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Petroleum and related products — Determination of spray ignition characteristics of fire-resistant fluids — Part 2: Spray test - Stabilized flame heat release method

Pétrole et produits connexes — Détermination des caractéristiques d'inflammation des fluides difficilement inflammables en jet pulvérisé — Partie 2: Essai sur jet pulvérisé - Méthode par dégagement de chaleur d'une flamme stabilisée

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Contents

Page

Foreword.....	v
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 Principle.....	2
5 Reagents and materials	2
6 Apparatus	2
6.1 Test installation	2
6.1.1 General.....	2
6.1.2 Combustion chamber	3
6.1.3 Extraction system.....	3
6.1.4 Spray delivery system (see Figure 3)	3
6.1.5 Burner system (see Figure 4).....	5
6.1.6 Burner and atomizer mounting	6
6.2 Instrumentation.....	6
6.2.1 Temperature sensors	6
6.2.2 Anemometer	6
6.2.3 Flame length scale.....	6
6.2.4 Smoke meter	6
6.2.5 Calibration of instruments	8
7 Sampling and sample preparation	8
8 Apparatus preparation	8
9 Procedure	9
9.1 Measurements at a propane flow rate of 0,13 Nm ³ /h	9
9.2 Measurements at a propane flow rate of 0,4 Nm ³ /h	9
9.3 Abandonment of tests.....	10
9.4 Tabulation of measurements.....	10
9.5 Number of tests	10
9.5.1 General.....	10
9.5.2 Calculation	10
9.5.3 Marginal values.....	11
9.5.4 Conclusion	11
10 Calculations	11
10.1 Ignitability factor.....	11
10.1.1 At propane flow rate of 0,13 Nm ³ /h	11
10.1.2 At propane flow rate of 0,4 Nm ³ /h	11
10.2 Flame length index	12
10.2.1 At propane flow rate of 0,13 Nm ³ /h	12
10.2.2 At propane flow rate of 0,4 Nm ³ /h	12
11 Expression of results	12
11.1 Individual results	12
11.2 Ranking system	12
12 Precision.....	13
13 Test report	13
Annex A (normative) Verification of propane pressure and flow rate.....	14

A.1	Apparatus	14
A.1.1	Pressure gauge	14
A.1.2	Flowmeter	14
A.2	Procedure	14
A.2.1	Measurement	14
A.2.2	Verification	14
Annex B	(normative) Verification of propane flame characteristics	15
B.1	Apparatus	15
B.1.1	General	15
B.1.2	Temperature sensor	15
B.1.3	Traverse system	15
B.1.4	Insulation board	16
B.2	Flame temperature measurements	16
B.2.1	Axial temperatures	16
B.2.2	Radial temperatures	16
B.3	Verification	16
B.3.1	Standard values	16
B.3.2	Conformity values	16
Annex C	(normative) Test apparatus calibration	19
C.1	Calibration fluids	19
C.2	Testing	19
C.3	Calibration	19
Annex D	(informative) Example pro formas for test results	21
D.1	General	21

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.

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ISO 15029-2 was prepared by Technical Committee ISO/TC 28, *Petroleum products and lubricants*.

ISO 15029 consists of the following parts, under the general title *Petroleum and related products — Determination of spray ignition characteristics of fire-resistant fluids*:

- *Part 1: Spray flame persistence — Hollow-cone nozzle method*
- *Part 2: Spray test — Stabilized flame heat release method*
- *Part 3: Spray test — Large scale method*

Petroleum and related products — Determination of spray ignition characteristics of fire-resistant fluids — Part 2: Spray test - Stabilized flame heat release method

WARNING — The use of this part of ISO 15029 may involve hazardous materials, operations and equipment. This part of ISO 15029 does not purport to address all of the safety problems associated with its use. It is the responsibility of the user of this part of ISO 15029 to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

1 Scope

This part of ISO 15029 specifies a method by which the fire hazards of pressurized sprays of liquid fire-resistant fluids can be compared. Two sizes of propane flame are used to ignite and stabilize combustion of an air-atomized release of fluid, and measurements related to the rate of heat release, length of flame and density of smoke are taken to give quantitative information on the fire behaviour of the fluid. A scheme for classification of the fluids is given, but no minimum performance requirements are specified.

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 3170:2004, *Petroleum liquids — Manual sampling*

ISO 3696:1987, *Water for analytical laboratory use — Specification and test methods*

ISO 5659-2:1994, *Plastics — Smoke generation — Part 2: Determination of optical density by a single-chamber test*

ISO 9162:1989, *Petroleum products — Fuels (class F) — Liquefied petroleum gases — Specifications*

IEC 60584-1:1995, *Thermocouples — Part 1: Reference tables*

3 Terms and definitions

For the purposes of this part of ISO 15029, the following terms and definitions apply.

3.1

stabilized flame

point at which the rate of energy release, flame length and other combustion properties, are steady as a function of time, so that sensible time-averaged values can be calculated

3.2

flame length

distance in millimetres from the vertical centre line of the gas burner to the furthest downstream point reached by the visible flame

- 3.3 flame length index**
function of the flame length and propane flow rate
- 3.4 ignitability factor**
corrected value, to the nearest integer, of a function of heat release at a specific propane flow rate
- 3.5 smoke density**
smoke density as defined in ISO 5659, as a function of smoke opacity of the propane flame before and after introduction of the test fluid

4 Principle

A pre-conditioned flux of the test fluid is delivered to a test chamber through a twin-fluid atomizer. Compressed air, supplied to the nozzle at a controlled rate, is used to produce an atomized spray, which is exposed to a defined flame of a gas burner present throughout the test. The gas flame acts to produce, by input of heat at a steady rate, a stabilized spray flame (3.1), so that combustion properties, such as the rate of energy release and flame length, are sufficiently steady over time to allow time-averaged values to be measured.

Temperatures are measured both at the entry to the combustion chamber and in the exhaust, with the burner operating first without, and then with, release of the test fluid. The flame length (3.2) and smoke opacity of the exhaust are also measured. Calculations of functions, such as flame length index (3.3), ignitability index (3.4) and smoke density (3.5) are made from these measurements. Sampling of the exhaust can enable the production rate of other combustion products to be determined. A grading system for the performance of fire-resistant fluids is developed from these determinations and calculations.

5 Reagents and materials

- 5.1 Propane**, high purity (minimum 98 %) grade, generally conforming to the requirements of ISO 9162.
- 5.2 Nitrogen**, oxygen-free, commercial grade.
- 5.3 Compressed air**.
- 5.4 Water**, conforming to the requirements of grade 3 of ISO 3696.
- 5.5 Ethylene glycol**, laboratory grade (mono, 98 % purity).

6 Apparatus

6.1 Test installation

6.1.1 General

Figure 1 gives a general layout of the test installation. The major components of the installation are described in 6.1.2 to 6.1.6.

