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Space systems — Gas contamination — Measurement methods for field tests

Systèmes spatiaux — Contamination des gaz — Méthodes de mesurage 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.

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.

The purpose of this International Standard is to provide the users with 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 oxidize increase equipment explosion and fire hazards and have a negative biological effect on persons who breathe it. 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 may be used for modernization and maintenance of the launch site equipment and technical complexes. Methodical procedures are simple, precise, and applicable in extreme conditions when other methods are difficult to apply. The equipment mentioned in this International Standard is portable, compact, and inexpensive.

Space systems — Gas contamination — Measurements methods for field tests

1 Scope

This International Standard covers gases (air, nitrogen, helium, and argon) compressed up to 40 megapascal (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 measuring methods. This International Standard may be used by countries and firms participating in the development, redesign, modernization, and maintenance of space vehicle launch 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 14951-3:1999, *Space systems – Fluid characteristics, Part 3: Nitrogen*

ISO 14951-4:1999, *Space systems – Fluid characteristics, Part 4: Helium*

ISO 14951-9:1999, *Space systems – Fluid characteristics, Part 9: Argon*

ISO 14951-13:1999, *Space systems – Fluid characteristics, Part 13: Breathing air*

3 Terms, symbols, and abbreviated terms

3.1 Terms and definitions

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

3.1.1

gas sampling isokinetics

the velocity and direction of a gas flow caught by a sample probe are the same as in the main flow in a tube

3.1.2

mechanical impurity

solid dispersal phase with a wide spectrum of aerosol particle size

3.1.3

oil impurity

oil contained in gas in the form of vapours and aerosols

3.1.4

particle concentration

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

3.1.5

particle size

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

3.1.6

safety requirements

determined requirements 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 allowable value, gases (air, nitrogen, helium, and argon) are subdivided into classes of industrial purity in accordance with ISO 14951-3; ISO 14951-4; ISO 14951-9; and ISO 14951-13. The gas purity class is specified in the design documentation in accordance with the appropriate ISO 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 homogenisation:
- and every 24 hours under 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 hours 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 pressurisation phase (after a relaxation time homogenisation);
- and every 24 hours (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 shall be allowed to 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 when oxygen content in the room is less than 19 % (on volume). The signal shall be sent in the room in which the problem occurs on two ways (acoustic signal and flash light). Personnel are prohibited in areas where the oxygen content is less than 20,9 % (by volume) 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's 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 point;
- 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) only use 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 the inspection date is current.

4.3 Measuring 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.

Determination of solid particle size and quantity by an optical method with the use of an analytic filter shall be allowed.

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)	100-60	60-40	40-20	20-14	14-8	8-4	4-2	2-1	1-0.5
Microscope magnification	20-30	30-40	40-50	50-80	80-100	100-250	250-500	500-1000	2000

4.3.2 Mechanical impurities content measurement by mass concentration

To measure a mass concentration of solid aerosol particles, the aerosol content transforming the dispersion content and amount of concentration signals into a mass concentration 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} milligram per cubic meter (mg/m^3) value shall be calculated by the formula.

$$r_{sc} = 5.23 \times 10^{-10} \times r \left(\frac{z_1 d_1^3 + z_2 d_2^3 + \dots + z_n d_n^3}{V_s} \right) \tag{1}$$

Where

- ρ solid particle density (g/cm^3) (if the particle density is unknown, it shall be assumed equal to 2,5 g/cm^3);
- D particle maximum size (mm);
- z number of particles of a certain size;
- V_s 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 micrometer (μm).

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

$$r_{sc} = \frac{m_2 - m_1}{Q \times t_s} \tag{2}$$

Where

- m_1 mass of the filter before gas sampling (mg);
- m_2 mass of the filter after gas sampling (mg);
- Q flow rate of a gas sample passing through the control analytic filter, cubic meter per minute (m^3/min);
- t_s gas sampling duration (min).

Solid particle content in compressed gas r_s (mg/m^3) shall be calculated based on results of not less than three measurements by the formula

$$r_{sc} = \frac{r_{s1} t_1 + r_{s2} t_2 + \dots + r_{sn} t_n}{t_1 + t_2 + \dots + t_n} \tag{3}$$

Where

$r_{S1}, r_{S2} \dots r_{Sn}$ solid particle content in compressed gas (mg/m^3);
 t_1, t_2, t_n gas sampling duration (min).

