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Space systems — Gas contamination — Measurement methods for field tests

Systèmes spatiaux — Contamination des gaz — Méthodes de mesure pour essais hors laboratoire

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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 15860 was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Introduction

This International Standard establishes the impurities contamination measurement methods for real compressed gas (air, nitrogen, helium, and argon) used in systems and facilities of space launch and technical complexes.

This International Standard provides recommendations for correct selection and use of compressed gas contamination measurement methods and means.

Compressed gas impurities have a mechanical, physical, chemical, and electrolytic effect on pneumatic devices that reduces their life and reliability. Oil impurities in contact with oxidizer increase equipment explosion and fire hazards and have a negative biological effect when inhaled. Compressed gas impurity contamination is one of the normalized parameters subjected to careful monitoring to ensure reliable operation of space system equipment as specified.

This International Standard can be used for modernization and maintenance of launch site equipment and technical complexes when other methods are difficult to apply. The equipment mentioned in this International Standard is portable, compact and inexpensive.

Space systems — Gas contamination — Measurement methods for field tests

1 Scope

This International Standard covers gases (air, nitrogen, helium, and argon) compressed up to 40 MPa used in systems and units of space vehicle launch and technical complexes.

This International Standard determines compressed gas impurities (mechanical impurities, water vapour, oil, and foreign gases) content measurement methods. This International Standard can be used by countries and firms participating in the development, redesign, modernization, and maintenance of space vehicle launch sites and technical complexes.

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 15859-3:2004, *Space systems — Fluid characteristics, sampling and test methods — Part 3: Nitrogen*

ISO 15859-4:2004, *Space systems — Fluid characteristics, sampling and test methods — Part 4: Helium*

ISO 15859-9:2004, *Space systems — Fluid characteristics, sampling and test methods — Part 9: Argon*

ISO 15859-13:2004, *Space systems — Fluid characteristics, sampling and test methods — Part 13: Breathing air*

3 Terms, definitions and abbreviations

3.1 Terms and definitions

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

3.1.1
mechanical impurity
solid dispersal phase with a wide spectrum of aerosol particle size

3.1.2
oil impurity
oil contained in gas in the form of vapours and aerosols

3.1.3
particle concentration
number of separate aerosol particles of specified size in a unit of gas volume

3.1.4
particle size
particle maximum linear size measured by an optical microscope or particle equivalent size received with the help of automatic instruments

3.1.5

safety requirement

determined requirement whose execution guarantees work safety

3.2 Abbreviated terms

GMC gas moisture content

4 Requirements

4.1 General requirements

Depending on the allowable gas impurity contamination value, gases (air, nitrogen, helium, and argon) are subdivided into classes of industrial purity in accordance with ISO 15859-3, ISO 15859-4, ISO 15859-9, and ISO 15859-13. The gas purity class is specified in the design documentation in accordance with the appropriate International Standard.

The gas purity test shall be conducted from a pumping manifold

- before the storage means are filled,
- following the storage filling (after a relaxation time for homogenization),
- every 24 h for a continuous filling.

A gas sample shall be taken from every set of filled cylinders and from the pipelines feeding the gas aboard the space system prior to every operation but not earlier than 24 h before erecting a vehicle on a launch pad.

During gas distribution from a compressor station directly to a user or into a receiver, the gas purity test shall be carried out

- at the beginning of the continuous work of the compressor station,
- at the end of the pressurization phase (after a relaxation time for homogenization),
- every 24 h (for a continuous process).

A list of controlled parameters of each gas purity test and acceptable impurity load acceptable levels shall be cited in the operation documentation. The recommended instruments and equipment are listed in Annex A.

Gas purity test results shall be recorded in a special register or document on a record tape or a computer diskette. At the user's request, the gas purity control service shall provide certificates testifying to gas purity.

4.2 Safety requirements

Only trained, skilled, and instructed persons may carry out work concerning the compressed gas impurity contamination measurements.