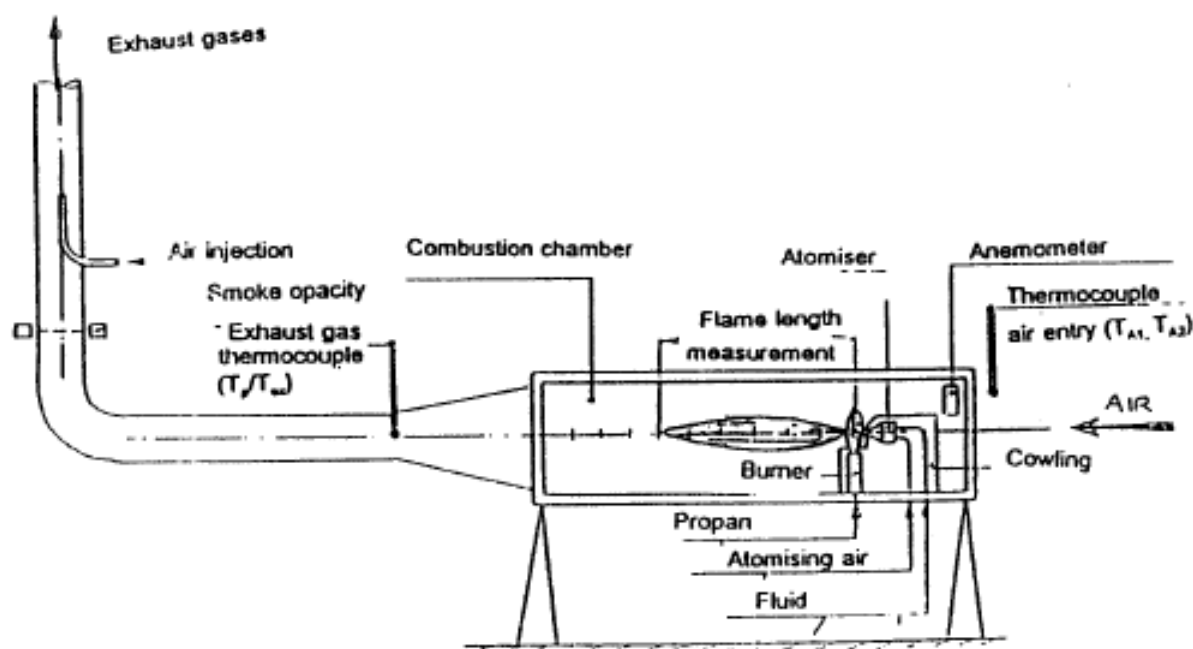


Figure 1 — General view of installation

6.1.2 Combustion chamber

This shall be fabricated from steel sheet, 8 mm thick, of square cross-section with internal dimensions of $(2\,000 \pm 5)$ mm x (490 ± 5) mm. The inner and outer surfaces shall be painted with black heat-resistant paint. A clear window of heat-resistant glass, 8,5 mm thick, shall be located in one side of the chamber. The glass shall be $(1\,920 \pm 10)$ mm x (525 ± 10) mm providing an open area of the window of $(1\,880 \pm 10)$ mm x (480 ± 10) mm. The window may be hinged to allow access to the chamber. All joints around the window shall be sealed during use. The combustion chamber is illustrated in Figure 2.

6.1.3 Extraction system

The combustion chamber exit shall be connected to a contraction fabricated from steel sheet 1 mm thick, providing a transition from the square to a circular cross-section with an internal diameter of $250 \text{ mm} \pm 4 \text{ mm}$. This contraction is connected to a horizontal section of flue pipe $1\,400 \text{ mm} \pm 10 \text{ mm}$ in length, which in turn may be connected to further exhaust ducting or clearing system that shall be designed to provide stable conditions in the combustion chamber during a test.

The air flow through the chamber is produced by a jet pump mounted in the exhaust duct, producing an air velocity of $1,4 \text{ m/s} \pm 0,1 \text{ m/s}$ measured $50 \text{ mm} \pm 2 \text{ mm}$ inside the combustion chamber inlet. The temperature of the air entering the chamber shall be sufficiently constant within the range $10 \text{ }^\circ\text{C}$ to $25 \text{ }^\circ\text{C}$, such that the temperature variation over a period of 30 s shall not exceed $1 \text{ }^\circ\text{C}$. The relative humidity of the air shall lie between 40 % and 80 %. The combustion chamber and exhaust system are illustrated in Figure 2.

6.1.4 Spray delivery system (see Figure 3)

6.1.4.1 Test fluid. The fluid shall be contained in a steel reservoir of minimum capacity 3 l, designed for an internal pressure of 2,5 MPa at $20 \text{ }^\circ\text{C}$. The flow of fluid from the reservoir is controlled by means of pressurized nitrogen (5.2) supplied to the upper part of the reservoir, with a valve situated in the nitrogen supply pipe. Means shall be provided to permit complete drainage of the system. The test fluid volume flow rate shall be controlled to $90 \text{ ml/min} \pm 0,5 \text{ ml/min}$ at a temperature between $13 \text{ }^\circ\text{C}$ and $20 \text{ }^\circ\text{C}$, by means of a valve, and measured

continuously during the test by means of a volumetric flowmeter. The fluid is delivered to the atomizer¹⁾ through nylon and/or steel piping with an internal diameter of $7,5 \text{ mm} \pm 2,5 \text{ mm}$, rated at 2 MPa, and the flowmeter shall be located $350 \text{ mm} \pm 150 \text{ mm}$ downstream of the valve.

6.1.4.2 Compressed air. Compressed air shall be supplied, via a filter to remove droplets and particulates, at a steady flow rate of $1,92 \text{ Nm}^3/\text{h} \pm 0,05 \text{ Nm}^3/\text{h}$ at a pressure of at least 0,2 MPa. The flow rate shall be measured by a variable area flowmeter having a flow range of $0,4 \text{ Nm}^3/\text{h}$ to $3,0 \text{ Nm}^3/\text{h}$, located $3\ 500 \text{ mm} \pm 500 \text{ mm}$ before the spray jet, and controlled by a valve installed downstream of the flowmeter. The temperature of the atomizing air shall be between $10 \text{ }^\circ\text{C}$ and $25 \text{ }^\circ\text{C}$.

