INTERNATIONAL STANDARD

ISO 8573-2

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Compressed air for general use —

Part 2:
Test methods for aerosol oil content

Air comprimé pour usage général —

Partie 2: Méthodes d'essai pour mesurer la teneur en huile présente sous forme d'aérosols

Reference number
ISO 8573-2:1996(E)

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.

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.

International Standard ISO 8573-2 was prepared by Technical Committee ISO/TC 118, *Compressors, pneumatic tools and pneumatic machines*, Subcommittee SC 4, *Quality of compressed air*.

ISO 8573 consists of the following parts, under the general title *Compressed air for general use*:

- *Part 1: Contaminants and quality classes*
- *Part 2: Test methods for aerosol oil content*
- *Part 3: Determination of humidity*
- *Part 4: Determination of solid particles and microbiological contaminants*
- *Part 6: Determination of gaseous contaminants*

Users should note that the titles to future parts 3 to 6 are working titles only and that, while it is at present planned to publish all the parts listed above, one or more may nevertheless be deleted from the work programme before publication, which may, in turn, lead to renumbering of the remaining parts.

Annex A forms an integral part of this part of ISO 8573. Annex B is for information only.

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Compressed air for general use —

Part 2:
Test methods for aerosol oil content

1 Scope

This part of ISO 8573 specifies test methods for the sampling and quantitative analysis of aerosol oil and liquid oil (excluding oil vapour) typically present in the air discharged from compressors and compressed air systems.

Using the sampling and analysing equipment as described, the accuracy of each method is better than ± 10 % of the measured value of oil content ranging from 0,001 mg/m^3 to approximately 20 mg/m^3 under Reference Atmosphere conditions[1] (ANR) with varying sampling times.

This part of ISO 8573 gives detailed instructions on the equipment to be used and the test methods to be employed for the measurement of aerosol oil content in a compressed air supply system.

It applies to compressed air systems up to 30 bar[2] working pressure and temperatures of the compressed air below 100 °C, but excluding systems intended to supply compressed air for medical use or for direct breathing.

Two different methods are described, Method A and Method B. Method B is subdivided into two parts to clearly distinguish between procedures for obtaining the quantity of oil for analysis.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 8573. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 8573 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 65:1981, *Carbon steel tubes suitable for screwing in accordance with ISO 7-1.*

ISO 5167-1:1991, *Measurement of fluid flow by means of pressure differential devices — Part 1: Orifice plates, nozzles and Venturi tubes inserted in circular cross-section conduits running full.*

ISO 8573-1:1991, *Compressed air for general use — Part 1: Contaminants and quality classes.*

3 Definitions

For the purposes of this part of ISO 8573, the definitions given in ISO 8573-1 and the following definition apply.

3.1 wall flow: That proportion of oil contamination no longer suspended within the air flow in the pipe.

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[1] The air flow is stated at Reference Atmosphere conditions (ANR) of 1 000 mbar, 20 °C and 65 % relative humidity.

[2] 1 bar = 10^5 N/m^2 = 100 kPa

4 Units

General use of SI units as given throughout this part of ISO 8573 is recommended.

However, in agreement with accepted practice in the pneumatic field, some nonpreferred SI units accepted by ISO are also used; these are given in table 1.

5 Typical sampling points

5.1 General

The test methods may be used at any point in the compressed air system. The choice between Methods A and B depends upon the actual level of oil contamination present in the compressed air system.

Typical conditions at four points in a compressed air system are indicated in 5.2 to 5.4, together with the recommended test method. Figure 1 indicates the positions of typical sampling points. Table 2 presents a guide for selection of the appropriate method.

5.2 Position 1 (see figure 1)

Typical boundary conditions occurring after the compressor/separator at final compressor temperatures:

Oil-flooded rotary compressor:	70 °C to 100 °C, 7 bar to 10 bar

Degree of contamination typical at this point:

Oil mist:	5 mg/m^3 to 20 mg/m^3 (ANR) in a spectrum of 0,01 µm to 10 µm
Oil vapour:	5 mg/m^3 to 20 mg/m^3 (ANR)
Solid particles:	less than 0,1 mg/m^3 (ANR)
Water condensate:	none
Water vapour:	unknown

Test method: Method A

Table 1 — Nonpreferred SI units

Quantity	Unit name	Unit symbol	Definition
Pressure	bar	bar	1 bar = 10^5 Pa
Volume	litre	l	1 l = 10^{-3} m^3
Time	minute hour	min h	1 min = 60 s 1 h = 60 min = 3 600 s

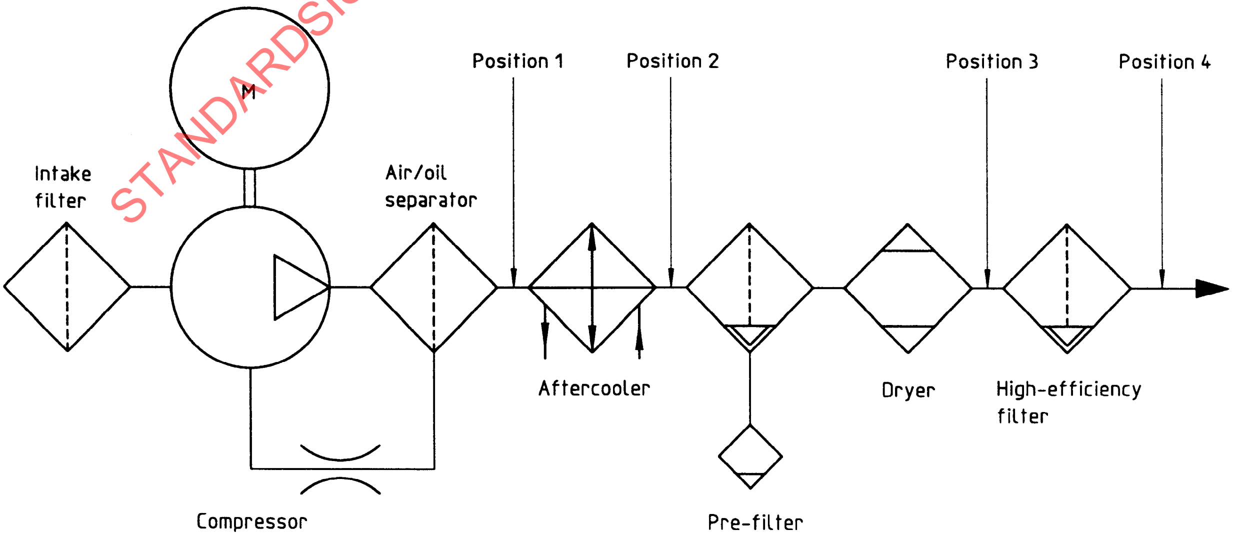


Figure 1 — Typical sampling points in the compressed air system

Table 2 — Guide for selection of test method

Parameter	**Method**		
	A Full flow	**B1** Full flow	**B2** Partial flow
Contamination range	5 mg/m^3 to 20 mg/m^3	0,001 mg/m^3 to 5 mg/m^3	0,001 mg/m^3 to 5 mg/m^3
Maximum velocity (pipe)	See table 4	See table 4	See table 4
Maximum velocity (filter)	See 6.1.2.2	1 m/s	1 m/s
Maximum diameter of pipe	No limit	DN 25	No limit
Sensitivity	0,5 mg/m^3	0,001 mg/m^3	0,001 mg/m^3
Accuracy	± 10 % of actual value	± 10 % of actual value	± 10 % of actual value
Maximum temperature	100 °C	40 °C	40 °C
Testing time (typical)	50 h to 200 h	2 min to 3 h	2 min to 3 h
Filter construction	Coalescing line filter	Three-layer membrane	Three-layer membrane
Typical sampling points	Compressor outlet	After high-efficiency filters	After high-efficiency filters

5.3 **Position 2** (see figure 1)

Typical boundary conditions occurring just after the aftercooler/centrifugal separator:

Operating temperature:	20 °C to 45 °C
Operating pressure:	5 bar to 10 bar
Water condensate:	slight traces
Water vapour:	saturated air
Oil mist:	5 mg/m^3 to 20 mg/m^3 (ANR) in a spectrum of 0,1 µm to 50 µm
Oil vapour:	0,1 mg/m^3 to 2 mg/m^3 (ANR)
Solid particles:	less than 0,1 mg/m^3 (ANR)

