BRITISH STANDARD

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12065 : 1998

Installations and equipment for liquefied natural gas — Testing of foam concentrates designed for generation of medium and high expansion foam and of extinguishing powders used on liquefied natural gas fires

The European Standard EN 12065 : 1997 has the status of a British Standard

ICS 13.220.10; 75.180.01

National foreword

This British Standard is the English language version of EN 12065 : 1997.

The UK participation in its preparation was entrusted to Technical Committee GSE/38, Installation and equiment for LNG, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled 'International Standards Correspondence Index', or by using the 'Find' facility of the BSI Standards Electronic Catalogue.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

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English version

Installations and equipment for liquefied natural gas — Testing of foam concentrates designed for generation of medium and high expansion foam and of extinguishing powders used on liquefied natural gas fires

Installations et équipements relatifs au gaz naturel liquéfié — Essais d'émulseurs destinés à la production de mousse haut et moyen foisonnement et de poudres extinctrices utilisés sur feux de gaz naturel liquéfié

Anlagen und Ausrüstung für Flüssigerdgas — Eignungsprüfung von Schaummitteln für das Aufschäumen von Mittelschaum und Hochschaum sowie Löschpulvern zur Bekämpfung von Flüssigerdgasbränden (LNG-Bränden)

This European Standard was approved by CEN on 22 September 1997.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

Ref. No. EN 12065 : 1997 E

Foreword

This European Standard has been prepared by Technical Committee CEN/TC 282, Installation and equipment for LNG, the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by March 1998, and conflicting national standards shall be withdrawn at the latest by March 1998.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

Contents

1 Scope

This European Standard specifies the tests to be carried out in order to assess the suitability of foam concentrates used to produce medium expansion foam (made from foam concentrates conforming to prEN 1568-1) or high expansion foam (made from foam concentrates conforming to prEN 1568-2) and fire extinguishing powder conforming to EN 615 when used alone or in combination on liquefied natural gas (LNG) fires.

This standard does not specify the general requirements for foam concentrates given in prEN 1568-1 and prEN 1568-2 or fire extinguishing powder given in EN 615.

This standard does not apply to foam concentrates used to produce low expansion foam (made from foam concentrates conforming to prEN 1568-3) which are not used on LNG installations.

2 Normative references

This European Standard incorporates, by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 615	*Fire protection — Fire extinguishing media — Specification for powders (other than class D powders)*
EN 1160	*Installations and equipment for liquefied natural gas — General characteristics of liquefied natural gas*
prEN 1568-1	*Fire extinguishing media — Foam concentrates — Part 1: Specification for medium expansion foam concentrates for surface application to water-immiscible liquids*
prEN 1568-2	*Fire extinguishing media — Foam concentrates — Part 2: Specification for high expansion foam concentrates for surface application to water-immiscible liquids*
prEN 1866	*Mobile fire extinguishers*

3 Definitions

For the purposes of this standard, the following definitions, and those given in EN 1160, apply:

NOTE. Other definitions will be given in the document WI 00191043 (*Fixed fire fighting systems — Foam systems — Part 1: Components*), still in preparation.

3.1 liquefied natural gas (LNG)

See EN 1160.

3.2 solution

Liquid formed by mixing foam concentrate and water.

3.3 application rate of solution

The flow rate of application of the solution, per surface unit area on fire, generally expressed in $l/(min \cdot m^2)$.

3.4 foam concentrate ratio

Ratio generally expressed in percentage of the foam concentrate volume over the solution volume.

3.5 proportioner

A device installed on a pipe to ensure mixing of water with foam concentrate in such a way that the resulting solution presents the desired foam concentrate ratio.

3.6 foam expansion ratio

The ratio between the resulting volume of foam and the volume of solution used.

3.7 initial radiation

The radiation of the LNG fire not covered with foam, burning in free combustion.

3.8 reduced radiation

The radiation of an LNG fire covered with a layer of foam.

NOTE. The value of this radiation varies as a function of the thickness of the foam.

3.9 containment of fire

A fire is contained when its radiation has been changed from the mean initial radiation to a mean reduced radiation that is 10 % of the mean initial radiation under the effect of the foam discharged.

3.10 control of fire

A fire is controlled when its mean reduced radiation is between 10 % and 25 % of the mean initial radiation between two additions of foam.