Dimensions in millimetres

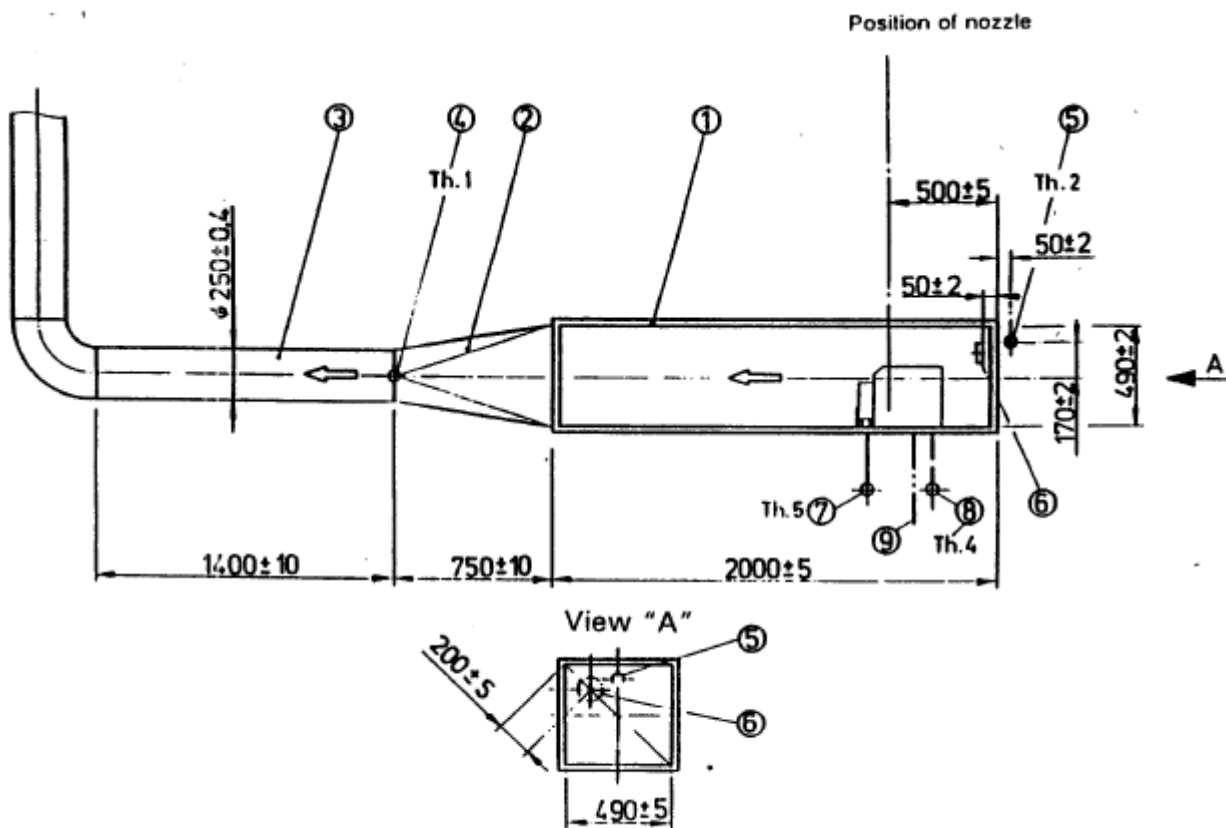


Figure 2 — Combustion chamber and exhaust system

Key

- | | |
|----------------------------|------------------------------|
| 1 combustion chamber | 6 anemometer |
| 2 contraction | 7 propane gas thermocouple |
| 3 flue pipe | 8 atomizing air thermocouple |
| 4 exhaust gas thermocouple | 9 fluid inlet pipe |
| 5 ambient air thermocouple | |

1) Type 1/4 JBC-12B Spraying Systems Co, supplied by CT Ltd., Guildford, Surrey, UK. This information is given for the convenience of users of this part of ISO 15029 and does not constitute an endorsement by ISO of this product.

Dimensions in millimetres

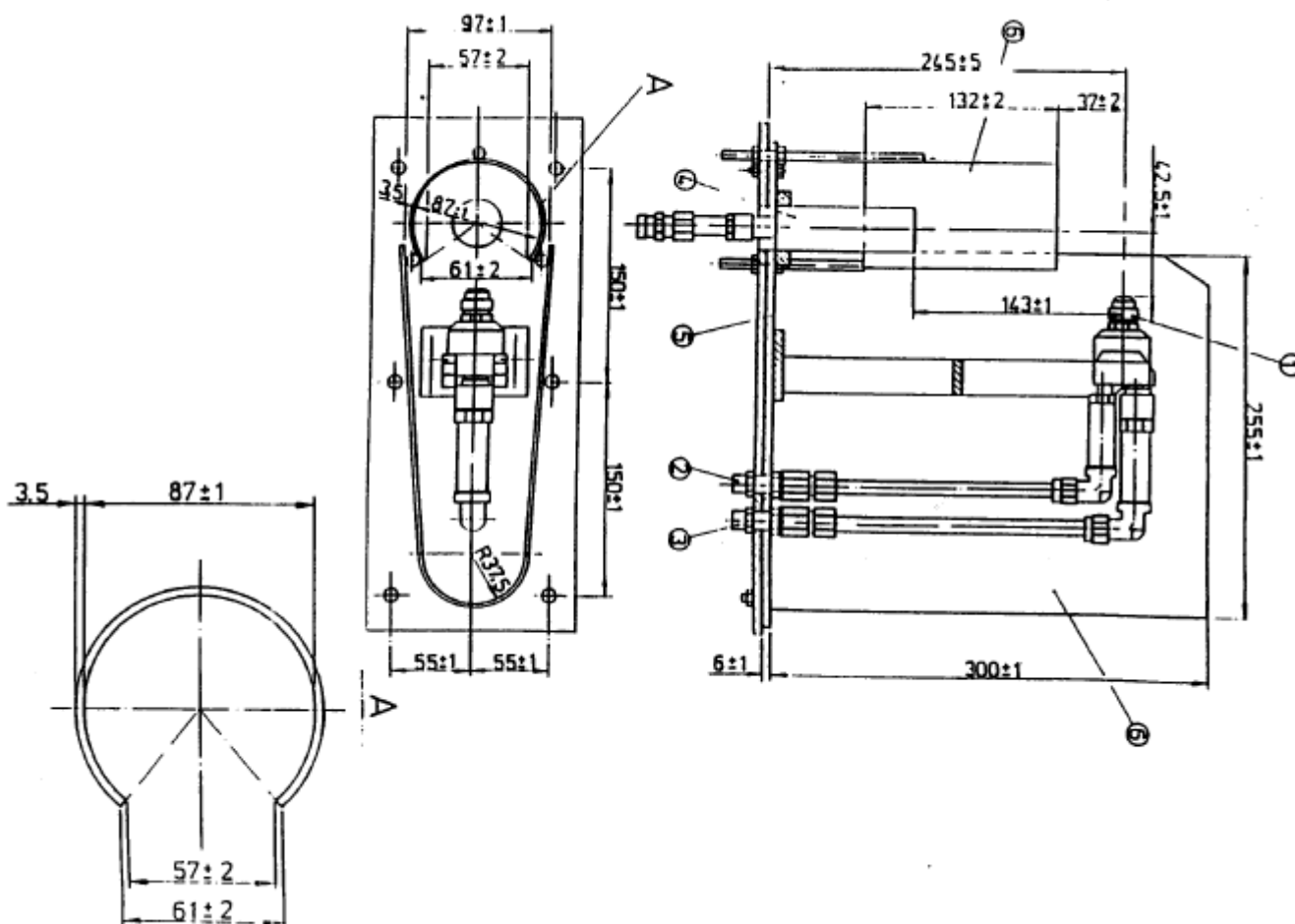


Figure 3 — Atomizer and burner system

Key

- 1 spray nozzle
- 2 fluid supply
- 3 propane burner
- 4 base plate
- 5 cowling

6.1.5 Burner system (see Figure 4)

6.1.5.1 System design. The gas burner, constructed of brass and illustrated in Figure 4, provides a continuous ignition source using propane (5.1) pre-mixed with air (5.3). It incorporates a nozzle²⁾, drilled to a diameter of 0,68 mm, and two mixing chambers, the whole mounted rigidly on to a steel base plate of 6 mm thickness (see Figure 3). The exit of the 26 mm internal diameter mixing chamber shall be 143 mm ± 1 mm below the centre line of the atomizer, and a distance of 42,5 mm ± 1 mm downstream of the atomizer orifice.

2) Type T1700 fire flame gas nozzle, supplied by Applications des Gaz, Paris, France. This information is given for the convenience of users of this part of ISO 15029, and does not constitute endorsement by ISO of this product.

Propane, at a minimum pressure of 0,25 MPa, shall be supplied through $4\text{ m} \pm 1\text{ m}$ of flexible tubing of $6\text{ mm} \pm 2\text{ mm}$ bore, to an assembly of a pressure gauge, flowmeter and valve. Further flexible and/or metal tubing, $2,5\text{ m} \pm 0,5\text{ m}$ in length and of a minimum bore of 6 mm, is installed between the valve in the assembly and the gas burner. At a controlled pressure of 0,2 MPa, the propane flow rate shall be either $0,13\text{ Nm}^3/\text{h} \pm 0,005\text{ Nm}^3/\text{h}$, or $0,40\text{ Nm}^3/\text{h} \pm 0,005\text{ Nm}^3/\text{h}$, depending on specific test requirements. The flow rate shall be measured with a variable area flowmeter having a range of $0,10\text{ Nm}^3/\text{h}$ to $0,50\text{ Nm}^3/\text{h}$ and of suitable resolution. The temperature of the propane on entering the burner shall be between $10\text{ }^\circ\text{C}$ and $25\text{ }^\circ\text{C}$.

6.1.5.2 System verification. On installation, and at intervals of not more than 12 months, the system shall be verified for conformity to the standard design. Annexes A and B describe protocols for checking the control systems and flame characteristics, respectively.

