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Mechanical vibration — Measurement and evaluation of machine vibration —

Part 8:
Reciprocating compressor systems

Vibrations mécaniques — Mesurage et évaluation des vibrations des machines —

Partie 8: Systèmes de compresseurs alternatifs

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 108, *Mechanical vibration, shock and condition monitoring*, Subcommittee SC 2, *Measurement and evaluation of mechanical vibration and shock as applied to machines, vehicles and structures*, in collaboration with ISO/TC 118, *Compressors and pneumatic tools, machines and equipment*.

This first edition of ISO 20816-8 cancels and replaces ISO 10816-8:2014, which has been technically revised. The main change is the addition of an annex dealing with vibration of small bore connections.

A list of all parts in the ISO 20816 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

ISO 20816-1 gives general guidelines for the evaluation of machine vibration by measurements on both non-rotating parts and rotating shafts. The present document, however, establishes special procedures and guidelines for the measurement and classification of mechanical vibration of reciprocating compressors. Since, in general, it is not common to measure shaft vibration, this document refers to vibration of the main structure of the compressor, including the foundation, pulsation dampers and attached pipe system. The guidance values given for these vibrations are defined primarily to classify the vibration and to avoid problems with auxiliary equipment mounted on these structures. Recommendations for measurements and evaluation criteria are provided in this document.

Typical features of reciprocating compressors are the oscillating masses, the cyclically varying torques, cylinder stretch and the pulsating forces in the cylinders, pulsation dampers and the pipe system. All these features cause alternating loads on the main supports and vibration of the compressor system. The vibration values of reciprocating compressor systems are generally larger than for rotating compressors but, since they are largely determined by the design features of the compressor, they tend to remain more constant over the life of the system than for rotating machinery.

In the case of reciprocating compressor systems, the vibration measured on the main structure of the compressor (including the foundation, pulsation dampers and piping) and quantified according to this document can only give a rough idea of the vibratory states of the components within the machine itself.

The damage which can occur when exceeding the guidance values based on experience with similar compressor systems is sustained predominantly by machine-mounted components (e.g. instrumentation, heat exchangers, filters, pumps), connecting elements of the compressor with its peripheral parts (e.g. pipelines) or monitoring instruments (e.g. pressure gauges, thermometers). The question as above which vibration values damage is to be expected largely depends on the design of these components and their fastenings. In some cases, special measurements on certain compressor system components can be required to ascertain that the vibration values do not cause damage. It also happens that, even if measured values are within the guidance values of this document, problems occur owing to the great variety of components which can be attached.

Local vibration problems as described above can be rectified by specific "local measures" (e.g. by elimination of resonances). Experience has shown, however, that it is possible in the majority of cases to state measurable quantities characterizing the vibratory state and to give guidance values for these. This shows that the measurable variables and the guidance values for acceptable vibration in most cases permit a reliable evaluation.

If the measured vibration values as given in this document do not exceed the guidance values, abnormal wear of internal compressor components caused by vibration is unlikely to occur.

The vibration values of reciprocating compressor systems are not only affected by the properties of the compressor itself but also, to a large degree, by the foundation. Since a reciprocating compressor can act as a vibration generator, vibration isolation between the compressor and its foundation can be necessary. The vibration response of the foundation and the vibration from adjacent equipment can have considerable effect on the vibration of the compressor system.

Mechanical vibration — Measurement and evaluation of machine vibration —

Part 8: Reciprocating compressor systems

1 Scope

This document establishes procedures and guidelines for the measurement and classification of mechanical vibration of reciprocating compressor systems. The vibration values are defined primarily to classify the vibration of the compressor system and to avoid fatigue problems with parts in the reciprocating compressor system, i.e. foundation, compressor, dampers, piping and auxiliary equipment mounted on the compressor system. Shaft vibration is not considered.

This document applies to reciprocating compressors mounted on rigid foundations with typical rotational speed ratings in the range 120 r/min up to and including 1 800 r/min. The general evaluation criteria which are presented relate to operational measurements. The criteria are also used to ensure that machine vibration does not adversely affect the equipment directly mounted on the machine, e.g. pulsation dampers and the pipe system.

NOTE The general guidelines presented in this document can also be applied to reciprocating compressors outside the specified speed range but different evaluation criteria might be appropriate in this case.

The machinery driving the reciprocating compressor, however, is evaluated in accordance with the appropriate part of ISO 10816, ISO 20816 or other relevant standards and classification for the intended duty. Drivers are not included in this document.