Test method: Method A

5.4 **Position 3** (see figure 1)

Typical boundary conditions occurring downstream of prefilters and refrigeration dryers:

Operating temperature:	20 °C to 45 °C
Operating pressure:	5 bar to 10 bar
Water condensate:	none
Water vapour:	pressure dew-point 2 °C to 10 °C
Oil mist:	0,5 mg/m^3 to 10 mg/m^3 (ANR) in a spectrum of 0,01 µm to 5 µm
Oil vapour:	0,1 mg/m^3 to 1 mg/m^3 (ANR)
Solid particles:	less than 0,1 mg/m^3 (ANR)

Test method: Method B

5.5 **Position 4** (see figure 1)

Typical boundary conditions occurring downstream from high-efficiency coalescing filters:

Operating temperature:	20 °C to 45 °C
Operating pressure:	5 bar to 10 bar
Water condensate:	none (after dryers)
Water vapour:	pressure dew-point − 70 °C to + 10 °C (after dryers)
Oil mist:	less than 0,1 mg/m^3 (ANR) within the range 0,01 µm to 0,5 µm
Oil vapour:	0,01 mg/m^3 to 1 mg/m^3 (ANR)
Solid particles:	less than 0,01 mg/m^3 (ANR)

Test method: Method B

6 General description of test equipment and method

6.1 Method A

6.1.1 General

This method samples all of the air flow which is passed through two high-efficiency coalescing filters in series, and measures oil in both aerosol and wall flow forms. The equipment and method are designed to operate up to 100 °C.

The method may also be used to determine the amount of aerosol oil present typically in the air discharged from an oil-lubricated compressor when fitted with an air/oil separator. Oil concentrations in the region of 0,5 mg/m^3 and above can be determined with an accuracy of ± 10 %. Typically all of the discharged air would be sampled over a time period of 50 h to 200 h. The method is also suitable for long-term testing over several thousand hours.

6.1.2 Test equipment

6.1.2.1 General description

The general arrangement of equipment used in Method A is shown in figure 2 and consists of the following items.

1 Compressor
2 Air/oil separator(s)
3 Separator oil sump
4 Discharge pipe
5 Oil scavenge return pipe
6 Aftercooler (optional)
7 Shut-off valve
8 "Y" piece (if required)
9 High-efficiency sampling filter housing
10 Coalescing filter element
11 Shut-off valve
12 Collecting vessel (transparent)
13 Drain valve
14 Measuring column
15 Differential pressure gauge
16 High-efficiency sampling filter housing
17 Coalescing filter element
18 Shut-off valve
19 Collecting vessel (transparent)
20 Drain valve
21 Measuring column
22 Differential pressure gauge
23 Pressure gauge
24 Flowmeter
25 Flow control valve
26 Silencer
27 Three-way valve
28 Discharge pressure gauge
29 Measuring column
30 Differential pressure gauge
31 Temperature gauge (t_1)
32 Shut-off valve
33 Ambient temperature gauge (t_2)
34 Hygrometer
35 Temperature gauge

6.1.2.2 Sampling filter [(9) and (10)]

Sampling filter elements shall be tested for integrity after manufacture and shall meet one of the following specifications:

- Particle penetration according to the dioctyl phthalate (DOP) method (see [1]): below 0,000 5 %.
- Particle penetration according to the NaCl method (see [2]): below 0,000 5 %.

NOTE 1 Filters passing the integrity tests (DOP or NaCl method) cannot be assumed to comply with the maximum oil content level using Method B1 or B2.

Air with entrained aerosol oil and wallflow oil enters the sampling filter housing (9) and flows out through the coalescing filter element (10) which will coalesce the oil into bulk liquid. The bulk liquid drains to the bottom of the housing and into the collecting vessel (12) (via open valve 11) awaiting measurement.

6.1.2.3 Back-up filter (16)

This filter is identical to the sampling filter and will, in the event of malfunction of the sampling filter, collect any oil which has passed through it.

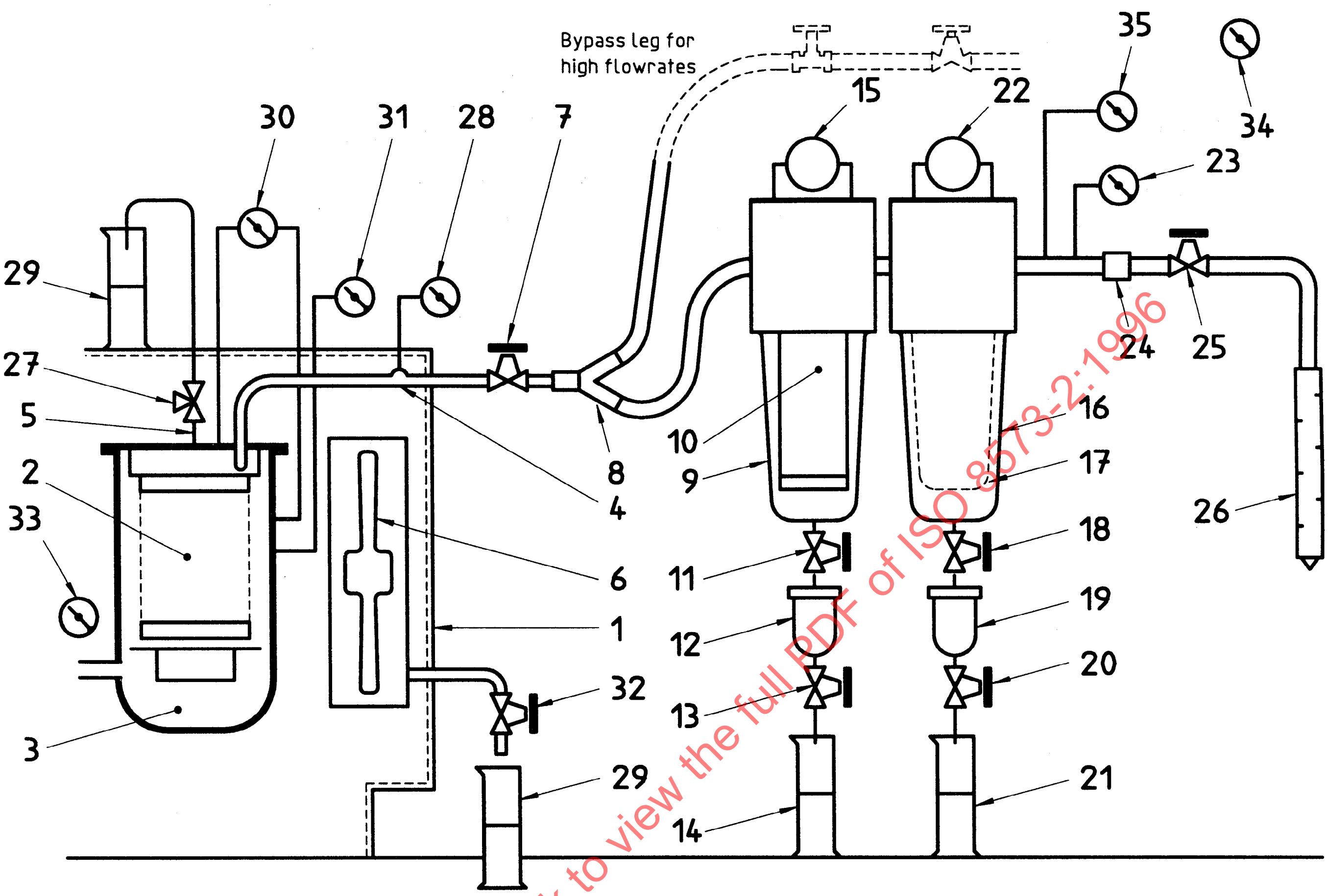


Figure 2 — Apparatus for Test Method A

6.1.2.4 Collecting vessels [(12) and (19)]

Transparent plastic bowls with protective guards are fitted to enable the oil collection to be observed during operation. Shut-off valves (11) and (18) are closed only for removal or draining of collecting vessels and are normally left in the open position.