6.1.6 Burner and atomizer mounting

6.1.6.1 Mounting. The atomizer and burner assembly, on the steel base plate, is protected by a cowling fabricated from 1 mm thick sheet steel bent into the form shown in Figure 3, with a height of $300\text{ mm} \pm 1\text{ mm}$, overall width of $97\text{ mm} \pm 1\text{ mm}$, and overall length of $255\text{ mm} \pm 1\text{ mm}$. The burner shall also be protected from the surrounding air flow by a cylindrical cowling of $87\text{ mm} \pm 1\text{ mm}$ diameter, containing a vertical slot with an external opening of $61\text{ mm} \pm 2\text{ mm}$ on its upstream face. Three thread supports provide a means of elevation of this cowling, with its upper part at a distance of $37\text{ mm} \pm 2\text{ mm}$ from the horizontal plane passing through the atomizer axis.

6.1.6.2 Placement. The base plate is positioned on the floor of the combustion chamber with the atomizer orifice $500\text{ mm} \pm 5\text{ mm}$ downstream of the combustion chamber inlet orifice. Connections through the base plate and combustion chamber floor shall be provided for the supply of air, propane and test fluid to the burner and atomizer as appropriate.

6.2 Instrumentation

6.2.1 Temperature sensors

Five T-type Cu-CuNi thermocouples with an outer diameter of 1,5 mm, conforming to the requirements of IEC 60584-1, or temperature measurement devices of equivalent precision and accuracy, are positioned as illustrated in Figure 2, and in the test fluid reservoir with at least 50 mm of sheath completely immersed in the fluid, and not in contact with the vessel wall. All the thermocouples shall be used with $0\text{ }^\circ\text{C}$ reference junctions in accordance with IEC 60584-1. Measurement accuracy shall be $\pm 0,5\text{ }^\circ\text{C}$ over the range $15\text{ }^\circ\text{C}$ to $200\text{ }^\circ\text{C}$, and the temperature resolution shall be $0,1\text{ }^\circ\text{C}$.

Where a computer is used, both this and the data acquisition system shall be capable of calculating averages of at least 100 values of each temperature measured over 120 s.

6.2.2 Anemometer

The air flow velocity in the combustion chamber is measured using a rotating vane anemometer with a vane diameter of $95\text{ mm} \pm 30\text{ mm}$ located as illustrated in Figure 2 (including section "A").

6.2.3 Flame length scale

A linear scale of at least 1 m in length, with a resolution of no greater than 10 mm, shall be attached to the combustion chamber side window.

6.2.4 Smoke meter

A white light obscuration smoke opacity meter, using an illuminated beam of $20\text{ mm} \pm 5\text{ mm}$ diameter, is mounted $625\text{ mm} \pm 125\text{ mm}$ downstream of the contraction in the flue pipe. The arrangement shall not reduce light transmission by soot deposits by more than 5 %.

Dimensions in millimetres

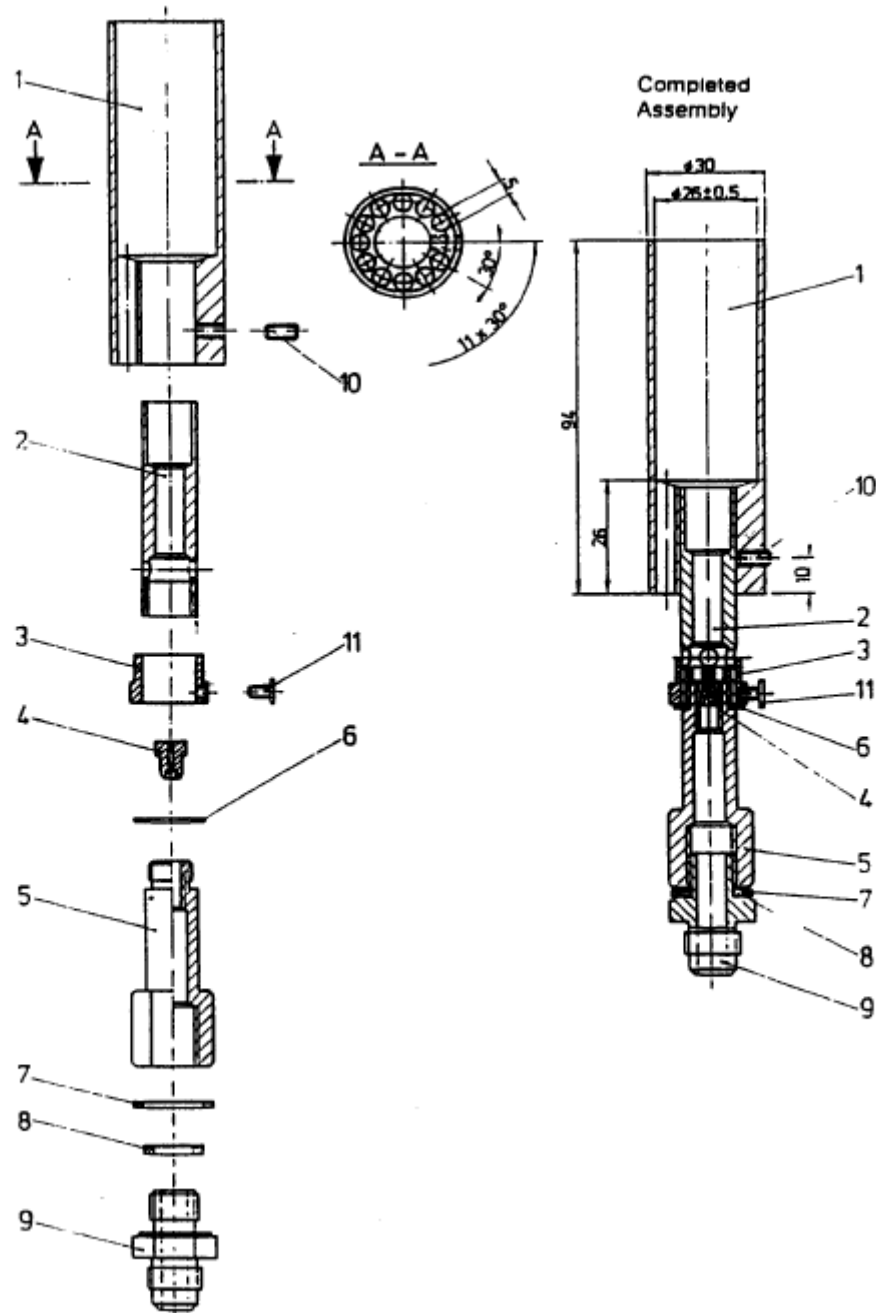


Figure 4 — Propane burner

Key

- | | |
|--------------------------------------|-------------------------|
| 1 mixing chamber 1 | 7 washer |
| 2 mixing chamber 2 | 8 sealing ring |
| 3 regulation collar | 9 straight male adaptor |
| 4 burner nozzle | 10 locking screw |
| 5 nozzle holder with flash-back unit | 11 locking screw |
| 6 washer | |

6.2.5 Calibration of instruments

6.2.5.1 Temperature sensors. All the temperature sensors shall have current calibration certificates traceable to a national standard, and appropriate corrections shall be applied to observed readings.

6.2.5.2 Smoke meter. The output of the smoke meter shall be calibrated using at least three neutral density filters inserted in the light beam, giving 25 %, 50 % and 75 % light obscuration. Observed readings shall be corrected for deviations in linearity.

6.2.5.3 Other meters. Flowmeters and the anemometer shall be calibrated at least annually by means traceable to a national standard, and the appropriate corrections made to observed readings.

6.2.5.4 Test apparatus. Prior to use, and at least annually, the entire test apparatus shall be calibrated for ignitability factor by the procedure described in Annex C, and corrected values used for reporting, as described in 10.1.