3.11 free LNG fire

A fire where LNG is in free combustion, not covered by any foam.

3.12 mitigated LNG fire

A fire where the combustion of LNG is reduced by foam coverage.

4 Description of equipment required for the foam concentrate tests

4.1 Components of the foam production unit

The foam discharge on an ignited LNG pool is obtained by injecting the solution into a foam generator.

4.1.1 *Foam generator*

The foam generator used for these tests shall be of the same type as the equipment installed on industrial sites. The output rate at its rated operating pressure shall be such that the application rate of the solution during testing is between 3 l/(m^2·min) and 10 l/(m^2·min).

4.1.2 *Equipment used to supply the solution to the foam generator*

The foam concentrate ratio of the solution selected for testing shall be defined either by the foam concentrate supplier or the industrial user, or by mutual agreement between both parties.

The solution may be supplied to the foam generator in two different manners:

a) the solution shall be prepared in advance by mixing in a container (open or closed tank or equivalent) the water volume required for testing with the quantity of foam concentrate necessary to obtain the desired foam concentrate ratio. The solution shall be used in a time limit specified by the foam concentrate supplier. The prepared solution shall then be transferred to the foam generator via a pump and transfer pipes;

b) water shall be supplied to a proportioner by a pump; the resulting solution shall then be transferred to the foam generator via transfer pipes.

Annex A provides the general recommendations on the design of the foam generating facilities required for testing.

4.1.3 *Measurements to be carried out to quantify the foam production*

In order to quantify the foam production during testing, the following values shall be measured and recorded:

a) the flow rate of the solution;

b) the solution pressure at the generator inlet;

c) the quantity of foam concentrate used;

d) the quantity of water used;

e) the temperature of the water used.

Annex B provides information on the means and methods that may be used to measure the above parameters.

4.2 Special equipment required to determine the foam expansion ratio

The foam expansion ratio shall be determined by releasing the produced foam into an impounding area with a surface area at least equal to 70 m^2 and a height at least equal to 1,2 m. In any case, the impounding area filling time shall be greater than 45 s. The impounding area shall be calibrated to measure its volume with a precision at least equal to 1 %.

4.3 Special equipment required to determine the efficiency of the foam on LNG fires

4.3.1 *Impounding area*

The fire test shall be performed in a circular impounding area, with a surface area at least equal to 50 m^2 and a height of 1,5 m. When necessary, the bottom of the impounding area shall be lined with insulating concrete in order to reduce LNG evaporation during impounding area filling.

The impounding area shall be fabricated from materials listed in EN 1160.

4.3.2 *Measuring equipment*

The following measuring devices shall be used to determine the condition of the fire:

a) eight thermocouples arranged on a vertical mast positioned at the centre of the impounding area;

b) four radiometers positioned crosswind on both sides of the impounding area, at a distance from the centre of the impounding area equal to twice the diameter of the impounding area.

The values shall be recorded throughout the entire LNG combustion.

Annex C specifies the measuring equipment to be used to determine the fire condition.

4.4 Other equipment required for the foam concentrate tests

Regardless of the test conducted, the following data relative to the test site shall be measured and recorded with appropriate equipment:

a) air temperature;

b) water temperature;

c) wind speed and direction;

d) air humidity.

In addition, video equipment shall be used to record all the tests carried out.

5 Foam concentrate tests

5.1 Measurement of foam expansion ratio

5.1.1 *General requirements for performing the test*

The quality of the water used for testing purposes shall be defined either by the supplier of the foam concentrate or the industrial user, or by mutual agreement between both parties.

The foam expansion ratio measuring test shall be performed only if the following conditions are met:

a) zero precipitation;

b) when comparing different foam concentrates, the air and water temperatures between the different tests shall be within 15 °C for each fluid;

c) the mean wind speed is under 4 m/s, and wind gusts are not exceeding 6 m/s;

d) the transfer pipes used to supply the foam generator are filled with solution.

5.1.2 *Test procedure*

The test shall be performed in accordance with the following procedure:

a) start up of the foam generator and discharge the resulting foam outside the test impounding area until nominal operating conditions of the foam generating unit are achieved;

b) continuously discharge the foam into the test impounding area;

c) stop the discharge of the foam once the test impounding area is filled.