A tentative testing duration shall be calculated by the formula

$$\frac{b_{\min}}{r_{s1} \times Q} \leq t \leq \frac{b_{\max}}{r_{s1} \times Q} \quad (4)$$

Where

b_{\min} minimum necessary content of solid particles on the filter (mg);
 b_{\max} maximum permissible content of solid particles on the filter (mg);
 r_{S1} supposed or limiting assumed content of solid particles value (mg/m^3);
 Q 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 blached and dried. Blanching shall be accomplished using a solvent containing for example 94 % of xylene $\text{C}_6\text{H}_4(\text{CH}_3)_2$ and 6 % of cresyl phosphate $(\text{CH}_3\text{C}_6\text{H}_2\text{O})_3\text{PO}$ or dibutyl phthalate $\text{C}_6\text{H}_4[\text{COO}(\text{CH}_2)_3\text{CH}_3]_2$. Solid particle sizes are determined by testing the particles with a microscope.

4.3.4 Water vapor content measurement

The water vapour content in gases shall be measured by hygrometers intended to measure water vapour concentrations in the range of $0,92 \text{ mg}/\text{m}^3$ to $1000 \text{ mg}/\text{m}^3$ with a basic error referred to full-scale value not more than:

- 2.5 % in ranges of $0 \text{ mg}/\text{m}^3$ to $1000 \text{ mg}/\text{m}^3$ and $0 \text{ mg}/\text{m}^3$ to $100 \text{ mg}/\text{m}^3$ -and
- 6 % in ranges of $0 \text{ mg}/\text{m}^3$ to $10 \text{ mg}/\text{m}^3$ and $0 \text{ mg}/\text{m}^3$ to $2 \text{ mg}/\text{m}^3$.

Hygrometer prestarting 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.

Control of the water vapour content by the dew point hygrometers at the standard atmospheric and operation pressures in a hygrometer test chamber is allowed. 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, mg/m³ [at 20 °C and 101,3 kilopascal (kPa)]

Dew point ranges and GMC					
of -20 °C to -50 °C		of -52 °C to -82 °C		of -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 Annex B (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 vapors contained in the flow are absorbed by a tube filter; thus the filter is partially or completely coated;
- b) the length of a coated layer of the detector tube filter depends on vapor concentration;
- c) to measure the tested gas water content, the detector tube shall be compared with the applied graduated scale;
- d) 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 vapors and aerosols contained in the flow; thus the filter is partially or completely coated;
- b) a length of a coated layer of the detector tube filter depends on an oil concentration;
- c) 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;
- d) to measure the tested gas oil content, the detector tube shall be compared with the applied graduated scale;
- e) then, the readings of values in mg/m^3 along the upper boundary of a coated layer shall be taken.

Control of oil content in the flow by a method of infrared absorption spectrophotometry or by a luminescent method with preliminary solution of the oil in organic solvents during gas sampling is allowed. In this case oil concentration C_g is calculated by the formula

$$C_g = \frac{m}{V_g} \quad (5)$$

where

m oil content in the solvent (mg);

V_g 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 e_s , the formula (6) looks like the following [formula (7)]:

$$r_g = \frac{1000 \sum_{i=1}^n (r_{dc_i} V_{sd_i} + r_{df_i} V_{sf_i})}{e_s Q t} \text{ mg} / \text{m}^3 \quad (6)$$

Where

$i = 1, 2 \dots n$ number of washes after sampling;

r_{dc} , r_{df} concentration of oil desorbed from the chamber and filter, milligram per liter (mg/l);

V_{sc} , V_{sf} solvent volumes (l);

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

t 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 percent j is calculated as a difference between 100 and the sum of impurity percentages by the formula

$$j = 100\% - \sum j_i \quad (7)$$

where

- j_i concentration of the measured impurity, in percent (%). (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 enterprises of the suppliers. Control of the content of foreign gases in the tested gas by detector tubes is allowed.

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 utilisation.