7 Sampling and sample preparation

7.1 Unless otherwise specified, samples, of at least 5 l, shall be obtained in accordance with the procedures described in ISO 3170.

7.2 Store samples at a temperature of 0 °C to 30 °C.

7.3 Mix the sample by shaking or stirring, and examine for clarity and contamination before transferring the test portion to the conditioning beaker. If phase separation and/or particulate are observed, discard the sample.

7.4 For water-mix fluids, such as those in categories HFAE or HFAS (as classified in ISO 6743-4³), prepare the concentrate with water (5.4) within 1 h of the start of the test.

7.5 Place 1 500 ml of sample or concentrate into a 2 000 ml glass beaker and heat or cool as appropriate to the test temperature (13 °C to 20 °C), stirring to maintain homogeneity.

7.6 Pour the test portion into the reservoir of the apparatus, and pressurize the reservoir to the pressure established for the specified flow rate. Pass fluid through the atomizer, without atomizing air, combustion chamber air or burner propane, until at least 200 ml of fluid has been collected at the atomizer exit. Check that the flow has been steady, there are no air bubbles in the delivery system, and the fluid is free of contaminant.

8 Apparatus preparation

8.1 Turn off the propane supply and thoroughly clean the apparatus in preparation for each test, in the manner described in 8.2 to 8.6.

8.2 Remove any traces of previous sample by draining the reservoir, pipework and flowmeter by means of disconnecting orifices at the various lowest points. Re-connect these orifices.

8.3 Flush the reservoir with 500 ml of solvent appropriate to the sample previously tested.

8.4 Open the valve in the fluid supply circuit and pressurize the reservoir with nitrogen. Allow at least 250 ml of liquid to be expelled through the atomizer. Close the valve and de-pressurize. Drain the fluid/solvent at the atomizer orifice. Repeat the procedure given in 8.2.

8.5 Remove any further traces of solvent in the apparatus by evaporation or careful wiping with a lint-free cloth.

3) ISO 6743-4:1999 *Lubricants, industrial oils and related products (class L) — Classification — Part 4: Family H (Hydraulic systems)*.

8.6 Place 500 ml of the new test fluid in the reservoir and repeat the procedure given in 8.4. If the new fluid is in the same category and quality as that last tested, repeat this operation twice. If the new fluid is a different category or quality, repeat the operation at least three times.

9 Procedure

9.1 Measurements at a propane flow rate of 0,13 Nm³/h

9.1.1 Set the air flow rate through the combustion chamber to obtain an air velocity of 1,4 m/s \pm 0,1 m/s.

9.1.2 Ignite the propane burner, and adjust the propane flow rate to 0,130 Nm³/h \pm 0,005 Nm³/h.

9.1.3 Adjust the atomizing air to a flow rate of 1,92 Nm³/h \pm 0,05 Nm³/h.

9.1.4 With the glass window of the combustion chamber closed and sealed, allow conditions to stabilize to a point at which the temperature of the exhaust gases at the chamber exit, T_p , and the temperature of the air at the chamber inlet, T_{A1} , vary by no more than 1 °C over a period of 30 s. Record these values to the nearest 0,1 °C, taking the average of at least four values over a 60 s period.

9.1.5 Pass test fluid to the atomizer at the specified flow rate of 90 ml/min \pm 0,5 ml/min and measure the new exhaust temperature, T_{EX} , at intervals of approximately 5 s, until the average of at least five values over a period of 30 s is within 2,5 % of the average of at least five values taken in a consecutive period of 30 s.

9.1.6 With conditions steady, take measurements of the temperature at the chamber inlet, T_{A2} , and the new exhaust temperature, T_{EX} , as the average of at least ten measurements of each taken over a period of 120 s.

9.1.7 Measure and record the flame length, L_A , as the average of at least ten measurements taken over a period of 120 s of steady conditions. In the case of a fluctuating flame, the length shall be the furthest distance downstream reached instantaneously.

9.1.8 Measure and record the light obscuration from the smoke meter under the steady conditions before test fluid flow described in 9.1.4, V_0 , as the average of at least four readings taken over a period of 60 s. Repeat the measurement after the steady conditions with test fluid flow described in 9.1.5 have been achieved, and record this new value as V_1 .

9.1.9 Calculate the ignitability factor, RI .

9.1.10 If the ignitability factor is above 50, or the flame length is less than 100 mm, repeat the test at a propane flow rate of 0,4 Nm³/h.

9.2 Measurements at a propane flow rate of 0,4 Nm³/h

9.2.1 If the test fluid is known to have an ignitability factor of above 50, carry out the procedure specified in 9.1.1 to 9.1.9 with the propane flow rate given in 9.1.2 adjusted to 0,400 Nm³/h \pm 0,005 Nm³/h.

9.2.2 During a test, if the test fluid has been found to have an ignitability factor above 50, or a flame length of less than 100 mm, at a propane flow rate of 0,13 Nm³/h, shut off the fluid supply to the atomizer and adjust the propane flow rate to 0,400 Nm³/h \pm 0,005 Nm³/h.

9.2.3 Establish and record new steady conditions as described in 9.1.4.

9.2.4 Carry out the procedure described in 9.1.5 to 9.1.9 at the new propane flow rate.

9.3 Abandonment of tests

Tests shall be discontinued if, during any test period, any item of stable conditions is not maintained. The definition of stable conditions is:

- a) the temperature at the combustion chamber inlet is constant to within ± 1 °C;
- b) the atomizing air flow rate is constant at $1,92 \text{ Nm}^3/\text{h} \pm 0,05 \text{ Nm}^3/\text{h}$;
- c) the propane flow rate is constant at either $0,130 \text{ Nm}^3/\text{h} \pm 0,005 \text{ Nm}^3/\text{h}$ or $0,400 \text{ Nm}^3/\text{h} \pm 0,005 \text{ Nm}^3/\text{h}$;
- d) the test fluid flow rate is constant at $90 \text{ ml}/\text{min} \pm 0,5 \text{ ml}/\text{min}$;
- e) the air velocity through the combustion chamber is constant at $1,4 \text{ m}/\text{s} \pm 0,1 \text{ m}/\text{s}$;
- f) the relative humidity of the air is 40 % to 80 %;
- g) the temperature of the test fluid is 13 °C to 20 °C;
- h) the temperature of the atomizing air at the chamber inlet, and of the propane, is 10 °C to 25 °C.

9.4 Tabulation of measurements

The relatively large number of measurements required to obtain the test results are best recorded on pro forma result sheets, which may also allow space for any calculation required. Examples of pro formas are given in Annex D.

9.5 Number of tests

9.5.1 General

The minimum number of tests is set on the basis of obtaining an ignitability factor, RI , which is the most sensitive property being measured, within some defined limits of accuracy. The minimum level of accuracy set is that the average of N individual RI measurements lies within 5 % of the true mean value, with 67 % confidence.

9.5.2 Calculation

Assuming a normal distribution of measurements, the number of test required to satisfy the relation specified in 9.5.1 is given by the equation:

$$400s_N^2/N RI_N \leq 1,0 \quad (1)$$

where

N is the number of tests;

RI_N is the average of N tests;

s_N is the variance, defined by equation (2).

$$s_N^2 = \sum (RI_i - RI_N)^2 / (N - 1) \quad (2)$$

where RI_i is the i th measurement of ignitability factor.