The rooms equipped with a stationary nitrogen and helium sampler shall be fitted with a gas analyser that signals automatically in two ways (acoustic signal and flash light) when the oxygen content in the room is less than a volume fraction of 19 %. Personnel are prohibited in areas where the oxygen content is less than a volume fraction of 20,9 % without using safety breathing devices. Unless otherwise provided by applicable safety rules, each group of workers going in a room in which a significant diminution of the oxygen level is possible shall use one portable oxygen detector.

Safety regulations shall be met before operating the equipment under positive pressure during gas sampling. Therefore, the following shall be performed:

a) before beginning the work, make sure that all the elements of gas-sampling circuits are in an operational starting position;

b) monitor gas pressure before working with compressed gases;

c) do not tighten seals and joints of pipes under positive pressure;

d) do not connect inoperative pipes and reducers to pipe connections;

e) do not shut and open valves with the help of levers;

f) do not keep the equipment under positive pressure without control;

g) after finishing work, leave the gas-sampling circuit elements in the initial state.

While working with the instrument, the following shall be performed:

a) use only a grounded instrument;

b) do not replace a safety device with another one calculated on the higher strength of the current;

c) do not open the switched-on instrument;

d) do not supply the gas sample for analysing before the instrument is energized;

e) do not supply the gas sample for analysing when a gas inlet coupling cover is not removed;

f) do not disconnect the instrument from a gas line under positive pressure;

g) verify that the inspection date is current.

4.3 Measurement methods

4.3.1 Mechanical impurities content measurement by dispersion composition

Aerosol meters based on measuring the intensity of the light dispersed by particles in a continuous flow are used for determining the dispersive composition and concentration of solid aerosol particles. Light diffusion pulses are recorded by a photoelectric analyser and transformed into an output signal. Therefore, the amount of concentration and the dispersion composition of aerosol particles are determined.

Solid particle size and quantity may be determined by an optical method with the use of an analytic filter.

The corresponding microscope magnification is set for each range of particle sizes (see Table 1). The greater magnifications are set on the microscope sequentially, and particle sizes and their quantity in other ranges of sizes are determined.

Table 1 — Choosing a microscope magnification in accordance with a size of determined particles

Size of determined particles (μm)	100 to 60	60 to 40	40 to 20	20 to 14	14 to 8	8 to 4	4 to 2	2 to 1	1 to 0,5
Microscope magnification (×)	20 to 30	30 to 40	40 to 50	50 to 80	80 to 100	100 to 250	250 to 500	500 to 1 000	2 000

4.3.2 Mechanical impurities content measurement by mass

To measure a mass content of solid aerosol particles, the aerosol content transforming the dispersion content and amount of concentration signals into a mass content value are used. If a channel for transforming the quantities and sizes of solid particles measured quantity and size into a mass concentration is absent in the aerosol counter, the solid particle content r_{Sc} (mg/m^3) value shall be calculated by the following formula:

$$r_{\text{Sc}} = 5{,}23 \times 10^{-10} \rho \left(\frac{z_1 d_1^3 + z_2 d_2^3 + ... + z_n d_n^3}{V_{\text{S}}} \right) \qquad (1)$$

where

ρ	is the solid particle density specific (g/cm^3) (if the particle density is unknown, it shall be assumed to be equal to 2,5 g/cm^3);
d	is the particle maximum size (µm);
z	is the number of particles of a certain size;
V_{S}	is the sample volume (m^3).

A gravimetric method of a solid particle content measurement consists of passing a certain quantity of gas through a control analytic filter and weighing the filter before and after sampling. The analytic filter shall guarantee compressed gas with a maximum particle size of 0,2 µm.

Solid particle content in a gas sample r_{Sc} (mg/m^3) shall be calculated by the following formula:

$$r_{\text{Sc}} = \frac{m_2 - m_1}{Q \times t_{\text{S}}} \qquad (2)$$

where

m_1	is the mass of the filter before gas sampling (mg);
m_2	is the mass of the filter after gas sampling (mg);
Q	is the flow rate of a gas sample passing through the control analytic filter (m^3/min);
t_{S}	is the gas sampling duration (min).