5.1.3 *Parameters derived from the measurements*

The foam expansion ratio, f, shall be calculated as follows:

$$f = \frac{V}{V_{sol}} \quad (1)$$

where:

V is the volume of the impounding area that is filled with foam;

V_{sol} is the volume of solution required to produce a volume, V, of foam.

If a proportioner is used, the foam concentrate ratio, τ , shall be calculated as follows:

$$\tau = \frac{V_{em}}{V_{sol}} \quad (2)$$

where:

V_{em} is the volume of the foam concentrate.

5.2 Evaluation of the efficiency of the foam on LNG fires

5.2.1 *General requirements for performing the test*

The quality of the water used for testing purposes shall be defined either by the supplier of the foam concentrate or the industrial user, or by mutual agreement between both parties.

The test shall be regarded as valid only if the following conditions are met:

a) the methane content of the LNG discharged into the impounding area is greater than 85 %;

b) the methane content of the LNG at the end of the impounding area filling is greater than 60 %;

c) the LNG level in the impounding area is at least equal to 0,15 m within 2 min before the start of the ignition;

d) zero precipitation;

e) the mean wind speed is under 4 m/s, and wind gusts are not exceeding 6 m/s;

f) the foam generator is positioned upwind of the impounding area;

g) the transfer pipes used to supply the foam generator are filled with solution.

5.2.2 *Test procedure*

The test shall be performed in accordance with the following procedure:

a) fill the impounding area with LNG;

b) ignite the LNG;

c) leave as a free LNG fire for 45 s, obtaining the mean initial radiation by averaging the radiation values measured by the four radiometers positioned crosswind during the last 30 s;

d) start the foam generator to operate under nominal operating conditions;

e) stop the foam discharge as soon as the mean reduced radiation measured over a period of 10 s is equal to or lower than 10 % of the mean initial radiation;

f) add foam when the mean reduced radiation measured over a period of 10 s reaches 25 % of the mean initial radiation;

g) stop the foam discharge as soon as the mean reduced radiation measured over a period of 10 s is equal to or lower than 10 % of the mean initial radiation;

h) repeat the last two steps (f and g) at least twice;

i) monitor the foam destruction until the end of combustion.

5.2.3 *Parameters derived from measurements*

The efficiency of each foam concentrate shall be determined by calculating the following parameters, in accordance with annex D:

a) the time for LNG fire containment;

b) the volume of foam concentrate required to contain the LNG fire;

c) the height of foam required for containment of fire;

d) the foam concentrate consumption required to control the LNG fire;

e) the rate of foam destruction.

6 The foam concentrate test report

The measurement of the foam expansion ratio and the evaluation of the foam efficiency on LNG fires shall be recorded in a test report containing the following information:

a) the date and time of the tests;

b) data concerning the test site (location, address);

c) the name of the testing company;

d) the technical data sheet for the foam concentrate under test, specifying the physico-chemical parameters as defined by prEN 1568-1 and prEN 1568-2;

e) the performance specification of the foam generator (flow rate and rated operating pressure);

f) the dimensions and volume of the impounding areas used in the foam expansion ratio measuring test and in the foam efficiency evaluation measuring test;

g) the quality of the water used (salt, brackish or fresh water);

h) technical data sheets of the measuring and recording devices;

i) the conditions of the foam expansion ratio measuring test as follows:

1) ambient temperature;

2) wind speed and direction;

3) air humidity;

4) water temperature;

5) flow rate and pressure of the foam generator;

6) foam concentrate ratio;

j) the results from the foam expansion ratio measuring test as follows:

1) time for filling the impounding area;

2) volume of solution;

3) foam expansion ratio;

k) the conditions of the evaluation of the foam efficiency on LNG fires as follows:

1) the LNG level in the impounding area at ignition time;

2) methane content of the LNG measured at the end of the impounding area;

3) description of the methods used to determine the LNG level and methane content at the end of impounding area filling;

4) ambient temperature;

5) wind speed and direction;

6) air humidity;

7) temperature of the water used to produce foam;

8) flow rate and pressure of the foam generator during the different discharges and additions of foam;

9) orientation of the foam generator in relation to the wind;

10) actual position of radiometers in relation to the wind;

l) the results from the evaluation of the foam efficiency on LNG fires as follows:

1) initial radiation from the fire;

2) curves of heat radiation as a function of time as measured by the four radiometers, accompanied by comments detailing the beginning and end of the foam discharge periods;

3) time for LNG fire containment;

4) volume of the foam concentrate required to contain the LNG fire;

5) height of foam required for fire containment;

6) foam concentrate consumption required to control the LNG fire;

7) rate of foam destruction.