The percentage error, δ , in the mean, RI_w , of N measurements of RI , is given by the equation:

$$\delta = 100S_N / RI_N N^{0,5} \quad (3)$$

Where the ignitability factor is found to be within 5 % of a grade boundary, a sufficient number of tests is required to derive a mean value of RI which is accurate to within one integer. This requires:

$$N \geq S_N^2 \quad (4)$$

9.5.3 Marginal values

When an average value of RI , obtained at a propane flow rate of 0,13 Nm³/h, lies between 35 and 60, and more than $N/2$ of these tests give individual values greater than 50, that fluid shall be re-tested at the higher propane flow rate of 0,4 Nm³/h, and the low propane flow rate results discarded. If less than $N/2$ tests at the low propane flow rate give individual values greater than 50, then all the values are included in the calculation of average RI . If the average of these values is greater than or equal to 50, then this fluid shall be re-tested at the higher flow rate. If a fluid, tested at the low propane flow rate, gives an average value of equal to or above 50, but re-tested at the higher propane flow rate, gives an average value of below 50, the value of RI for that fluid shall be taken as 50.

9.5.4 Conclusion

On the basis of the above considerations, the minimum number of tests required at a specified propane flow rate, is eight.

10 Calculations

10.1 Ignitability factor

10.1.1 At propane flow rate of 0,13 Nm³/h

Calculate the uncorrected ignitability factor, RI_W , at the low propane flow rate from the following equation:

$$RI_W = 500(T_p - T_{A1}) / [7(T_{EX} - T_{A2})] \quad (5)$$

where

T_p is the exhaust temperature without release of the test fluid, expressed in degrees Celsius;

T_{A1} is the air temperature at the chamber inlet without release of the test fluid, expressed in degrees Celsius;

T_{EX} is the exhaust temperature with release of the test fluid, expressed in degrees Celsius;

T_{A2} is the air temperature at the chamber inlet with release of the test fluid, expressed in degrees Celsius.

Correct RI_W to obtain RI from the low propane flow rate calibration curve developed by the method described in Annex C, and in accordance with 6.2.5.4.

10.1.2 At propane flow rate of 0,4 Nm³/h

Calculate the uncorrected ignitability factor, RI_X , at the high propane flow rate from the following equation:

$$RI_X = [100(T_p - T_{A1}) / (T_{EX} - T_{A2})] + 30 \quad (6)$$

Correct RI_X to obtain RI from the high propane flow rate calibration curve developed by the method described in Annex C, and in accordance with 6.2.5.4.

10.2 Flame length index

10.2.1 At propane flow rate of 0,13 Nm³/h

Calculate the flame length index, RL_W , from the measured flame length at the low propane flow rate, L_A , from the following equation:

$$RL_W = 5\,000/L_A \quad (7)$$

10.2.2 At propane flow rate of 0,4 Nm³/h

Calculate the flame length index, RL_X , from the measured flame length at the high propane flow rate, L_B , from the following equation:

$$RL_X = (6\,250/L_B) + 37,5 \quad (8)$$

10.3 Smoke density

Calculate the smoke density, D , from the relationship given in ISO 5659-2, and defined by the equation:

$$D = \lg(V_0/V_1) \quad (9)$$

where

V_0 is the light obscuration obtained from the meter before test fluid flow;

V_1 is the light obscuration obtained from the meter during test fluid flow.

11 Expression of results

11.1 Individual results

Round the ignitability factor, RI , and the flame length index, RL , to the nearest integer, with values of exactly 0,5 being rounded up.

Round the smoke density, D , to the nearest 0,001.

11.2 Ranking system

Report the result as a spray ignition characteristic in terms of an alphabetical ranking, described in Table 1. In all cases, A represents the most fire-resistant category of the property evaluated. The primary reference is the ignitability factor, RI , with flame length index, RL , and smoke density, D , being secondary factors. Thus the most fire-resistant category possible in this system is A(A/A), and the lowest fire-resistant is H(F/D). Report the spray ignition characteristics in the manner shown, with letter categories appropriate to the results obtained in the tests.

Table 1 — Fire-resistant categories

Category	A	B	C	D	E	F	G	H
Ignitability factor, RI	> 100	100 to 80	79 to 65	64 to 50	49 to 36	35 to 25	24 to 14	≤ 13
Flame length index, RL	> 100	100 to 56	55 to 51	50 to 11	10 to 7	≤ 6	–	–
Smoke density, D	< 0,01	0,01 to 0,05	0,051 to 0,1	> 0,1	–	–	–	–

12 Precision

It is not possible to generate precision in a conventional manner for this procedure due to the small number of test apparatus in regular use. Each laboratory shall therefore produce a quality-control procedure based on the values for ignitability for the calibration fluids given in Table C.1.

13 Test report

The test report shall contain at least the following information:

- a) a reference to this part of ISO 15029;
- b) the type and complete identification of the product tested;
- c) the result of the test (see Clause 11);
- d) any deviation, by agreement or otherwise, from the procedure specified;
- e) the date of the test.

Annex A (normative)

Verification of propane pressure and flow rate

A.1 Apparatus

A.1.1 Pressure gauge

A calibrated digital or analogue gauge, with a minimum range of 20 kPa to 500 kPa, and with an accuracy of ± 5 kPa or better over the range 200 kPa to 400 kPa.

A.1.2 Flowmeter

A calibrated flowmeter, or flowmeters, with a resolution of 0,001 Nm³/h or better over the range 0,1 Nm³/h to 0,5 Nm³/h.

NOTE The flowmeter(s) used in the test apparatus is(are) suitable (see 6.1.5.1).

A.2 Procedure

A.2.1 Measurement

At a distance of no more than 3 m from the propane burner, and at a point beyond which there are no restrictions or sharp bends in the supply line, insert the pressure gauge (A.1.1) and immediately downstream of it, the flowmeter (A.1.2). Supply propane from a source via a variable regulator until the pressure at the gauge is steady for at least 10 s. Read the pressure and flow under steady conditions. Increase the pressure and repeat the readings. Take pressure and flow readings at at least four pressures between 40 kPa and 200 kPa.

A.2.2 Verification

Table A.1 gives the standard pressure/flow curve points for propane supply. Fit the readings obtained in accordance with A.2.1 on to this curve and compare the values. For satisfactory performance, the measured flow rate shall be within $\pm 0,01$ Nm³/h of the corresponding point on the curve.

Table A.1 — Propane pressure and flow rate calibration curve

Gauge pressure kPa	40	50	70	100	150	200
Flow rate Nm ³ /h	0,164	0,184	0,222	0,261	0,333	0,400

Annex B (normative)

Verification of propane flame characteristics

B.1 Apparatus

B.1.1 General

Figure B.1 illustrates a general view of the positioning of the thermocouple in the combustion chamber for temperature measurement of the burner flame. Measurements are carried out with the inner and outer cowlings in place, but with the front window of the combustion chamber fully open to allow access and adjustment to the traverse system.

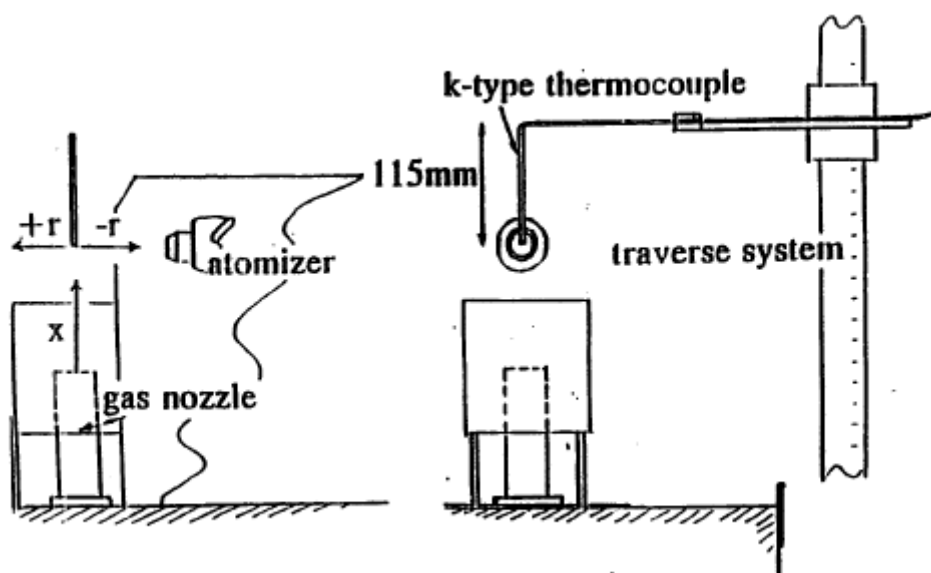


Figure B.1 — General arrangement of flame temperature measurement system

B.1.2 Temperature sensor

K-type 3 mm stainless steel sheathed thermocouple, bent through 90° at a distance of 115 mm \pm 5 mm from the sensing tip.