Solid particle content in compressed gas $r_{\text{S}n}$ (mg/m^3) shall be calculated based on results of not less than three measurements by the following formula:

$$r_{\text{Sc}} = \frac{r_{\text{S}1} t_1 + r_{\text{S}2} t_2 + ... + r_{\text{S}n} t_n}{t_1 + t_2 + ... + t_n} \qquad (3)$$

where

$r_{\text{S}1}, r_{\text{S}2}, ... r_{\text{S}n}$	is the solid particle content in compressed gas (mg/m^3);
$t_1, t_2, ... t_n$	is the gas sampling duration (min).

A tentative testing duration shall be calculated by the following formula:

$$\frac{b_{\mathrm{min}}}{r_{\mathrm{SI}}Q} \leqslant t \leqslant \frac{b_{\mathrm{max}}}{r_{\mathrm{SI}}Q} \qquad (4)$$

where

b_{min}	is the minimum necessary content of solid particles on the filter (mg);
b_{max}	is the maximum permissible content of solid particles on the filter (mg);
r_{SI}	is the supposed or limiting assumed content of solid particles value (mg/m^3);
Q	is the gas flow through the control analytic filter (m^3/min).

4.3.3 Particle maximum size measurement

Particle maximum size shall be measured by passing gas through an aerosol counter or a controlled analytic filter. After gas passing, the control analytic filter shall be blanched and dried. Blanching shall be accomplished using a solvent containing for example 94 % of xylene C_6H_4 $(CH_3)_2$ and 6 % of threecresyl orto phosphate $(CH_3C_6H_2O)_3$ PO or dibutyl phthalate C_6H_4 $[COO(CH_2)_3$ $CH_3]_2$. Solid particle sizes are determined by testing the particles with a microscope.

4.3.4 Water vapour content measurement

The water vapour content in gases shall be measured by hygrometers intended to measure water vapour concentrations in the range of 0,10 mg/m^3 to 764 mg/m^3.

Hygrometer preparation and operation procedures shall be carried out in accordance with a hygrometer manual.

A coulometric method is based on continuous absorption of water from a dosed flow of the tested gas by a sorbent film and simultaneous water decomposition on hydrogen and oxygen. Therefore, an electrolysis current value in a steady state in the coulometric hygrometer is a measure of the water content in the tested gas.

Water vapour content may be controlled by dew point hygrometers at standard atmospheric and operation pressures in a hygrometer test chamber. The water vapour content can also be controlled by absorption-frequency hygrometers.

Water vapour volume fraction and mass concentration in accordance with a measured dew point can be determined (see Table 2).

Table 2 — Conversion of the gas moisture content (GMC) through dew point into water vapour content (at 20 °C and 101,3 kPa)

Dew point ranges and GMC					
−20 °C **to** −50 °C		−52 °C **to** −82 °C		−84 °C **to** −114 °C	
Dew point (°C)	**GMC** (mg/m^3)	**Dew point** (°C)	**GMC** (mg/m^3)	**Dew point** (°C)	**GMC** (mg/m^3)
−20	764	−52	23,25	−84	0,20
−22	629	−54	17,50	−86	0,14
−24	517	−56	13,70	−88	0,10
−26	424	−58	10,48	−90	—
−28	345	−60	7,94	−92	—
−30	281	−62	6,04	−94	—
−32	254	−64	4,56	−96	—
−34	184	−66	3,44	−98	—
−36	148	−68	2,57	−100	—
−38	118	−70	1,90	−102	—
−40	95	−72	1,40	−104	—
−42	75	−74	1,03	−106	—
−44	59	−76	0,75	−108	—
−46	47	−78	0,55	−110	—
−48	37	−80	0,39	−112	—
−50	29	−82	0,28	−114	—

Dew point temperatures, depending on the water vapour content and gas pressure, are given in Figure B.1 for air and nitrogen, Figure B.2 for helium, and Annex C.