6.1.2.5 Drain valves [(13) and (20)]

Drain valves are used to drain the liquid contained in collecting vessels (12) and (19); they are normally left in the closed position.

6.1.2.6 Measuring columns [(14) and (21)]

Collected oil is measured in the measuring column(s) (graduated in millilitres).

6.1.2.7 Differential pressure gauges [(15) and (22)]

These gauges determine the pressure drop across the sample and back-up filters.

6.1.2.8 Air flowmeter (24)

A suitable flowmeter is used to determine the air sample volume. Many types are available; an accuracy of better than ± 5 % of the measured value is necessary. Temperature (35) and pressure (23) gauges are also required to relate measured flow to 1 bar absolute pressure, 20 °C and 65 % relative humidity air (see ISO 2787).

6.1.2.9 Flow control valve (25)

In order to adjust the flow accurately, a valve (25) with fine adjustment is required.

6.1.3 Flow range of test equipment

The equipment described should be capable of handling a flow of 200 l/s (ANR) at an effective (gauge) pressure of 7 bar. For greater flow, multiples of the test equipment can be used or excess air diverted using a "Y" piece (8). The velocity in the "Y" piece shall be matched in the outlet legs to ensure representative sampling. It is necessary to monitor diverted air flow only to determine the total discharge. The test equipment shall operate independently.

6.1.4 Other measurements

The following additional data are essential if the intention is to measure the efficiency of the air/oil separator in the compressor.

6.1.4.1 Temperature

In order to determine performance within a specified temperature range, the temperature is recorded during the entire period of the test. A temperature gauge measures temperature at the inlet. The temperature gauges shall have an accuracy of ± 1 K.

6.1.4.2 Air pressure before sampling filter

The air pressure shall be measured using a pressure gauge. The pressure gauge shall have an accuracy of ± 0,25 % of the maximum scale reading.

6.2 Method B

6.2.1 Method B1 — Full flow sampling

6.2.1.1 General

Method B1 deals with the sampling and analysis of airborne aerosols at constant flowrate.

Within the constraints detailed above, this method permits the quantification of aerosol oil present in a compressed air system, provided wall flow contamination is not present. Air flow is normally diverted through the test equipment via suitable in-line valves which have been previously checked to ensure they do not contribute to the level of oil contamination already present. As this method concerns the measurement of relatively low concentrations of oil in air, particular attention shall be paid to the cleanliness of the test equipment and other precautions shall be taken, e.g. valve purging and stabilization to constant test conditions. Good analytical techniques will help improve the confidence level of the measurements.

The optimum duration of a test measurement may be determined after an initial test to determine the approximate oil concentration present. When carrying out full flow tests, it is possible to route the air back into the compressed air system, preventing loss of the product. Conversely, it is also possible to vent the flow to the atmosphere. Flow measurement is required to determine the volume of air used during the test, whichever method is adopted. As the test apparatus is portable, different test locations may be chosen, provided the stated parameters are not exceeded and suitable valving for insertion of the test equipment into the circuit exists. Obvious precautions to prevent shock depressurization, which may damage the test filter membrane, or ingress of atmospheric contamination, are necessary. Appropriate physical parameters, e.g. temperature, pressure, flowrate, etc., shall be recorded as stipulated for Method A.

The sampling and analysing equipment used as described give an accuracy of better than ± 10 % over the range from 0,001 mg/m^3 to approximately 5 mg/m^3 oil content, with sampling times from 30 min to 2 min respectively. The upper limit for the air velocity (at operating pressure) in front of the test membrane is 1 m/s. The test is performed under full flow conditions.

The temperature range should be from 0 °C to 40 °C. If the compressed air temperature is above 40 °C, the oil vapour shall also be taken into account.

Using Method B1, the total air flow passes through the test membrane.

6.2.1.2 Test equipment

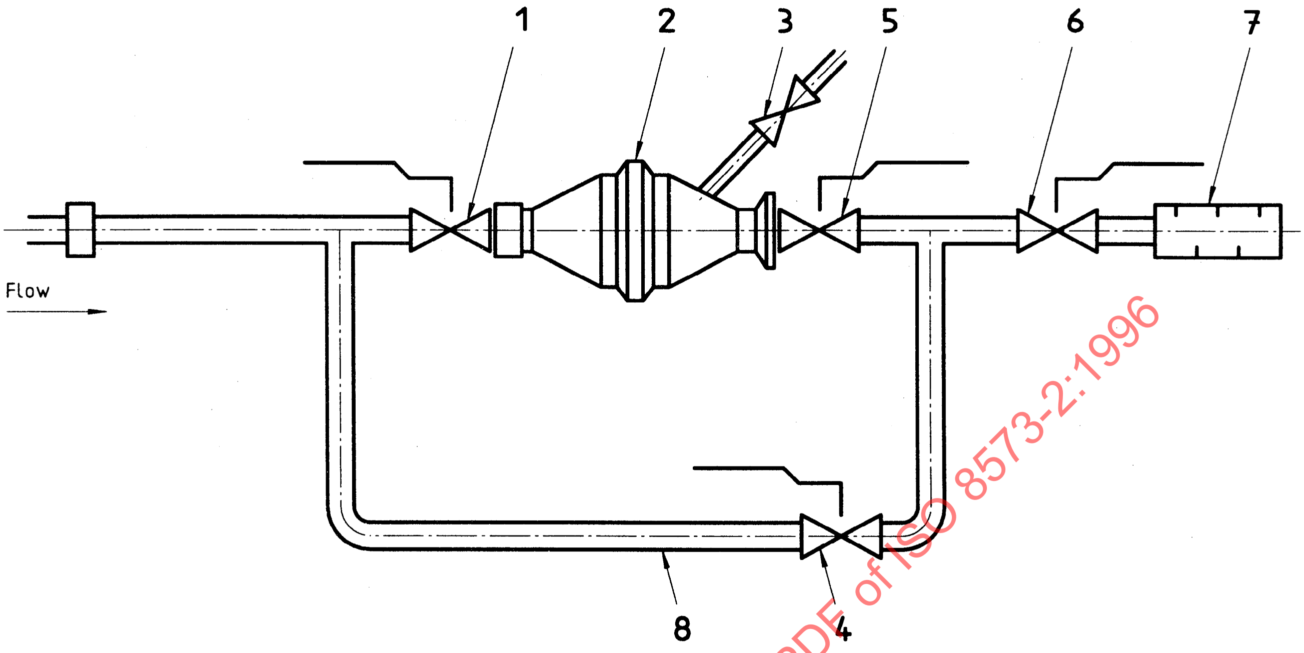
The general arrangement of the test equipment is shown in figure 3.

6.2.1.2.1 Membrane

In order to obtain good measuring accuracy, a high-efficiency microfibre glass membrane should be used. To achieve the accuracy specified for this method, three layers of membrane in series and in intimate contact shall be used and the membrane shall meet the following requirements (see table 2):

surface mass:	88,5 g/m^2
pressure drop for air at 0,014 m/s:	23,1 mbar at atmopsheric pressure
particle penetration:	below 0,000 5 % (see [2])

To fit the described equipment, the membrane must be circular. A diameter of 55 mm is typically used.



Key

1 4 5	Full flow ball-type shut-off valves
2	Membrane holder
3	Valve for evacuating membrane holder
6	Flow control valve
7	Silencer
8	Bypass tube

Figure 3 — Test equipment for Method B1

6.2.1.2.2 Membrane support

In order to prevent the collection membrane from bursting, a stainless steel sintered disc must be placed as support just behind the membrane. This disc should also be circular and have the same diameter as the membrane. A suitable disc is 3 mm thick and can remove 95 % of all solid particles 40 µm or larger in size.

6.2.1.2.3 Pipes and valves

It is important that the pipe inner diameter, from the connection point in the compressed air system to the membrane holder, is constant and that the inner surface is smooth, to minimize system loss.

The shut-off valve (1) in figure 3 should be of a ball type, and the hole in the ball should have approximately the same diameter as the pipe.

The bypass pipe may consist of a flexible tube.

6.2.1.2.4 Membrane holder

A general diagram of a typical membrane holder is shown in figure 4.