It is recognized that the evaluation criteria might only have limited application when considering the effects of internal machine components, e.g. problems associated with valves, pistons and piston rings might be unlikely to be detected in the measurements. Identification of such problems can require investigative diagnostic techniques which are outside the scope of this document.

Examples of reciprocating compressor systems covered by this document are

— horizontal, vertical, V-, W- and L-type compressor systems,

— constant and variable speed compressors,

— compressors driven by electric motors, gas and diesel engines, steam turbines, with or without a gearbox, flexible or rigid coupling, and

— dry running and lubricated reciprocating compressors.

This document does not apply to hyper compressors.

The guidelines are not intended for condition monitoring purposes. Noise is also outside the scope of this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 2041, *Mechanical vibration, shock and condition monitoring — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 2041 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
compressor system
machinery system comprising foundation, compressor (crankcase, crosshead guide, cylinders), pulsation dampers and piping

3.2
overall vibration value
single numeric representation of a feature or aggregate of features derived from a raw or processed time waveform or frequency spectrum of a vibration signal and often accompanied by descriptive text or indicators to specify methods used in its derivation

Note 1 to entry: The overall vibration value is measured in the frequency range from 2 Hz to 1 000 Hz.

3.3
corner frequency
frequency used to convert the vibration displacement to vibration velocity and vibration velocity to vibration acceleration for a sinusoidal signal

Note 1 to entry: The corner frequencies are 10 Hz and 200 Hz, respectively.

3.4
vendor
manufacturer or manufacturer's agent who supplies the compressor system

3.5
purchaser
agency that issues the order and specification to the vendor

3.6
mainline piping
piping of which the small bore connections are branched

Note 1 to entry: Mainline piping can also refer to stationary components of rotating machinery and pressure containing equipment like vessels or coolers.

Note 2 to entry: The defintion of mainline piping diameter for non-cylindrical parts is given in Figure E.1.

3.7
small bore connection
SBC
branch connection on mainline piping, vessels or equipment that has an actual outer diameter of 60,3 mm or smaller, or that has an actual outer diameter larger than 60,3 mm with a *branch ratio* (3.8) of less than or equal to 12 %

Note 1 to entry: All connections that have a branch ratio greater than 36 % are excluded.

Note 2 to entry: The small bore connection piping extends until the effect of the mainline piping vibration is negligible, which is typically the first support.

Note 3 to entry: Diameters of small bore connection are given in Table E.1.

3.8
branch ratio
ratio of small bore connection actual outer diameter to mainline piping actual outer diameter

Note 1 to entry: For a definition of the actual diameter of non-cylindrical parts (e.g. compressor frame) to which a small bore connection is connected, see Figure E.1.

4 Measurements

4.1 Measurement procedure

The primary measurement quantity shall be the overall root-mean-square (RMS) vibration velocity, in mm/s.

If frequencies below the corner frequency of 10 Hz are expected or observed, it is recommended additionally to measure the overall RMS vibration displacement, in mm (it is also common to display displacement in micrometres where 1 µm = 10^{-3} mm).

If frequencies above the corner frequency of 200 Hz are expected or observed, it is recommended additionally to measure the overall RMS vibration acceleration, in m/s^2 (it is still common, but not recommended, to display acceleration in units of g where g = 9,81 m/s^2).

NOTE The relationship between displacement, velocity and acceleration is given in B.1.

Consequently, and in accordance with ISO 20816-1, acceptance criteria based on velocity take the general form of Figures B.1 to B.10. These figures indicate the corner frequencies of 10 Hz and 200 Hz and show that below and above these corner frequencies, the guidance vibration velocity is a function of vibration frequency.

All values shall be within the values for acceptable overall vibration as summarized in 5.3.

Spectral data should be retrieved for each of the measured quantities if they exceed the vibration values of evaluation zone boundary B/C as defined in 5.2 to aid in analysis and possible correction.

Vibration acceleration values are often measured to carry out condition monitoring of internal compressor components. However, this document is not intended to be applied for condition monitoring purposes. For example, if the condition of the compressor valves is to be monitored, other procedures and standards with different values can apply. The vibration acceleration values given in this document should, therefore, only serve as a criterion to judge the overall integrity of the compressor system and attached equipment, e.g. pressure and/or temperature transmitters and valve-lifting devices. When the acceleration values given in this document are exceeded, this does not, by definition, imply that corrective actions are required. The susceptibility of components to large acceleration values (instruments, heavy components on small equipment nozzles, etc.), the presence of audible noise or knocking sounds, or unusual or sudden changes of vibration values should then become a point of attention and further analysis.