In excessively moist gaseous atmospheres and during starting, adjustment, and alignment work, the water vapour content shall be measured by the linear-colorimetric method with the help of expendable detector tubes. This method includes the following operations.

a) After the detector tube is opened and placed into a gas line, the tested gas is passed through the tube, where water vapours contained in the flow are absorbed by a tube filter; thus the filter is partially or completely coated.

NOTE The length of a coated layer of the detector tube filter depends on vapour concentration.

b) To measure the tested gas water content, the detector tube shall be compared with the applied graduated scale.

c) Then, the readings of water content values along the upper boundary of a coated layer shall be taken.

4.3.5 Oil content measurement

The content of oil impurities in the form of vapours and aerosols shall be measured by the linear-colorimetric method with the help of expendable detector tubes. The measuring method includes the following operations:

a) After the detector tube is opened and placed into a gas line, a tested gas passes through the tube, where its filter absorbs oil vapours and aerosols contained in the flow; thus the filter is partially or completely coated.

NOTE The length of a coated layer of the detector tube filter depends on oil concentration.

b) To raise the sensitivity of the instrument and its indication effect, a solvent is poured through the detector tube from an ampoule, which is a part of the tube.

c) To measure the tested gas oil content, the detector tube shall be compared with the applied graduated scale.

d) Then, the readings of values in milligrams per cubic metre along the upper boundary of a coated layer shall be taken.

Oil content in the flow may be controlled by a method of infrared absorption spectrophotometry or by a luminescent method with preliminary solution of the oil in organic solvents during gas sampling. In this case oil concentration r_g is calculated by the following formula:

$$r_\mathrm{g} = \frac{m}{V_\mathrm{g}} \tag{5}$$

where

m is the oil content in the solvent (mg);

V_g is the tested gas sample volume (m^3).

Taking into account the number of washes of the sampler chamber and filter, and the efficiency of compressed gas sampling ε_s (value middle $=$ 0,9), Formula (5) becomes the following ($\mathrm{mg/m}^3$):

$$r_\mathrm{g} = \frac{1000 \sum_{i=1}^{n} \left(r_{\mathrm{dc}_i} V_{\mathrm{sd}_i} + r_{\mathrm{df}_i} V_{\mathrm{sf}_i} \right)}{\varepsilon_\mathrm{s} Q t} \tag{6}$$

where

$i = 1,2 \ldots n$ is the number of washes after sampling;

$r_\mathrm{dc}, r_\mathrm{df}$ is the concentration of oil desorbed from the chamber and filter (mg/L);

$V_\mathrm{sc}, V_\mathrm{sf}$ is the solvent volumes (L);

Q is the gas flow rate during the test (L/min);

t is the sampling time (min).

The nomograph in Annex D can be used for determining the concentration r_g of oil in the gas flow.

4.3.6 Foreign gases content measurement

The helium and nitrogen volume percentage j is calculated as a difference between 100 and the sum of impurity percentages by the following formula:

$$j = 100\% - \sum j_i \tag{7}$$

where j_i is the concentration of the measured impurity (%). (For nitrogen: oxygen, water vapour, hydrogen, sum of carbon compounds in terms of carbon dioxide; for helium: hydrogen, nitrogen, oxygen, hydrocarbons, sum of carbon dioxide and carbon monoxide, argon and neon.)

Control of the impurity content in nitrogen and helium shall be carried out by methods and equipment specified in the documentation of the suppliers. The content of foreign gases in the tested gas may be controlled by detector tubes.

4.4 Sampling for analysis

4.4.1 Sampling devices

Sampling devices shall be configured with shutoff valves and fittings for connecting the instruments and samplers to a gas system. The length of a pipe connecting the instrument and samplers with the sampling unit shall be minimal. The pipe shall be fabricated from stainless steel. Its internal surface shall be cleaned, degreased, and dried before the first utilization.