6.2.1.2.5 Construction materials

Aluminium and its alloys shall not be used for any components which may come into contact with solvents.

Dimensions in millimetres

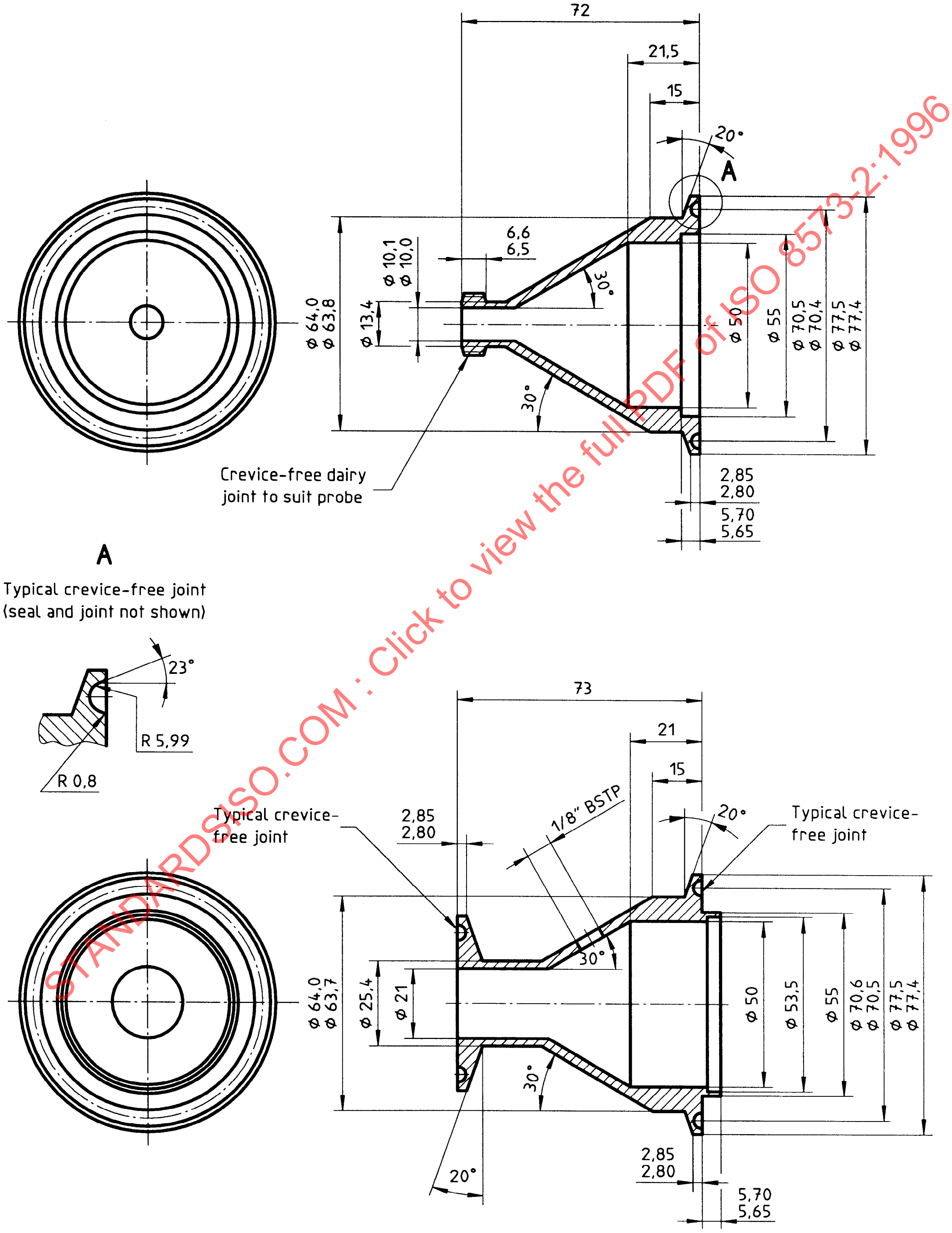


Figure 4 — Typical membrane holder

6.2.2 Method B2 — Partial flow sampling

Method B2 uses the same test equipment employed in Method B1, with the addition of a sampling probe to allow partial flow sampling under isokinetic conditions from the main pipe flow should the velocity constraints of Method B1 be exceeded. Accuracy and limitations are as stated in Method B1.

The sampling probe may be inserted into any section of the pipe, using suitable connections and valves, and allows a sample of air to be taken from the main pipe flow under identical velocity conditions. Both main pipe flow and sample flows need to be known to define the test conditions. The probe may be inserted to an approximately central position across the main pipe diameter, and it is recommended that a number of preliminary tests be made. The design of the test membrane holder and probe allows back-flushing with solvent to remove any contamination deposited on the walls of the holder or probe to ensure it is included in the analysis.

It is also possible to leave the probe in position and analyse the oil deposited on the membrane and holder by using suitable in-line valves only. This allows the main pipe system to remain pressurized while analysis is performed and also permits intermittent tests to be carried out over a period of time. The pressure seals used in the probe/holder connectors must not release any hydrocarbon into solution when immersed in the analysing solvent. It is impractical to return the sample flow to the main pipe flow downstream from the membrane holder, and it is usual to vent this flow to atmosphere.

At very low oil concentrations (0,01 mg/m^3 and below) the recommended sampling time is 1 h to 3 h.

6.2.2.1 Isokinetic sampling — General

For sampling from high flow systems, isokinetic sampling may be used when wall flow is not present (e.g. below 5 mg/m^3 total aerosol oil content).

Accurate isokinetic sampling is not critical for small particles (less than 1 µm), although approximate isokinetic conditions are advisable.

Isokinetic sampling devices should exhibit the following characteristics:

a) The probe should be a minimum distance of 10 pipe diameters from upstream bends or restrictions and 3 diameters from downstream bends or restrictions (see reference [3]).

b) The size of the probe should not influence the airstream. The nozzles may vary in shape and construction.

c) Impaction onto the internal surface of the probe should be taken into account. Precautions are necessary to prevent surface condensation of oil vapours unless the internal surfaces are washed with solvent.

d) Under the test conditions specified, scanning across the pipe with a sampling probe is unnecessary.

e) Turbulent flow conditions within the main airstream are required for sampling (Reynolds number greater than 4 000).

In normal industrial use, compressed air is in a state of turbulent flow, which occurs when the following conditions are met:

$$Q > d/20$$

where

Q is the pipe flow, in litres per second (ANR);

d is the pipe bore, in millimetres.

6.2.2.2 Equipment set-up for isokinetic sampling

The experimental set-up for isokinetic sampling comprises the following elements (see figure 5):