B.1.3 Traverse system

A suitable stand and clamping system that holds the thermocouple with the 115 mm straight section aligned at $\pm 5^\circ$ to the vertical, and has both vertical and horizontal linear scales for measurement of the spatial position of the thermocouple tip.

B.1.4 Insulation board

A ceramic fibre insulating board, $7 \text{ mm} \pm 1 \text{ mm}$ in thickness, and with a minimum size of $300 \text{ mm} \times 300 \text{ mm}$, shall be fitted to the inner upper surface of the combustion chamber during testing. It shall be held in place by supports that do not interfere with the flame characteristics, or the free movement of the thermocouple in the traverse system.

B.2 Flame temperature measurements

B.2.1 Axial temperatures

Adjust the propane flow rate to either the low ($0,13 \text{ Nm}^3/\text{h}$) or high ($0,4 \text{ Nm}^3/\text{h}$) rate and light the burner. Position the tip of the thermocouple at a distance of $x = 0$, corresponding to the exit orifice plane of the gas nozzle, and within $\pm 2 \text{ mm}$ of the orifice centre line. Measure and record this temperature. Move the thermocouple upwards in the same vertical plane and repeat the temperature measurements at 10 mm intervals up to a distance of 200 mm above the nozzle. Repeat the procedure for the second propane flow rate.

B.2.2 Radial temperatures

Position the thermocouple at a distance of $143 \text{ mm} \pm 1 \text{ mm}$ above the gas nozzle exit orifice and traverse 40 mm in a horizontal plane towards the atomizer. Light the burner and adjust the propane flow to either the low or high rate, and measure and record the temperature. Move the thermocouple horizontally away from the atomizer and repeat the temperature measurements at 5 mm intervals across the flame width until a position of 60 mm on the other side of the flame centre line is reached. Repeat the procedure for the second propane flow rate.

B.3 Verification

B.3.1 Standard values

Table B.1 gives the standard values for axial and radial temperature measurements under the conditions of test. These are illustrated as curves in Figures B.2 and B.3.

B.3.2 Conformity values

B.3.2.1 Axial tests. The burner shall be deemed to conform to the standard burner if, at each measurement position, the measured temperature is within $\pm 50 \text{ }^\circ\text{C}$ of the standard temperature.

B.3.2.2 Radial tests. The burner shall be deemed to conform to the standard burner if, at each measurement position, the measured temperature is within $\pm 40 \text{ }^\circ\text{C}$ of the standard value, within the range -30 mm to 30 mm for the low propane flow rate, and -40 mm to 50 mm for the high propane flow rate.

Table B.1 — Propane burner temperature distribution

Axial			Radial		
Distance from burner exit mm	Temperature at low propane flow rate °C	Temperature at high propane flow rate °C	Distance from burner centre line mm	Temperature at low propane flow rate °C	Temperature at high propane flow rate °C
0	861	550	−40	88	310
10	869	568	−35	95	435
20	871	567	−30	125	540
30	874	580	−25	228	718
40	872	611	−20	430	820
50	864	629	−15	570	948
60	866	675	−10	800	975
70	861	718	−5	900	986
80	860	762	0	905	970
90	858	817	5	900	950
100	852	852	10	920	970
110	862	880	15	820	1 006
120	870	905	20	650	1 000
130	884	927	25	460	918
140	890	938	30	273	778
150	891	946	35	145	593
160	904	960	40	103	455
170	901	971	45	—	318
180	888	977	50	—	234
190	875	980	55	—	150
200	854	988	60	—	121
210	802	994			
220	796	996			

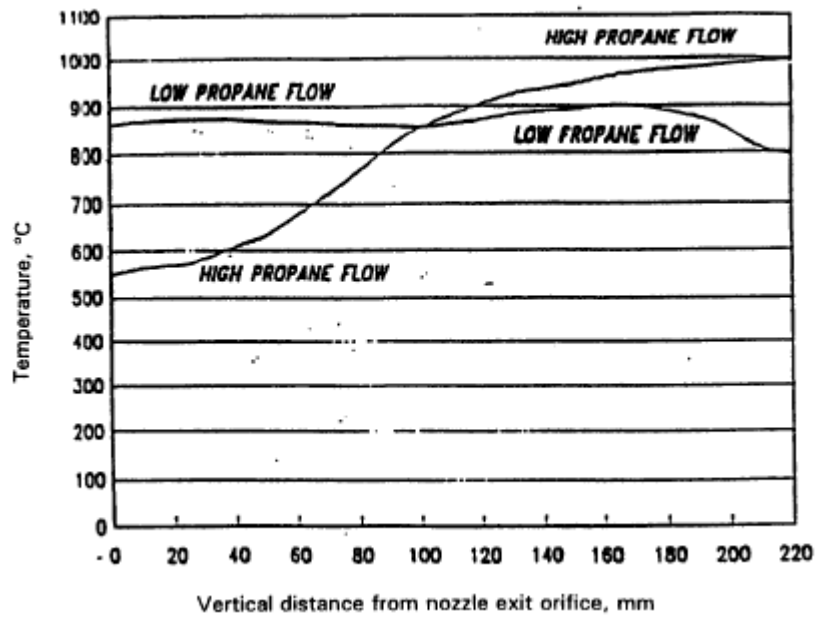


Figure B.2 — Axial temperature distribution of propane flame

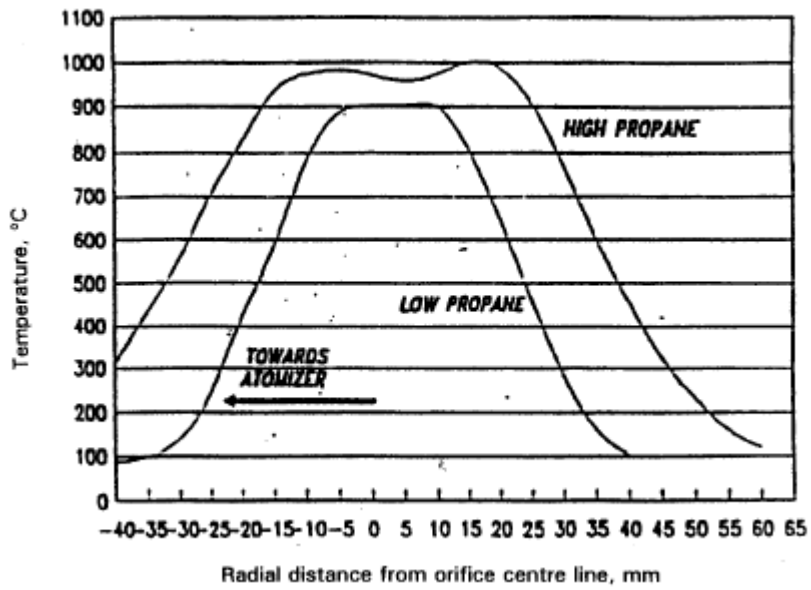


Figure B.3 — Radial temperature distribution of propane flame

Annex C (normative)

Test apparatus calibration

C.1 Calibration fluids

Prepare a series of calibration fluids (CF₀ to CF₇₅) by volumetric mixing of ethylene glycol (5.5) with water (5.4). Table C.1 gives the composition of this series.