4.4.2 Sampling requirements

The physical and chemical parameters for sampling shall conform to the physical and chemical parameters of the gas being tested.

Annex A
(informative)

Recommended instruments and equipment

Gas dust loading analyser

Analytic filter for dispersion and gravimetric analysis

Compressed gas mechanical impurity control device

Increased accuracy balance

Microscope with a magnification of not less than 200 powers

Coulometric hygrometer

Dew point hygrometer

Samplers

Detector tubes for oil, moisture, foreign gas, acid, and alkali content measurement

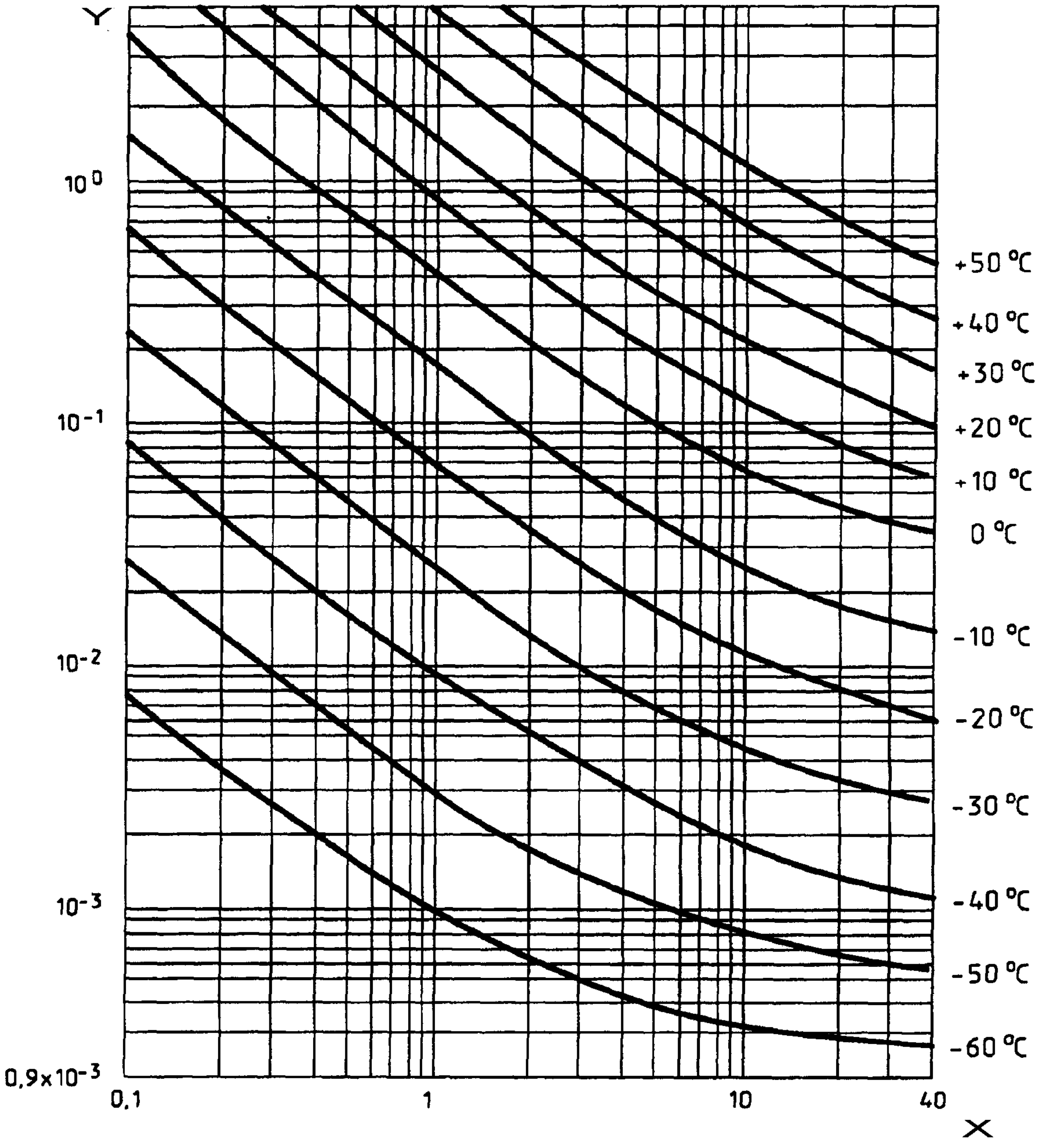
Gas flow meter

Gas analyser

NOTE The device accuracy selection depends on a gas purity class and customer requirements.