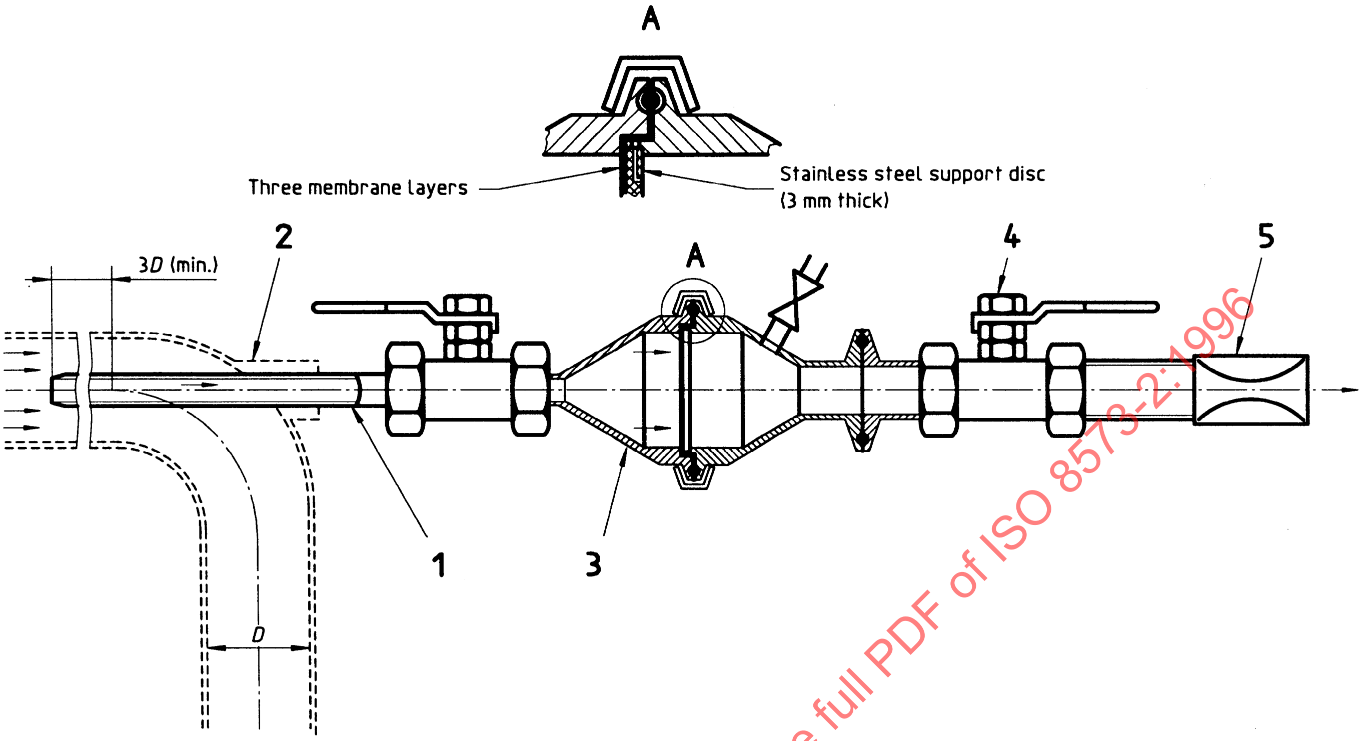
1 Probe
2 Nozzle with gland
3 Membrane holder with vent valve
4 Full-flow ball valve

The ball valve (4) and flowmeter (5) allow adjustment and measurement of full pipe flow, respectively.

6.2.2.3 Design of the isokinetic probe

The general construction of the probe is shown in figure 6 and is intended for use with pipe velocities up to 15 m/s and sampling flowrates up to 3 l/s when used with a suitable membrane holder designed for a 55 mm diameter standard disc.

The probe should be of circular cross-section, the open end having a thickness of less than 1,3 mm and the internal and external surfaces having an inclination not greater than 30° to the axis of the nozzle (figure 6) (see references [5] and [7]).



Key

1 Probe
2 Nozzle with gland
3 Membrane holder
4 Full-flow ball valve
5 Flowmeter

Figure 5 — Equipment set-up for Method B2, isokinetic sampling (shown for bend insertion of probe)

The angle at the nozzle minimizes the effect of impact onto the end of the probe.

Advice on the design and construction of isokinetic sampling probes is given in references [4] and [5].

6.2.2.4 Probe installation

An isokinetic sampling probe should not create a problem, providing the general design in figure 6 is followed. A simple compression seal may be used, provided a fluorocarbon elastomer (or similar) seal is used to prevent contamination during the analysis procedure.

This seal must be capable of maintaining the probe in the pipe up to maximum working pressure. Ideally this gland should allow insertion of the probe to differing lengths if necessary.

6.2.2.5 Compressed air flowrates

The air velocities within the main pipeline and within the probe must be identical throughout the sampling period. This is accomplished through adjustment of the flow controllers to provide appropriate readings on the flowmeters.

Identical pipe and probe velocities exist when

$$\frac{Q}{q} = \frac{D^2}{d^2}$$

and the pressure is constant and identical

where

Q is the total pipe discharge, in litres per second (ANR);

q is the probe discharge, in litres per second (ANR);

D is the internal pipe bore, in millimetres;

d is the probe bore, in millimetres.

At the standard test pressure of 6,3 bar and a maximum probe velocity of 15 m/s with a probe flowrate in the region of 3 l/s and probe bore of 7 mm, the maximum discharges through the pipe are given in table 3. These results were obtained from the formula:

$$Q = \frac{D^2 q}{d^2}$$

by substituting 3 for q and 7 for d.

7 Test procedure — Method A

7.1 General

This test method may be used at any point in a compressed air system where heavy contamination levels of oil are believed to exist.

The test equipment shall be in good working order.

Bends and elbows are not permitted. All valves shall be closed and the test equipment checked for leaks by pressurizing, by opening the shut-off valve (item 7 in figure 2).

7.2 Measuring procedure (see 6.1.2.1 and figure 2)

7.2.1 Start-up

Open shut-off valve (7) fully to pressurize the test equipment. Adjust flow using flow control valve (25) to required flow conditions shown on the flowmeter (24). Open valves (11) and (18) and close valves (13) and (20).

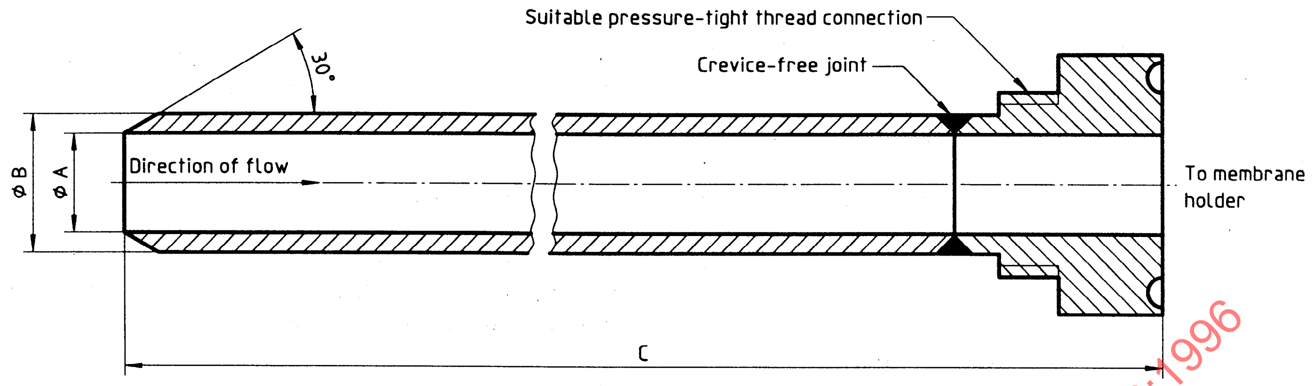
7.2.2 Stabilizing sample filter (9 and 10)

The sample filter element (10) operates in a saturated condition and time must be allowed for this condition to be reached.

Measurement shall be taken only when the differential pressure of the sample filter reaches the stable part of the graph (figure 7) and oil is visible in the collecting vessel (12). A stable pressure drop is indicated by the differential pressure gauge (15). An unused sample filter will take longer to reach stable condition than a filter which has previously been used. The time required to reach a stable pressure drop will depend upon the oil/water loading.

Table 3 — Maximum pipe discharge for sampling with 7 mm probe at 6,3 bar working pressure

Nominal pipe size (mm)	50	65	80	100	125	150
Average internal pipe diameter (medium weight pipe in accordance with ISO 65) (mm)	53,0	68,7	80,7	105,1	130,0	155,4
Maximum pipe discharge [l/s (ANR)]	170	290	400	680	1 030	1 480



Dimensions in millimetres

Probe size	ø A	ø B	C
1	7	9,6	200
2	10	12,6	200
3	17	19,6	400

Figure 6 — Typical isokinetic sampling probe

7.2.3 Oil measurement

Drain collecting vessels (12) and (19) prior to commencement of test run. Retain the oil separated by the sample filter in the collecting vessel (12). Drain the oil for measurement by closing valve (11), gently opening valve (13) and collecting the liquid in the measuring column (14). Measuring intervals depend upon the amount of liquid collected. Allow the collected oil to settle in order to avoid incorrect readings due to foaming, and take care during measurement to account for the meniscus. Alternatively, the collected oil may be weighed, and the mass recorded in milligrams. The first sample filter collects the oil to the required accuracy. The back-up filter is used to ensure the first sample filter has functioned correctly. Any significant sign of oil in the second filter indicates that the first filter element needs to be replaced.