Table C.1 — Calibration fluid composition and ignitability factor

Fluid designation	Ethylene glycol % (V/V)	Water % (V/V)	Standard ignitability factor
CF ₀	100	0	17,1
CF ₁₅	85	15	23,8
CF ₂₀	80	20	34,2
CF ₂₅	75	25	45,6
CF ₃₀	70	30	59,7
CF ₄₀	60	40	64,0
CF ₄₅	55	45	71,8
CF ₅₀	50	50	81,0
CF ₆₀	40	60	90,8
CF ₇₅	25	75	108,5

NOTE For the purposes of this part of ISO 15029, "% (V/V)" is used to represent the volume fraction of a material.

C.2 Testing

Carry out the procedure given in 9.1 at the low propane flow rate on fluids CF₀, CF₁₅, CF₂₀ and CF₂₅, and the procedure given in 9.2 at the high propane flow rate for the other fluids in the series, omitting the measurements of flame length and smoke density. Calculate the average uncorrected ignitability factor (RI_W or RI_X) on each fluid from a minimum of eight tests. Further tests shall be carried out if the accuracy does not conform to within 5 % of the mean value (see 9.5). Irrespective of the actual measured value of ignitability factor, do not re-test the fluids at the other propane flow rate. Table C.1 gives "standard" ignitability factor values for each calibration fluid.

C.3 Calibration

For the measured ignitability factors, RI_W for the low propane flow rate and RI_X for the high propane flow rate, solve the quadratic equations below to obtain factors a , b , c , d and e , using a least-squares fit to obtain the mean values. Plot these mean values against the standard values given in Table C.1.

$$\text{For low propane flow rate and } RI < 50 \quad RI = aRI_W + bRI_W^2$$

$$\text{For high propane flow rate and } RI \geq 50 \quad RI = c + dRI_X + eRI_X^2$$

Use the values of *a*, *b*, *c*, *d* and *e* to correct all measured values of ignitability factor obtained on test samples in the same apparatus under constant operating conditions. Figure C.1 gives an illustration of a typical calibration curve.

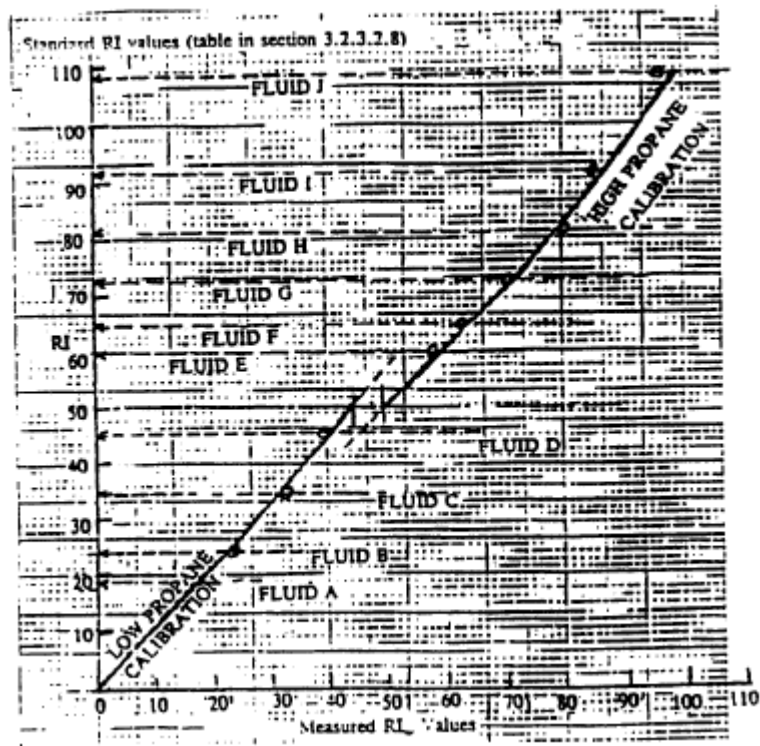


Figure C.1 — Illustration of calibration curve

Annex D (informative)

Example pro formas for test results

D.1 General

Figures D.1 and D.2 give example pro formas (worksheets) for test results obtained at the low propane flow rate and high propane flow rate respectively.

Figure D.1 — Example worksheet for low propane rate results

LABORATORY:

Fluid type:

Fluid identification:

Low propane flow rate

A Stage 1: No fluid flow

Time h/min/s	Propane flow rate [0,130 ± 0,005] m ³ /h	Fluid temperature [13 to 20] °C	Exhaust temperature <i>T_p</i> °C	Atmospheric temperature <i>T_{A1}</i> °C	Smoke opacity <i>V₀</i>
		—			
		—			
		—			
		—			
		—			
		—			
		—			
Average of at least four readings over 60 s			<i>T_p</i> =	<i>T_{A1}</i> =	<i>V₀</i> =

B Stage 2: With fluid flow

Time h/min/s	Fluid flow rate [90 ± 0,5] ml/min	Propane flowrate [0,130 ± 0,005] m ³ /h	Fluid temperature [13 to 20] °C	Exhaust temperature <i>T_{EX}</i> °C	Atmospheric temperature <i>T_{A2}</i> °C	Flame length <i>L_A</i> mm	Smoke opacity <i>V₁</i>
			—				
			—				
			—				
			—				
			—				
			—				
			—				
			—				
			—				
			—				
Average of at least ten readings over 120 s				<i>T_{EX}</i> =	<i>T_{A2}</i> =	<i>L_A</i> =	<i>V₁</i> =

C Calculations

Uncorrected ignitability factor $RI_W = 500(T_p - T_{A1})/[7(T_{EX} - T_{A2})]$ = 500(—)/[7(—)]
= _____

Flame length index $RL_A = 5\ 000/L_A$ = 5\ 000/
= _____

Smoke density $D = \lg(V_0/V_1) = \lg(/)$ = _____

Figure D.2 — Example worksheet for high propane rate results

LABORATORY:

Fluid type:

Fluid identification:

High propane flow rate

A Stage 1: No fluid flow

Time h/min/s	Propane flow rate [0,400 ± 0,005] m ³ /h	Fluid temperature [13 to 20] °C	Exhaust temperature <i>T_p</i> °C	Atmospheric temperature <i>T_{A1}</i> °C	Smoke opacity <i>V₀</i>
		—			
		—			
		—			
		—			
		—			
		—			
		—			
Average of at least four readings over 60 s			<i>T_p</i> =	<i>T_{A1}</i> =	<i>V₀</i> =

B Stage 2: With fluid flow

Time h/min/s	Fluid flow rate [90 ± 0,5] ml/min	Propane flowrate [0,400 ± 0,005] m ³ /h	Fluid temperature [13 to 20] °C	Exhaust temperature <i>T_{EX}</i> °C	Atmospheric temperature <i>T_{A2}</i> °C	Flame length <i>L_B</i> mm	Smoke opacity <i>V₁</i>
			—				
			—				
			—				
			—				
			—				
			—				
			—				
			—				
			—				
			—				
Average of at least ten readings over 120 s				<i>T_{EX}</i> =	<i>T_{A2}</i> =	<i>L_B</i> =	<i>V₁</i> =

C Calculations

Uncorrected ignitability factor $RI_X = [100(T_p - T_{A1}) / (T_{EX} - T_{A2})] + 30 = [100(\quad - \quad) / (\quad - \quad)] + 30$
 = _____

Flame length index $RL_X = (6\,250 / L_B) + 37,5 = (6\,250 / \quad) + 37,5$
 = _____

Smoke density $D = \lg(V_0 / V_1) = \lg(\quad / \quad)$
 = _____