Annex B
(informative)

Equilibrium moisture content diagram

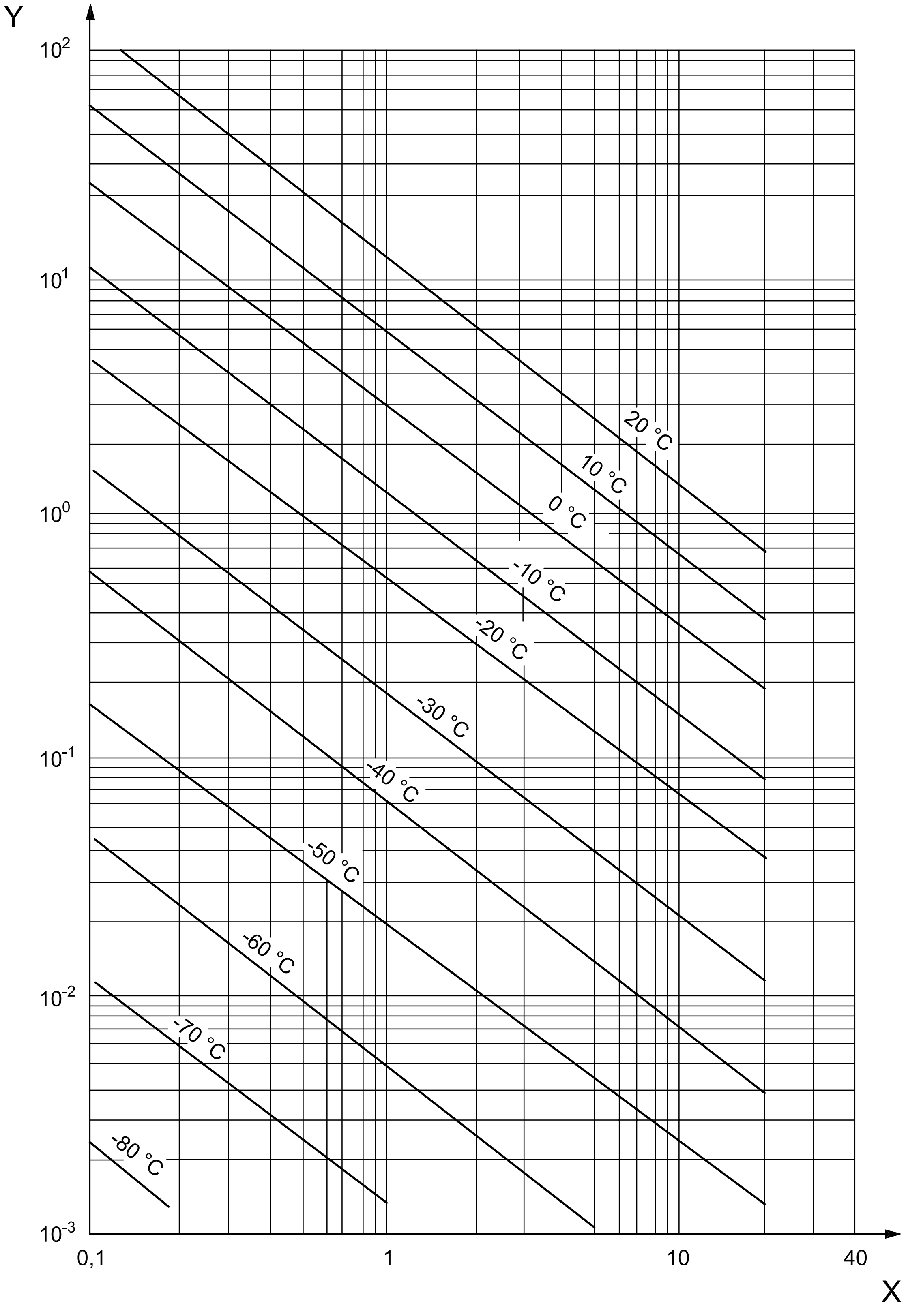


Key

X pressure (MPa)

Y moisture content (g/kg)

Figure B.1 — Diagram for air and nitrogen



Key

X pressure (MPa)

Y moisture content (g/kg)

Figure B.2 — Diagram for helium

Annex C
(informative)

Determination of the mass concentration of water vapours by a dew point method at different pressures of nitrogen (or oxygen)

Table C.1 — Mass concentration and dew point at different pressures

Water vapour mass concentration at 20 °C **and** 101,3 kPa	**Dew point (°C) at different pressures of nitrogen (or oxygen) over condensation mirror**				
mg/m³	0,1 MPa	5 MPa[a]	10 MPa[a]	15 MPa[a]	20 MPa[a]
95,00	−40	−2	+6	+10	+13
75,00	−42	−5 (−5)	+2 (+1,5)	+6 (+5,5)	+9 (+8,5)
59,00	−44	−7,5 (−7,5)	−1 (−1,5)	+2 (+2,5)	+5 (+4,5)