Furthermore, the measured acceleration values on locations as shown in Figures 1 to 5 are not the values of the attached equipment but the values of the compressor system parts (foundation, crankcase, cylinder, dampers and piping) to which they are mounted.

4.2 Measuring instrumentation and measured quantities

Criteria for classifying vibration values for reciprocating compressor systems are specified in Clause 5. It is recognized that the main excitation frequencies for reciprocating compressor systems are generally found in the range 2 Hz to 300 Hz. However, when considering the complete compressor system, including auxiliary equipment that is a functional part of the compressor, a typical range of 2 Hz to 1 000 Hz is applied to characterize the overall vibration. For the purposes of this document, the overall RMS vibration value shall represent vibration across the frequency range from 2 Hz to 1 000 Hz. For special purposes, a different range can be agreed between the vendor and purchaser.

Since the overall vibration signal usually contains many frequency components, there is no simple mathematical relationship between the RMS, peak or peak-to-peak overall vibration measurements; see Annex D.

The measuring system should provide the RMS values of displacement, velocity and acceleration with an accuracy of ±10 % over the range 10 Hz to 1 000 Hz and with an accuracy of +10 % and −20 % over the range 2 Hz to 10 Hz. These values can be obtained from a single transducer whose signal is processed to derive the quantities not directly measured, preferably an accelerometer whose output is integrated once for velocity and twice for displacement. ISO 2954 gives requirements for instruments for measuring vibration severity. Guidelines on applying methods of signal processing and display, e.g. time and frequency domain, windowing and averaging, are covered in ISO 13373-2 and ISO 18431-1 and common examples are given in ISO 18431-2.

For small bore connections, the difference between the highest and lowest vibration velocity value between two locations shall be measured as specified in Annex E because this determines the maximum cyclic stress values. The guidance values for acceptable overall vibration are for that reason based on the difference in vibration time waveforms measured on the two locations, as defined in E.2.1. The correct phase between these two locations shall be taken into account.

Care should be taken to ensure that any processing does not adversely affect the required accuracy of the measuring system. Both the frequency response and measured vibration values are affected by the method of attachment of the transducers. It is especially important to maintain a good attachment between the transducer and the compressor when the vibration velocities and frequencies are high. ISO 5348 gives guidelines on the mounting of accelerometers.

NOTE The guidance vibration values are not applicable for ovalling shell modes of pulsation dampers and large diameter pipe systems.

4.3 Locations and direction of measurements

4.3.1 Locations

As a minimum, the vibration measurements shall be carried out on the locations shown in Figures 1 to 5 as follows:

— foundation: at all compressor frame bolt locations;

— frame (top): on each corner point and between all cylinders for a compressor with more than two cylinders, all at the top of the frame;

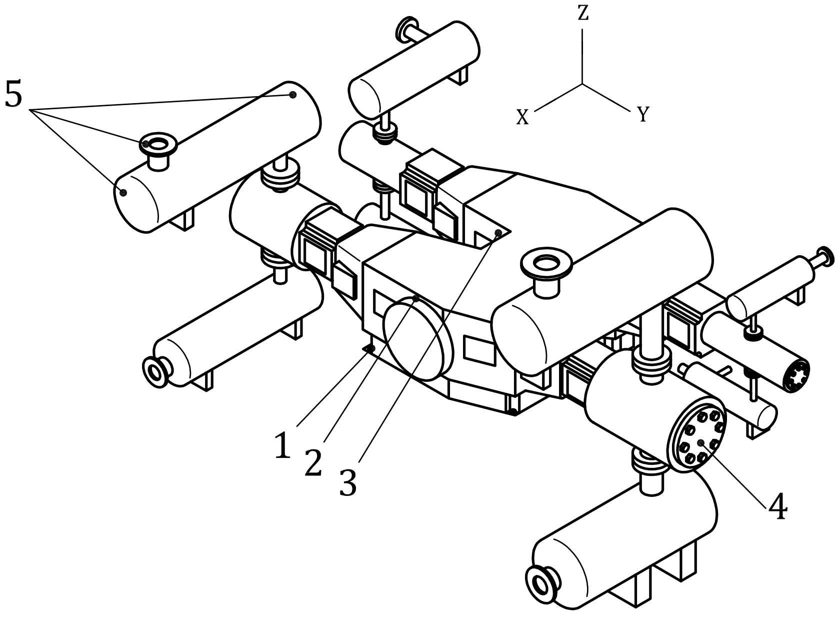
— cylinders (lateral and rod): at the rigid part of each cylinder cover flange;

— pulsation vessels: at the inlet and/or outlet pipeline flange and at the heads;

— piping: at all critical parts of the system, to be determined by inspection and in agreement with the purchaser;

— small bore connections: see Figure E.2.

