the flow measuring device shall then be determined from condensate measurements.

7.2.4 To determine the capacity, i.e. the flow through the measuring device, the moisture content there can be measured separately. This measurement will also serve as a check of the readings according to 7.2.3.

8 COMPUTATION OF TEST RESULTS

8.1 Test results, except those for flow measurements, shall be calculated from the arithmetic average values of the accepted readings.

8.2 The mass rate of flow shall be determined according to 5.3 or 5.4.

8.3 When the measured fluid is hot or cold, expansion or contraction of the measuring device takes place depending upon the material used and the temperature difference. The flow area of the measuring device shall be corrected.

8.4 When the gas being compressed is not dry, the influence of the moisture shall be taken into account by correcting the specific energy consumption.

8.5 The actual inlet capacity 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.

8.6 Any vapour condensed between the standard inlet point and the measuring device shall be added to the measured mass flow to obtain the mass flow at the standard inlet point.

Then from the mass flow at the standard inlet point the volume flow at this point is calculated. This is the actual inlet capacity.

8.7 Some unloading systems exhaust warm gas from the unloaded side of the piston to the inlet at part load. The inlet temperature thus becomes higher at part load than at full load, whereby the capacity apparently seems to attain a higher value. In such cases, therefore, the part load capacity is calculated with the inlet temperature valid for full load.

9 CORRECTION OF TEST RESULTS

9.1 General remarks

9.1.1 The test conditions never agree exactly with those which, according to tenders or purchase specifications, constitute the contract conditions for the capacity and the specific energy consumption. Therefore, before the test results and contract values are compared, corrections shall be introduced.

9.1.2 The test supervisor shall always try to keep the deviations of the test conditions from those specified as small as possible, as every correction adds uncertainty to the final result. But, as outlined in 9.1.1, corrections may be necessary to allow a proper comparison between test results and contract values.

9.1.3 When the specified operating conditions cannot be met, the influence of the 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.

If this is difficult to arrange, the correction methods given in this clause shall be used.

9.1.4 Within the limits specified in 9.1.6, this International Standard provides for adjustment of the capacity and specific energy consumption when the test conditions deviate from those specified. The capacity shall be adjusted for deviation in shaft speed, pressure ratio, isentropic exponent and coolant temperature. The specific energy consumption shall be adjusted for deviation in inlet pressure, isentropic exponent, pressure ratio, coolant temperature, humidity and shaft speed.

NOTE — Other corrections, such as correction for the compressibility factor, may have to be entered.

9.1.5 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 consumption at the compressor shaft.

9.1.6 The maximum allowable differences between test values and specified values, and maximum allowable fluctuation from average during any set of readings are specified in table 1.

9.1.7 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 capacity. Such corrections shall be agreed upon by both parties.

9.1.8 If the deviation or fluctuation exceeds the values given in 9.1.6, the methods described in 9.1.3 shall be used if agreed to by both parties.

9.2 Corrections for capacity

9.2.1 *Correction for shaft speed;* K_1

The correction factor is

$$K_1 = \frac{n_c}{n_m}$$

where

n_c is the contract shaft speed;

n_m is the measured shaft speed during the test.

TABLE 1 — **Maximum deviations from specified values and fluctuations from average readings**

Measured variable		Maximum allowable deviations	Maximum allowable fluctuation from average during any set of readings
Inlet pressure	p_1	± 8 %	± 0,5 %
Pressure ratio	r	± 5 %	± 0,5 %
Inlet temperature	t_1	—	± 2 K
Absolute inlet humidity	x	—	± 5 %
Isentropic exponent	κ	± 3 %	—
Gas constant	R	± 2 %	—
Shaft speed	n	± 4 %	± 1 %
Difference between coolant temperature and gas temperature		± 10 K	± 2 K
Coolant flow rate		± 10 %	± 10 %
Temperature at the nozzle or orifice plate		—	± 2 K
Differential pressure at the nozzle or orifice plate		—	± 3 %
Voltage		± 5 %	± 2 %
Net frequency		± 1 %	± 0,5 %

NOTES

1 The test shall be accepted if the deviations from the specified conditions are equal to or less than the sum of the tolerances for deviations and those on measurement.

2 If the deviation from test conditions results in a deviation in specific energy consumption higher than 8 % then the test is not within the limits.

3 See also 5.2.1 g).

4 For outdoor tests with portable compressors, the allowable inlet temperature fluctuation is increased to ± 3 K.

5 A test at a shaft speed different from the specified value is not accepted if unpermitted resonant pressure pulsations occur.

9.2.2 *Correction for polytropic exponent and pressure ratio;* K_2

This correction applies only for single-stage reciprocating compressors. (It is negligible for two-stage and multi-stage compressors.)

A change in the ratio of specific heats and in the pressure ratio will influence the capacity as the expansion of the gas trapped in the clearance volume is affected. The degree of this influence is not fully known, so that the test supervisor should strive to operate as near the specified pressure ratio as possible. For differences within the limits given in 9.1.6 the formula below shall be used.

$$K_2 = \frac{1 - c\,(r_c^{\,1/u_c} - 1)}{1 - c\,(r_m^{\,1/u_m} - 1)}$$

where

r_m is the measured pressure ratio;

r_c is the contract pressure ratio;

c is the relative clearance volume;

u is the polytropic exponent (should be taken as 0,9 κ).

For pressure ratios below 3 the correction is simplified to

$$K_2 = 1 + c\,(r_m^{\,1/u_m} - r_c^{\,1/u_c})$$

9.2.3 *Correction for coolant temperature;* K_3

The temperature difference between the coolant and the gas at their intake points will affect the gas temperature in the compressor cylinders as well as in the intercoolers. As this influence varies with compressor type, size and speed, no general correction formula can be given. If the specified conditions cannot be met, the compressor shall be operated at two different coolant inlet temperatures and at constant