47,00	−46	−10 (−11)	−4 (−4,5)	−2 (−1)	+1,5 (+1,5)
37,00	−48	−13 (−14)	−7,5 (−7,5)	−5 (−5)	−2 (−3)
29,00	−50	−16 (−16)	−11 (−10,5)	−8 (−7,5)	−6 (−5)
23,25	−52	−18 (−19)	−14 (−13,5)	−11 (−9,5)	−8 (−8)
17,50	−54	−21 (−22)	−17 (−16)	−14 (−13,5)	−12 (−11,5)
13,70	−56	−24 (−25)	−20 (−20)	−18 (−17)	−14 (−15,5)
10,48	−58	−27 (−28)	−23 (−23)	−21 (−20)	−19 (−18,5)
7,94	−60	−30 (−31)	−26 (−26)	−24 (−23,5)	−21 (−22)
6,04	−62	−33 (−33,5)	−29 (−29,5)	−27 (−27)	−24 (−26)
4,56	−64	−36 (−36,5)	−31,5 (−31,5)	−30 (−30)	−27 (−28,5)
3,44	−66	−39 (−39,5)	−35 (−35,5)	−33 (−33,5)	−31 (−31,5)
2,57	−68	−42 (−42)	−38 (−38)	−36 (−36)	−34 (−32)
1,90	−70	−45 (−45)	−41 (−41,5)	−39 (−39,5)	−37 (−37,5)

[a] The values outside of brackets are for nitrogen; the values in brackets for oxygen.

Annex D
(informative)