7 Evaluation of the efficiency of an extinguishing powder on a free LNG fire

The efficiency of an extinguishing powder on a free LNG fire shall be evaluated in accordance with EN 615, substituting LNG for the class B combustible in the fire test. Portable fire extinguishers with a rated load equal to 6 kg or 9 kg shall be used for testing purposes.

8 Description of the equipment required to test the compatibility between foam and extinguishing powder

8.1 Components of the foam production unit

The equipment used shall be as in **4.1**.

8.2 Equipment required for the application of extinguishing powder

The equipment used for these tests shall be of the same type as the equipment used on industrial sites.

Each nozzle shall have a flow rate between 2,5 kg/s and 3,3 kg/s and shall be capable of discharging a load of extinguishing powder equal to 100 kg.

8.3 Special equipment required for the test

The impounding area used to perform this test shall be circular shaped, with a base area equal to (50 ± 5) m^2 and a height equal to 1,5 m. When necessary, the base of the impounding area shall be lined with insulating concrete in order to reduce LNG evaporation during the filling of the impounding area.

Annex E specifies the equipment to be used.

8.4 Other equipment required for the test

The following data relative to the test site shall be measured and recorded with appropriate equipment:

a) ambient temperature;

b) wind speed and direction;

c) air humidity.

In addition, video equipment shall be used to record all the tests carried out.

9 The test for compatibility between foam and extinguishing powder

9.1 General requirements for performing the test

The test for compatibility between foam and extinguishing powder shall be performed only if the following conditions are met for each extinction attempt:

a) the methane content of the LNG discharged into the impounding area is greater than 85 %;

b) the LNG level in the impounding area is at least equal to 0,15 m obtained within a maximum time of 1 h following start of filling the impounding area;

c) zero precipitation;

d) the mean wind speed is under 4 m/s, and wind gusts are not exceeding 6 m/s;

e) the foam generator is positioned upwind of the impounding area;

f) the transfer pipes used to supply foam generator are filled with solution;

g) fire-extinguishing equipment is properly installed prior to LNG ignition, so that two operators can be positioned crosswind on both sides of the impounding area at the beginning of the extinction attempt;

h) the handling of the extinguisher shall be conducted in accordance with the recognized codes of practice.

9.2 Test procedure

Each extinction attempt shall be performed in accordance with the following procedure:

a) fill the impounding area with LNG;

b) ignite the LNG;

c) leave as a free LNG fire for 45 s;

d) start the foam generator to operate under nominal operating conditions;

e) stop the foam discharge as soon as the impounding area is filled;

f) extinguish the mitigated LNG fire using two operators working simultaneously.

9.3 Criterion of acceptance of extinguishing powder

The compatibility between foam and extinguishing powder shall be assessed on the basis of five successful extinctions out of eight attempts. No further testing is required as soon as five successful extinctions are achieved.

The quantity of powder used during each successful extinction shall be measured.

10 The test report for the efficency of the extinguishing powder on an LNG fire

10.1 Test report

The results from the free fire test and from the test for compatibility between foam and extinguishing powder shall be recorded in a test report.

10.2 Extinction test on a free fire

The following information shall be recorded:

a) the date and time of the extinction attempts;

b) data concerning the test site (location, address);

c) the name of the testing company;

d) the technical data sheet for the portable fire extinguishers in accordance with prEN 1866;

e) the technical data sheet for the extinguishing powder under test in accordance with EN 615;

f) the dimensions of the impounding area, surface area of the pool and the LNG height before ignition;

g) the number of successful extinctions and number of extinction attempts;

h) the quantity of powder used for each successful extinction.