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

A.1 General

Gas dust loading analyzer

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 power

Coulometric hygrometer

Dew point hygrometer

Samplers

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

Gas flow meter

Gas analyzer

Annex B
(informative)

Equilibrium moisture content

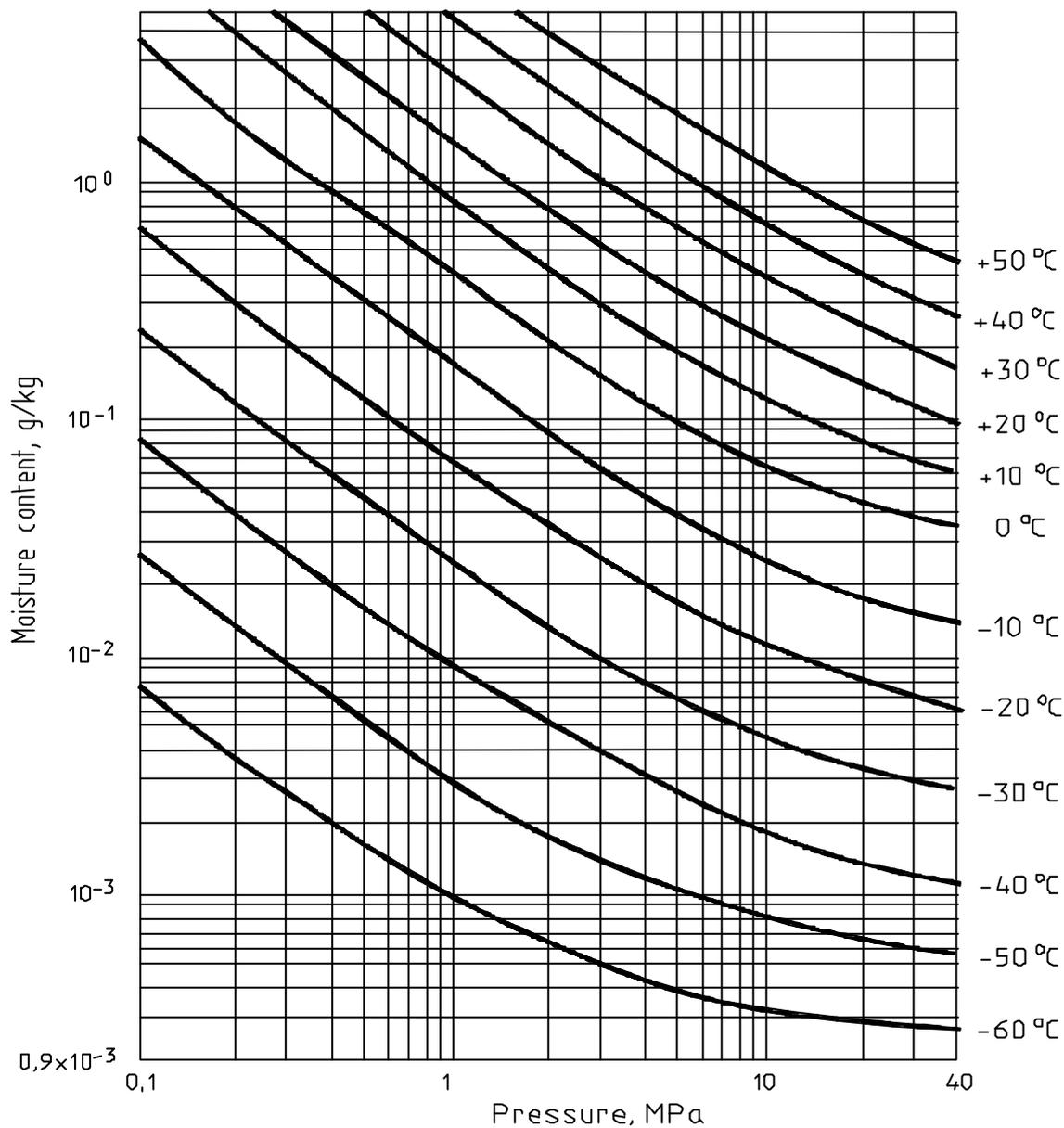


Figure B.1 — Diagram for air and nitrogen

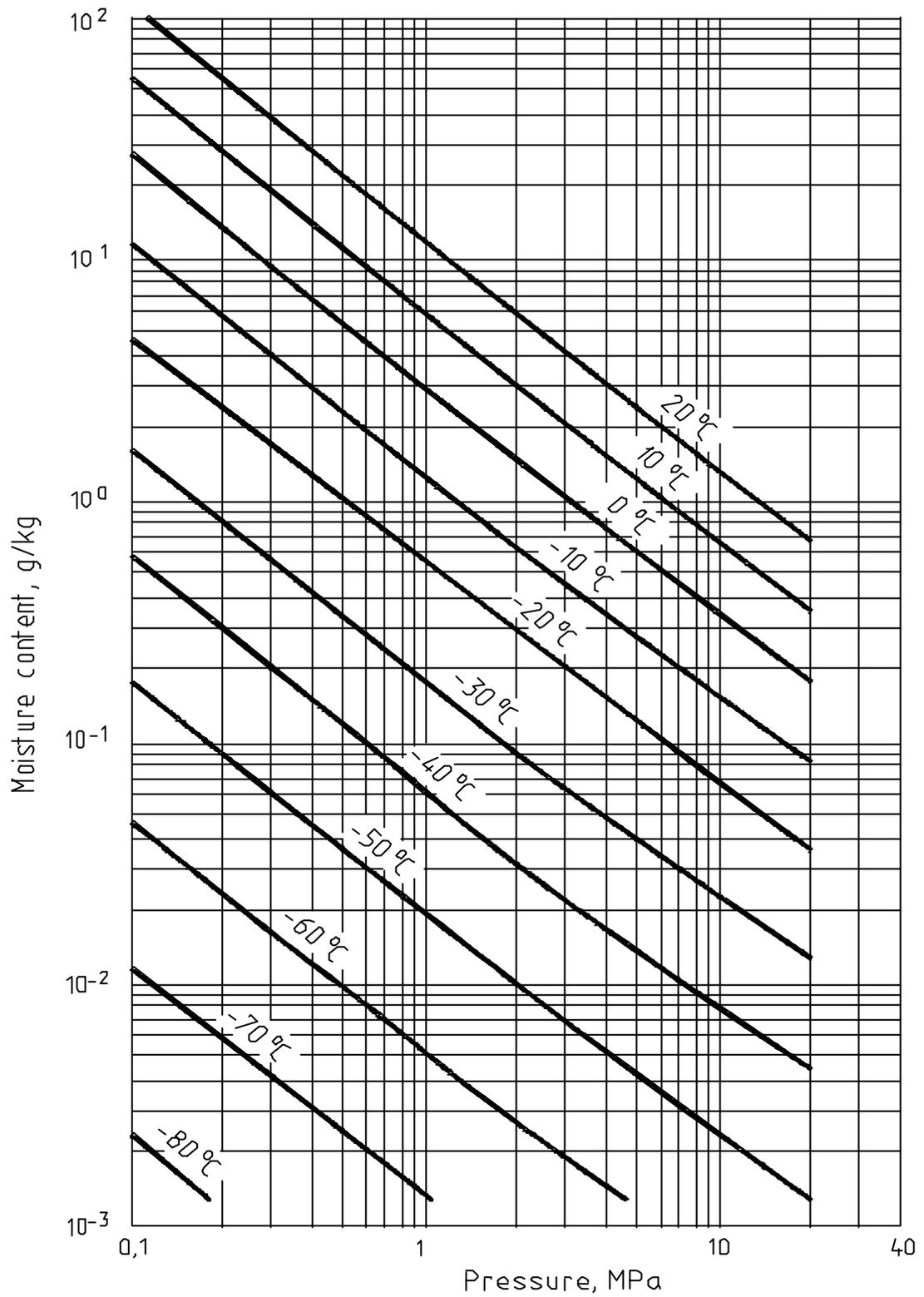


Figure B.2 — Diagram for helium

Annex C (informative)