Nomograph for determining the concentration of oil in gases

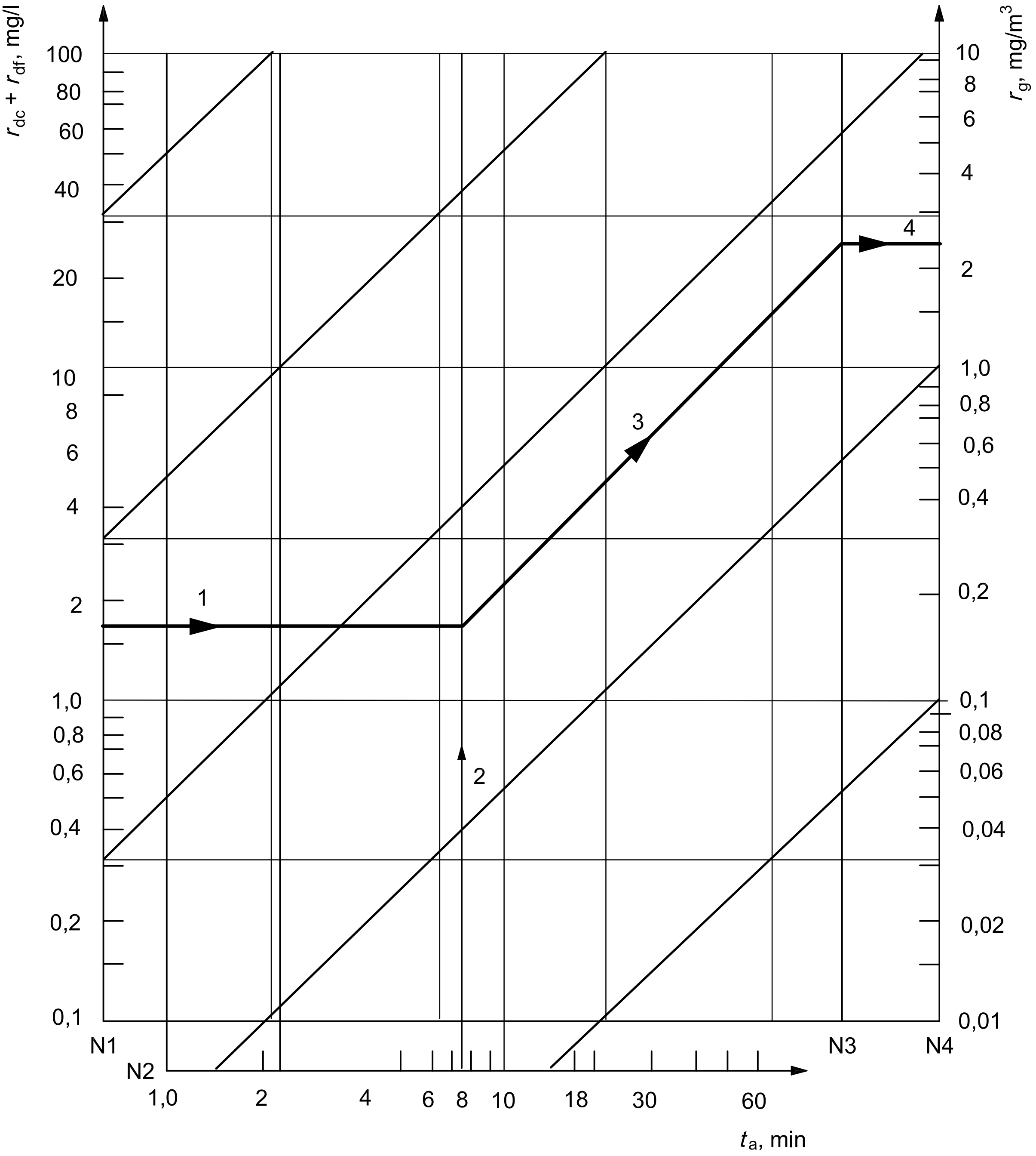


Figure D.1 — Nomograph for determining the concentration of oil in gases

The nomograph was constructed based on Formula (7) subject to the following values:

$$V_\text{p} = 0{,}05L, Q = 5 \text{ L/min}, \varepsilon_\text{s} = 0{,}91$$

A gas oil impurity concentration is determined in Figure D.1 as follows.

a) A sum of values r_dc and r_df is marked along vertical scale N1. The horizontal **1** is passed from the received point until it intersects with a perpendicular **2** constructed from a corresponding point of scale N2, on which sampling time values t_a are marked.

b) Then, a diagonal **3** is passed (parallel other) from the intersection point of the horizontal and the perpendicular until it crosses vertical scale N3. A horizontal **4** is passed from this intersection point until it crosses scale N4, where desired values of oil concentration in gases r_g (mg/m^3) are marked.

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