10.3 Test for compatibility between foam and extinguishing powder

The following information shall be recorded:

a) the date and time of extinction attempts;

b) data concerning the test site (location, address);

c) the name of testing company;

d) the technical data sheet for the foam generator;

NOTE. CEN/TC 191 is preparing a document on this subject (00191043 *Fixed fire fighting systems — Foam systems — Part 1 : Components*).

e) the technical data sheet for the mobile fire extinguishers in accordance with prEN 1866;

f) the technical data sheet for the foam concentrate under test used for foam production specifying the physico-chemical parameters as defined in prEN 1568-1 and prEN 1568-2;

g) the technical data sheet for the extinguishing powder under test in accordance with EN 615;

h) the technical data sheets of the measuring and recording devices used;

i) the conditions of the foam discharge over the LNG fire as follows:

1) LNG level in the bund at time of ignition;

2) methane content of the LNG discharged into the impounding area;

3) ambient temperature;

4) wind speed and direction;

5) air humidity;

6) temperature of the water used for foam production;

7) flow rate and pressure of the foam generator;

8) orientation of the foam generator and extinguishers in relation to the wind;

j) the number of successful extinctions and number of extinction attempts;

k) the quantity of powder used for each successful extinction.

Annex A (informative)
General recommendations on the design of the foam generating equipment required for testing

A.1 General remarks

Foam concentrate tests may be carried out on request from:

a) the foam concentrate supplier who prescribes the foam concentrate ratio;

b) an industrial user such as an engineering firm or operator wishing to assess the performance of the foam concentrate related to a given piece of equipment. In this case, the foam concentrate ratio selected for the test should be the subject of a prior agreement between the supplier and the industrial user.

In order to obtain a given foam concentrate ratio, the solution may be prepared in a container by mixing finite volumes of water and foam concentrate.

In the event that testing is intended to demonstrate the compatibility between the foam concentrate and the foam generating equipment, a proportioner may then be used, similar to the equipment selected by the industrial user.

A.2 Foam producing equipment with prior preparation of solution in a container

A.2.1 *Overall design*

A diagram of the proposed test rig is presented on figure A.1. It consists of the following components:

a) a tank designed to prepare the solution required for testing;

b) a pump designed to provide recycling of the solution and its transfer into the foam generating system;

c) rigid pipes, fire hoses pipes and valves comprising the solution recycling circuit and the solution transfer circuit to the foam generator;

d) foam generator.

A.2.2 *Preparation and production of solution*

In this case, the applicable procedure is as follows:

a) the water and foam concentrate volumes required to obtain the desired foam concentrate ratio are determined;

NOTE. These volumes can be determined on the basis of the total estimated quantity of solution required for the test.

b) the tank is filled with the water volume previously calculated;

c) the foam concentrate volume previously calculated is added;

d) the solution to ensure homogeneous mixing of the water and the foam concentrate is recycled.

NOTE. Measures should be taken in order to prevent the formation of foam inside the solution tank.

e) the pipes and fire hoses connected to the foam generator are filled with solution;

f) the foam expansion ratio measuring test is started.

NOTE. The foam generator should be placed on a rotating table, thereby enabling the generated foam to be discharged outside the impounding area at the beginning of the test. Once the foam generator operates under nominal operating conditions, the rotating table can then be oriented to discharge the foam into the test impounding area.

A.3 Design of a foam generating system with preparation of solution using a proportioner

A.3.1 *Overall design*

A diagram of the proposed test rig is shown in figure A.2. The system consists of the following:

a) a water supply, either a tank or a tanker from which the water is pumped;

b) a pump;

c) a proportioner used to add the foam concentrate;

d) a system of rigid pipes, fire hoses and valves to transfer the solution to the foam generator;

e) a waste water circuit fitted with a flow-control valve.

A.3.2 *Production of solution*

A.3.2.1 *Preliminary adjustment*

The following preliminary adjustments are carried out:

a) start up and adjustment of the pump to ensure operation of the foam generator at its rated output;

NOTE. It is not necessary when adjusting the pump to supply foam concentrate to the proportioner.

b) release of the water returned by the pump through the waste water circuit, in order to adjust the flow control valve and ensure that its head loss is identical to that of the transfer circuit to the foam generator;

c) filling of the pipes and the fire hoses connected to the foam generator, with solution.