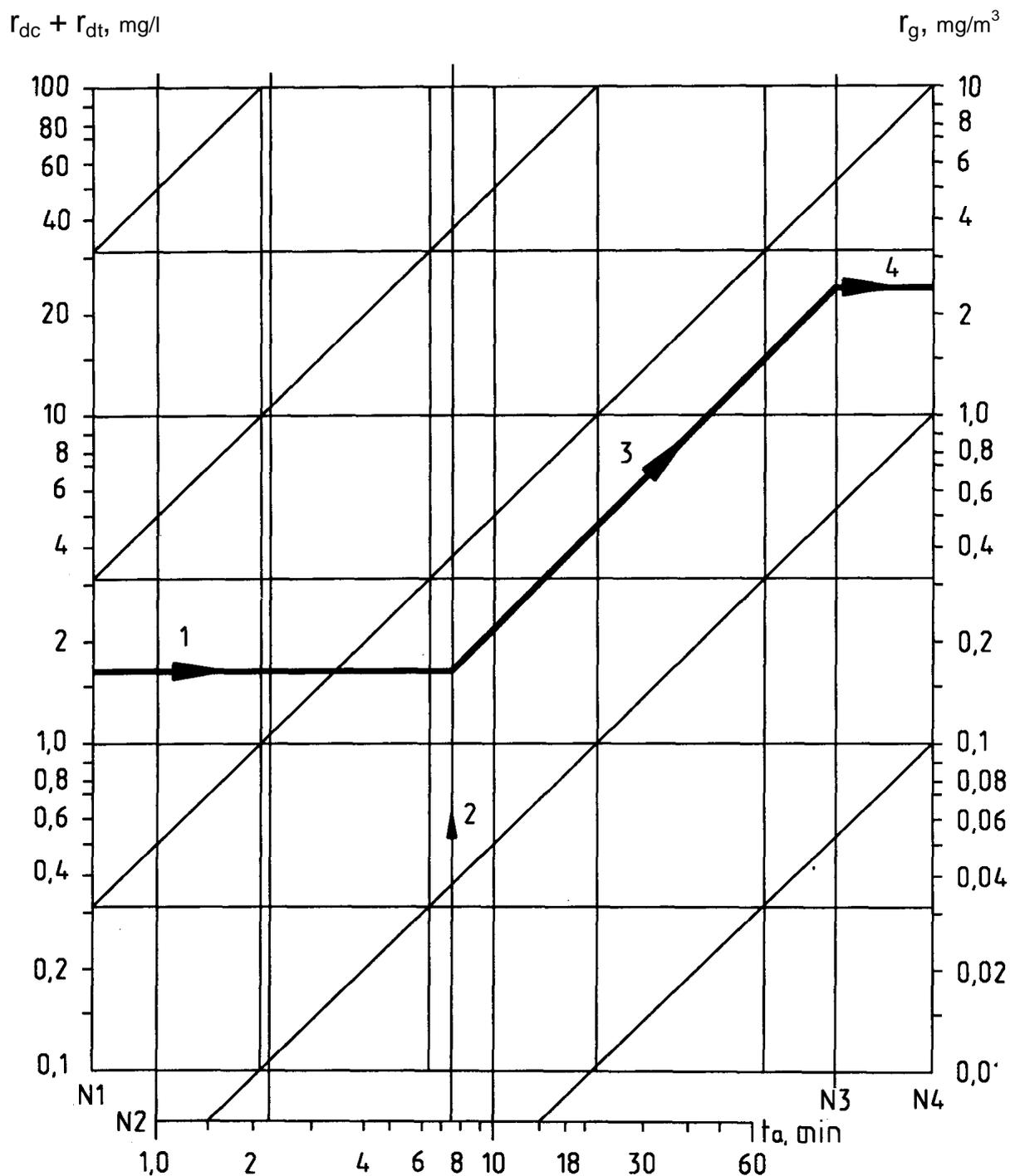
Determination of the mass concentration of water vapours by a dew point method at different pressures of nitrogen (oxygen)

Water vapour mass concentration at 20 °C and 101.3 kPa, mg/m ³	Dew point (°C) at different pressures (MPa) over condensation mirror				
	0,1	5	10	15	20
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)

NOTE The values outside of brackets fall into nitrogen, the values in brackets fall into oxygen.

Annex D (informative)

Nomograph for determining the concentration of oil in gases



The nomograph was constructed based on formula 7 (subclause 4.3.6) subject to the values

$$V_p = 0,05L, Q = 5 \text{ L/min}, E_s = 0,91.$$

A gas oil impurity concentration is determined as follows:

- a) a sum of values r_{dc} and r_{df} is laid off along vertical scale number 1 and the horizontal is passed from the received point until it meets with a perpendicular constructed from a corresponding point of scale number 2, on which sampling time values t_a are laid off;
- b) then, a diagonal is passed from the point of meeting the horizontal with the perpendicular until it crosses vertical number 3, and a horizontal is passed from this intersection point until it crosses scale number 4 where desired values of oil concentration in gases r_g (mg/m^3) are laid off.