7.2.4 Oil/water measurements

Condensate may also be collected at the sampling filter. When high levels of condensate are present, collection rates increase and larger collecting containers are needed.

The liquid collected consists of water, oil/water emulsion and oil. Depending upon the type of oil, separation of the oil/water emulsion may occur, allowing the water to be drained off and the oil to be measured (see figure 8).

If a water/oil emulsion zone occurs, drain the oil-free water, then add a measured quantity of solvent and stir to dissolve the oil. A recommended solvent is inhibited trichloroethylene (see figure 9).

WARNING — Observe manufacturer's safety instructions and ensure that filter bowls are compatible with the solvent.

Drain the heavier oil/solvent solution and measure the actual quantity of oil collected by subtracting the measured quantity of solvent from the total.

Measurement of the water content in an oil emulsion may also be carried out in accordance with reference [6].

7.2.5 Other measurements

If the test procedure is intended to measure the efficiency of the air/oil separator, rather than ascertaining the level of oil aerosol present in the compressed air system, the following additional data shall be recorded.

7.2.5.1 Oil/water measurement — Aftercooler

Oil may also be present in the condensate at the aftercooler separator drain, in significant quantity to affect the total oil carry-over level.

Drain the aftercooler using valve (32), ensuring all liquid is removed. Leave valve (32) just cracked open and collect the condensate in measuring column (29) until a minimum of 0,5 l of liquid has been obtained. Repeat the procedure at each sampling period. Measure as indicated in 7.2.4.

7.2.5.2 Pressure drop — Air/oil separator

The oil-saturated operational pressure drop is dependent upon the oil loading. Pressure drop readings shown on gauge (30) must reach the horizontal part of the graph before oil carry-over results are significant (see figure 10).

7.2.5.3 Temperature

The air/oil separator temperature t_1 and the ambient air temperature t_2 shall be monitored by gauges (31) and (33) respectively, and recorded.

7.2.5.4 Oil scavenge return

WARNING — Extreme caution is required during this operation, as the scavenged oil will be hot and at discharge pressure.

The three-way valve (27) is normally set to return scavenged oil to the compressor. To obtain a reading, temporarily divert the oil return into a measuring column (29) until a measurable quantity of oil is collected, noting the time required. The reading is recorded in millilitres per minute.

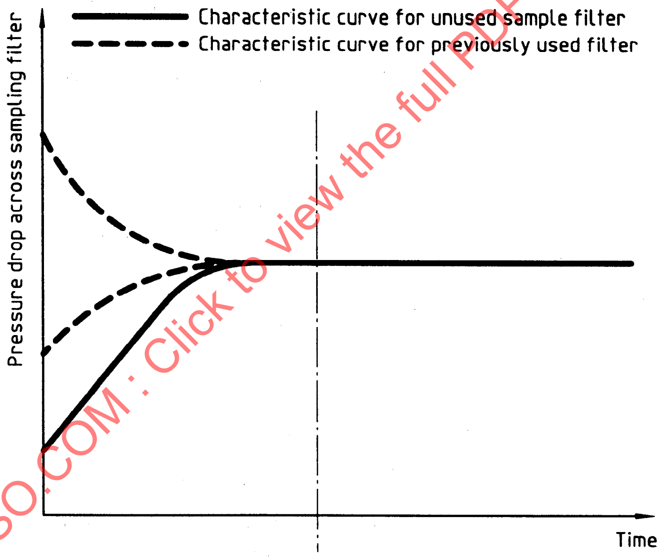


Figure 7 — Characteristic curves for sampling filters

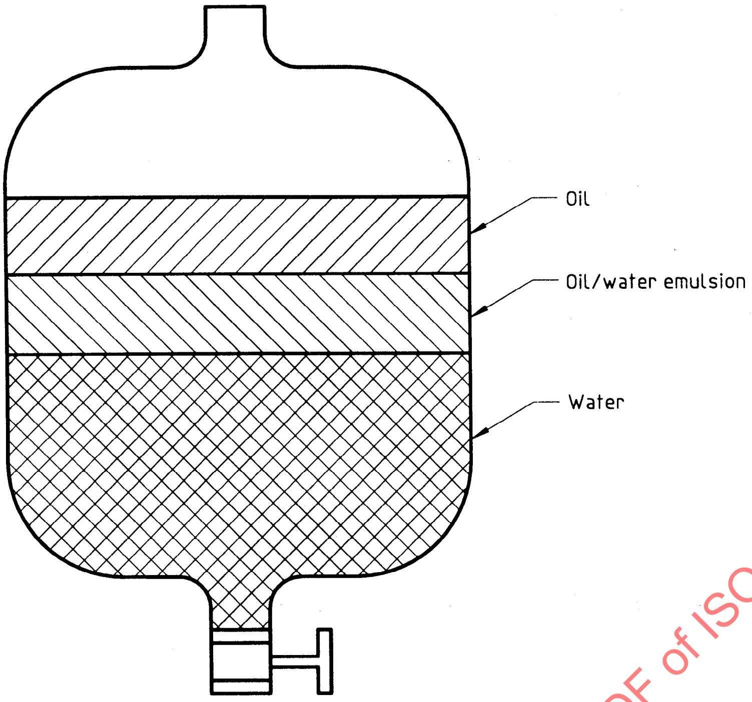


Figure 8 — Oil/water separator

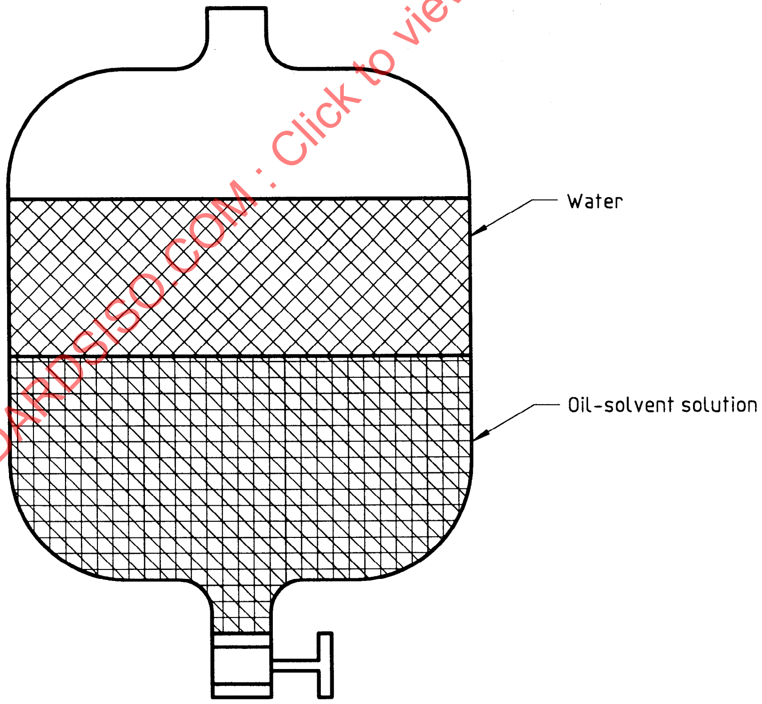


Figure 9 — Oil-solvent/water separator

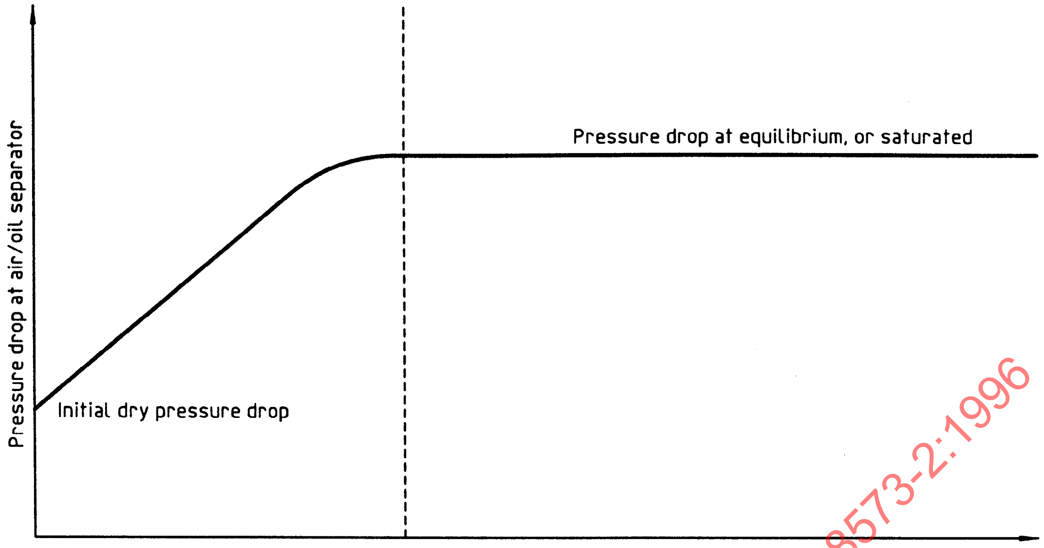


Figure 10 — Drop in pressure shown as a function of time

7.3 Calculation of test results

7.3.1 General

Results normally stabilize within a 200 h period, although meaningful results can be obtained in less time. It is necessary to ensure that results are stable, repeatable and presented in a form which shows that this has been achieved.