NOTE Accelerometers are often mounted on the crosshead guide for condition monitoring purposes of internal parts of the compressor. The vibrations are measured in the direction of the force exerted by the crosshead on this guide, which is in vertical direction of a horizontal compressor. Experience on horizontal compressors has shown that the vibration values measured on the crosshead guide can be used in addition to the vibration values of other locations to judge the integrity of the compressor. The procedures for measuring the vibration values on the crosshead guide are summarized in Annex C.



Key

1 all compressor frame bolt locations

2 each frame corner point

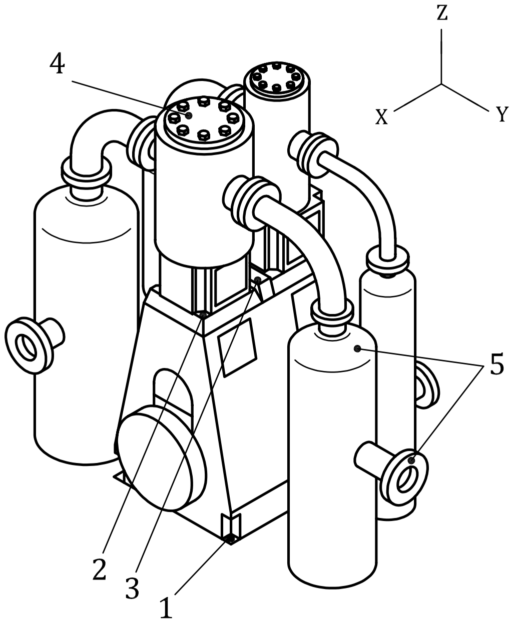
3 each frame location between the cylinders (required for a compressor with more than one cylinder on the same side)

4 each cylinder (cover flange at rigid location)

5 pulsation vessels (only shown for one vessel in the figure)

NOTE The numbers apply to all types of these compressors (for clarity, only one point is shown in the figure for most of the locations). As piping is agreed upon with the vendor, it is not shown in the figure. A detailed description of the directions is given in 4.3.2.

Figure 1 — Measuring locations for a horizontal compressor



Key

1 all compressor frame bolt locations

2 each frame corner point

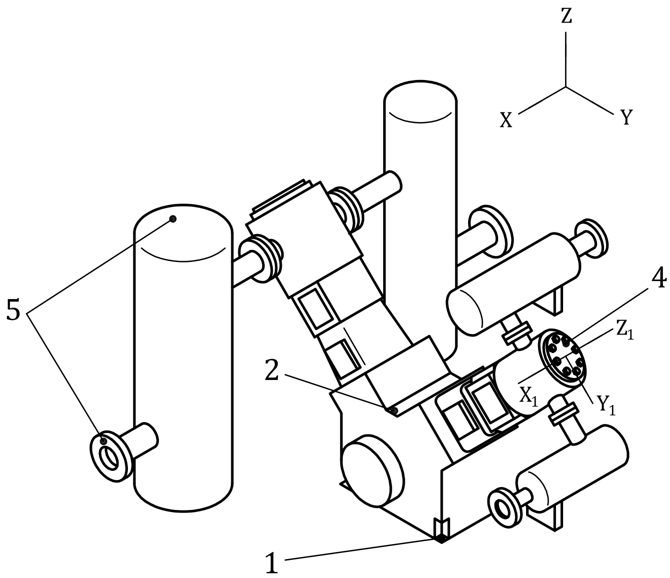
3 each frame location between the cylinders (required for a compressor with more than one cylinder)

4 each cylinder (cover flange at rigid location)

5 pulsation vessels (only shown for one vessel in the figure)

NOTE The numbers apply to all types of these compressors (for clarity, only one point is shown in the figure for most of the locations). As piping is agreed upon with the vendor, it is not shown in the figure. A detailed description of the directions is given in 4.3.2.

Figure 2 — Measuring locations for a vertical compressor



Key

1 all compressor frame bolt locations

2 each frame corner point

3 each frame location between the cylinders (not shown in this figure, required for a compressor with more than two cylinders; see Figures 1 and 2)

4 each cylinder (cover flange at rigid location)

5 pulsation vessels (only shown for one vessel in the figure)

NOTE The numbers apply to all types of these compressors (for clarity, only one point is shown in the figure for most of the locations). As piping is agreed upon with the vendor, it is not shown in the figure. A detailed description of the directions is given in 4.3.2.

Figure 3 — Measuring locations for a V-type compressor