7.3.2 Differential pressure

Differential pressure is measured in millibars.

7.3.3 Air flowrate (discharge)

The air flowrate is measured in accordance with ISO 5167-1.

7.3.4 Temperature

The temperature is measured in degrees Celsius.

7.3.5 Oil content

The oil content, X, in milligrams oil per cubic metre air, is calculated using the following formula:

$$X = \frac{V\rho}{qH} \times \frac{10^3}{3\,600}$$

where

V is the volume of oil collected, in millilitres;

ρ is the specific density of the oil, in kilograms per cubic metre;

q is the air flowrate, in litres per second;

H is the duration of the test, in hours.

When the mass of oil is measured, the formula becomes:

$$X = \frac{m}{qH} \times \frac{10^3}{3\,600}$$

where m is the mass of oil, in milligrams.

7.3.6 Data recorded for air/oil separator test

7.3.6.1 Duration of test

Results shall show that a stable condition has been achieved within the limits of experimental accuracy. In cases where a limited time period is required, express test duration in hours, e.g. 200 h. In cases where results are required over a longer period, or in relation to the total lifetime of the air/oil separator, express the duration as a maximum lifetime, e.g. 2 000 h. Alternatively, express the test duration as the time required for the differential pressure at the air/oil separator to reach a set value, e.g. 1 bar.

7.3.6.2 Oil scavenge return (where relevant)

The oil scavenge return is expressed in milligrams oil per cubic metre air.

7.4 Presentation of results

Data to be recorded and their form of presentation are shown in annex A.

8 Test procedures — Method B

8.1 Oil vapour

Depending on the kind of oil and the temperature of the compressed air, the oil vapour content is of special importance. In order to avoid condensation of oil vapour in the system, the sample should be extracted under isothermal conditions, i.e. membrane holder and pipelines should be well insulated, and the temperature of the compressed air should be measured both in the main stream and in the sample stream.

The oil vapour quantities require particular attention at temperatures above 40 °C and for oils with a flash point of less than 250 °C.

8.2 Maximum air velocity

The velocity of the air through the membrane shall not exceed 1 m/s at operating pressure.

The membrane holder shall be cone-shaped to ensure an even velocity distribution across the area of the membrane.

8.3 Handling

Clean membranes must be stored protected against dust and atmospheric contamination. When inserting and removing membranes from the membrane holder, use a pair of tweezers. After measurement is complete and before analysis, the exposed membrane must be stored protected from dust. Do not store the membrane in containers made from organic or hydrocarbon materials. Clean glass Petri dishes are most suitable. If several hours elapse between measuring and analysis, the membrane should be stored in a cool place.

8.4 Zero sample

In order to check that the membranes are clean, choose a new membrane at random. Analyse this membrane to make sure that it does not contain oil.

8.5 Preparation

Ensure there is no hydrocarbon contamination of the membrane holder or components caused by degreasing procedures. Once the holder has been cleaned, only handle using polyethylene gloves to protect from finger-grease contamination. Using tweezers, preload the holder with three layers of suitable sampling discs (see table 1) and insert a polytetrafluoroethylene (PTFE) "O"-ring on the inlet flow side of the outside diameter of the sampling disc to provide an integral seal.

The chamber may then be suitably clamped (e.g. clover leaf design) externally to allow pressurization to between 0 bar to 10 bar. Mount the holder in the test pipe as shown schematically in figure 3.

The test equipment must be completely free from oil, hydrocarbons and other contaminants before it is connected to the system. This is particularly important for the parts between the connection point and the membrane holder, which should be very carefully cleaned. Bends are not permitted at a distance of less than ten pipe diameters upstream of the measuring equipment.

8.6 **Test Method B1** (see figure 3)

The aerosol oil content is measured by means of a collection membrane (see 6.2.1.2.1) which is placed in the membrane holder. Before inserting the membrane, divert the air through the bypass tube as follows.

Turn valve (4) to the open position. Shut valves (1) and (5) and evacuate the membrane holder by means of valve (3). The air flow is now diverted through the bypass tube (8). Open the membrane holder and place three layers of membrane and a supporting disc in the holder (the disc must be placed after the membrane). (See also 8.5.) Shut valve (3) and the membrane holder. The aerosol measuring device is now ready and is used in the following way.

Open valve (1) carefully, so that the membrane holder is pressurized. Turn valve (5) to the open position and carefully close valve (4), valve (6) having been pre-set to provide the required flow through the sampling membrane, and collect between 0,2 mg and 20 mg of oil in the sampling membrane.

Measure the time required for collection, which should be at least 2 min. Stop the test by opening valve (4) and closing valve (5). Shut valve (1) and evacuate the membrane holder using valve (3). Take out the membrane, place it in a clean hydrocarbon-free container and protect it from contaminants.

For methods of analysis and calculation of the amount of oil present, see clause 9.

8.7 Test method B.2

The air flow shall be sampled and tested using the method described in 6.2.2.1.

Select a suitable discharge Q_1, in litres per second (ANR), for the main pipe flow.

Calculate the sample discharge q_1, in litres per second (ANR), to be extracted by the sampling probe, using the formula:

$$q_1 = \frac{Q_1 d^2}{D^2}$$

Table 4 gives the recommended maximum compressed air discharge for pipes at 6,3 bar pressure.

9 Analytical procedure for Methods B1 and B2

9.1 Principle

The oil collected on the membrane or in the isokinetic sampling probe or membrane holder is dissolved in 1,1,2-trichlorotrifluoroethane and the amount determined by infrared spectrometry (see figure 11).

The concentration of oil in solution is proportional to the absorbance of IR light at three wavenumbers[3] characteristic for oil. These are normally 2 960 cm^{-1}, 2 925 cm^{-1} and 2 860 cm^{-1}, depending on the type of oil. The absorbance A is calculated as follows:

$$A = \log_{10}\left(\frac{I_0^3}{I_1 I_2 I_3}\right)$$

where

I_0 is the intensity of light absorption by the solvent (baseline) and

I_1, I_2, I_3 are the intensities of light absorption of the solution at the three characteristic wavenumbers respectively.

This absorbance is then compared with the graph of absorbances calculated similarly for solutions of known concentration.

9.2 Reagents

9.2.1 1,1,2-Trichlorotrifluoroethane (TCTFE), spectral grade, used as solvent.

NOTE 2 To ensure that the trichlorotrifluoroethane is clean, a spectrum with air as a reference should be taken.

WARNING — 1,1,2-Trichlorotrifluoroethane should be handled with care using appropriate protective equipment.

9.3 Apparatus

9.3.1 Infrared spectrometer, double-beam type or Fourier-transform single cell type covering a wavenumber range of at least 3 400 cm^{-1} to 2 500 cm^{-1} and with a transmittance reproducibility of better than 0,3 %.

9.3.2 Infrared cells, designed and matched for infrared analysis and with 40 mm to 50 mm path length, in order to detect oil collected in the range of 0,2 mg to 4,8 mg.

9.4 Accuracy of the method

Using the test apparatus as described, the accuracy of the method is better than ± 10 % and the range is from 0,001 mg/m^3 to approximately 5 mg/m^3 with free air volume, or from 0,007 mg/m^3 to 35 mg/m^3 at a pressure of 6,3 bar and sampling times from 3 h to 2 min respectively.

9.5 Procedure

9.5.1 Analysis of oil collected by the membrane

Using the membrane holder as a funnel (see figure 11), back-wash the oil from the membranes (the expected amount of oil is in the range 0,2 mg to 4,8 mg) into solution with TCTFE, carefully noting the amount of solvent used. Typically, approximately 25 ml of solvent is sufficient to remove all of the oil from the disc and holder.

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[3] The wavenumber is the reciprocal of the wavelength.

Table 4 — Recommended maximum air discharge in pipes at 6,3 bar pressure

Pipe size (ISO 65, medium series, nominal bore) mm	**Discharge at maximum recommended velocity of 6 m/s** l/s (ANR)	**Discharge at maximum recommended velocity of 15 m/s** l/s (ANR)
6	1	2,5
8	3	7,5
10	5	12,5
15	10	25
20	17	43
25	25	63
32	50	125
40	65	163
50	100	250
65	180	450
80	240	600
100	410	1 025
125	610	1 525
150	900	2 250
NOTE — The limiting velocity of 6 m/s applies to lengthy air mains. 15 m/s should be confined to branch lines not exceeding 15 m in length.		

Pour the solution into an IR cell and place the cell in the sample beam.

Pour pure TCTFE into the reference cell and place the cell in the reference beam.

Record the spectrum from 3 400 cm^{-1} to 2 500 cm^{-1}.

NOTE 3 A typical IR spectrum which might be obtained is shown in figure 11.

Determine the amount of oil collected by the membrane using the calibration graph obtained (see 9.6 and figure 12).

9.6 Preparation of the calibration graph

Take 100 mg of the oil being used and dilute it with TCTFE to 100 ml, to make a solution of concentration 1 mg/ml.

Dilute this solution further in accordance with table 5.

Take spectra with each of the resulting solutions, to enable a graph similar to figure 12 to be obtained.

The calibration graph is valid only for the oil used and for the type of cell used.

NOTE 4 The calibration graph will vary according to the degree of oxidation that the oil has undergone. Where possible use oil of known origin, taken from the compressor at the time of test to prepare the calibration graph. Alternatively, oils or oil mixtures may be artificially oxidized.

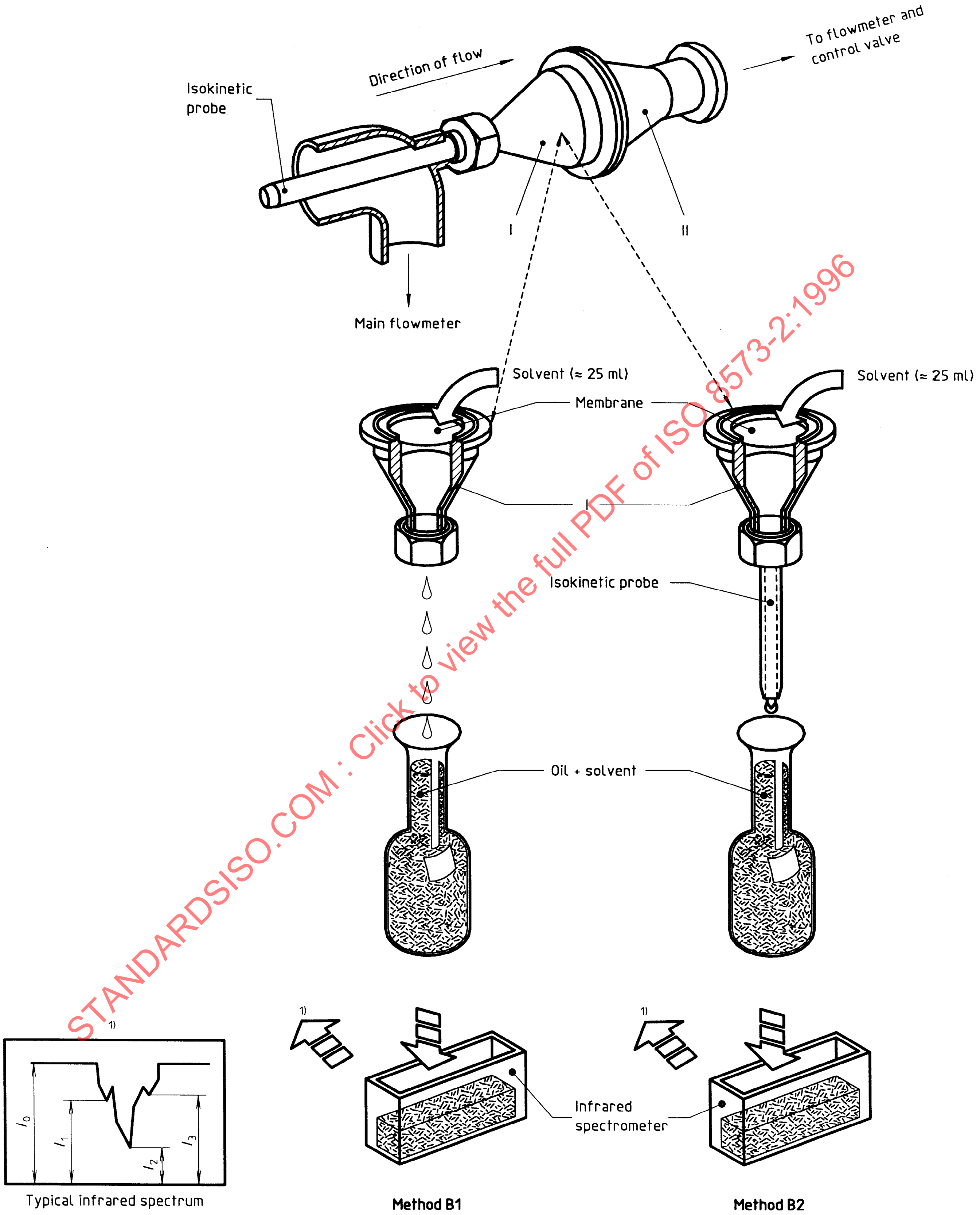

Figure 11 — Analytical test method

Table 5 — Dilution of the standard solution (1 mg/ml) to 50 ml with TCTFE

Volume of standard solution (1 mg/ml) used ml	Resulting concentration of oil in the calibration solution µg/ml
0,1	2
0,5	10
1,0	20
2,0	40
3,5	70
5,0	100

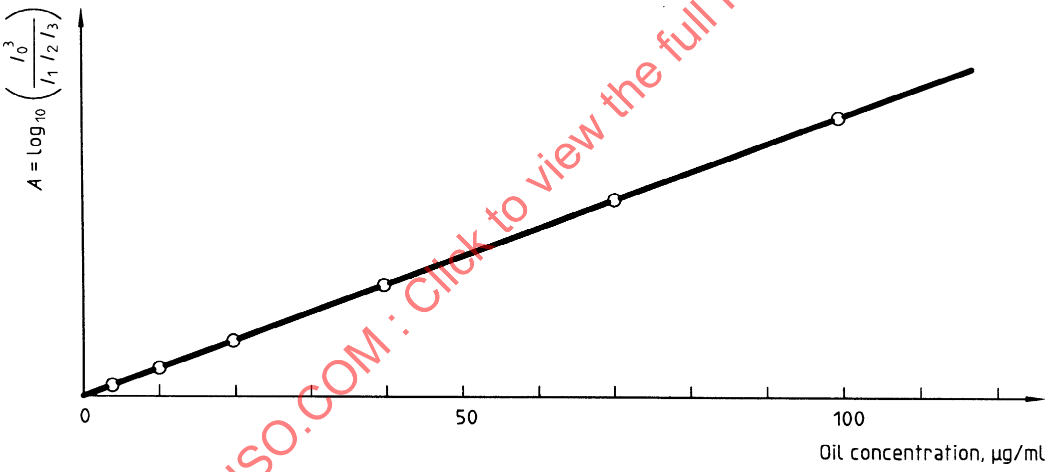

Figure 12 — Calibration curve