A.3.2.2 *Test procedure*

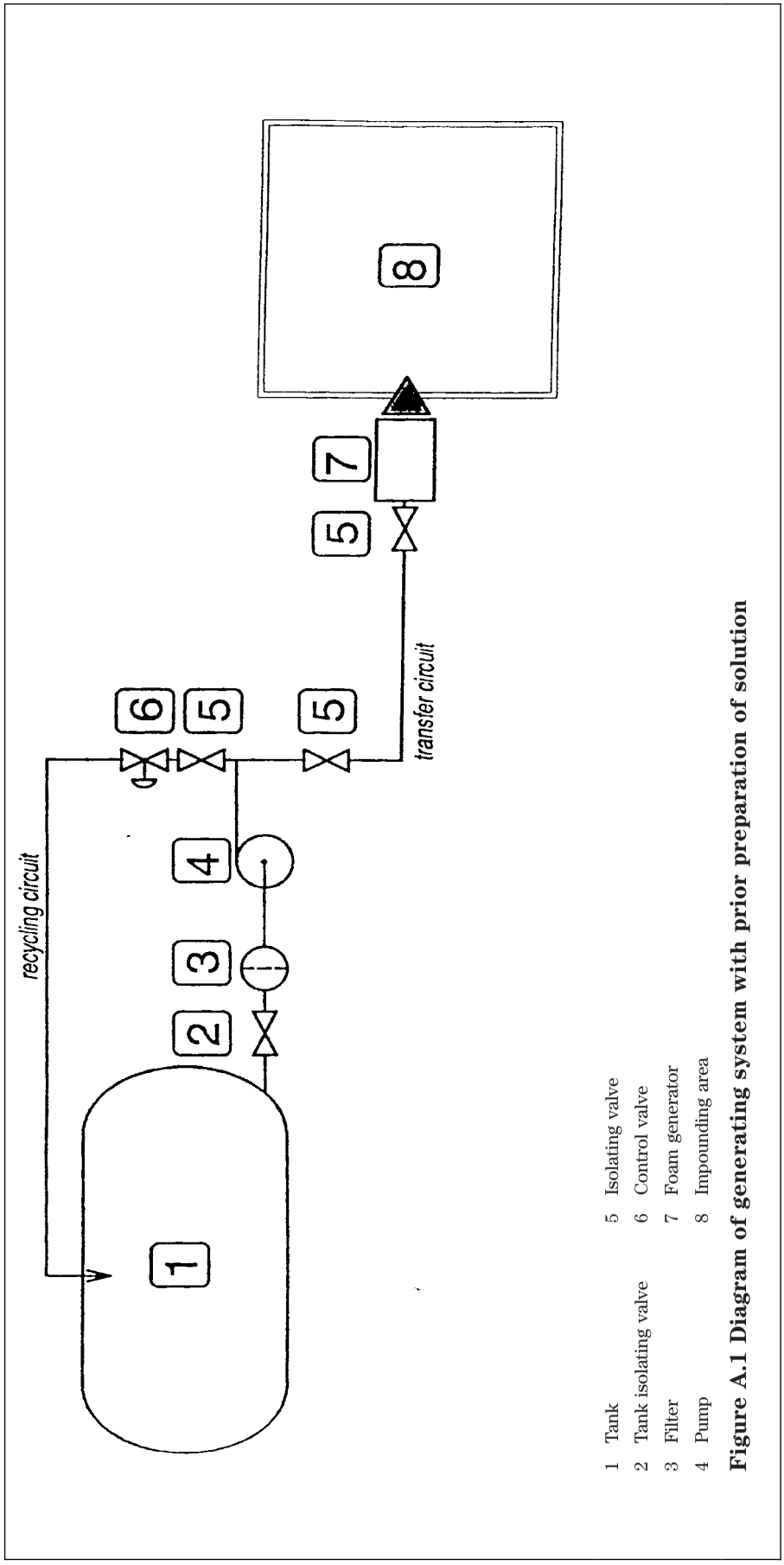
For production of foam using a foam generator operating under nominal conditions, it is recommended to apply the following procedure:

a) start up of the pump to ensure that the foam generator operates at its rated output; water is returned through the waste water circuit;

b) closure of the waste water circuit and, simultaneously, opening of the transfer circuit to the foam generator;

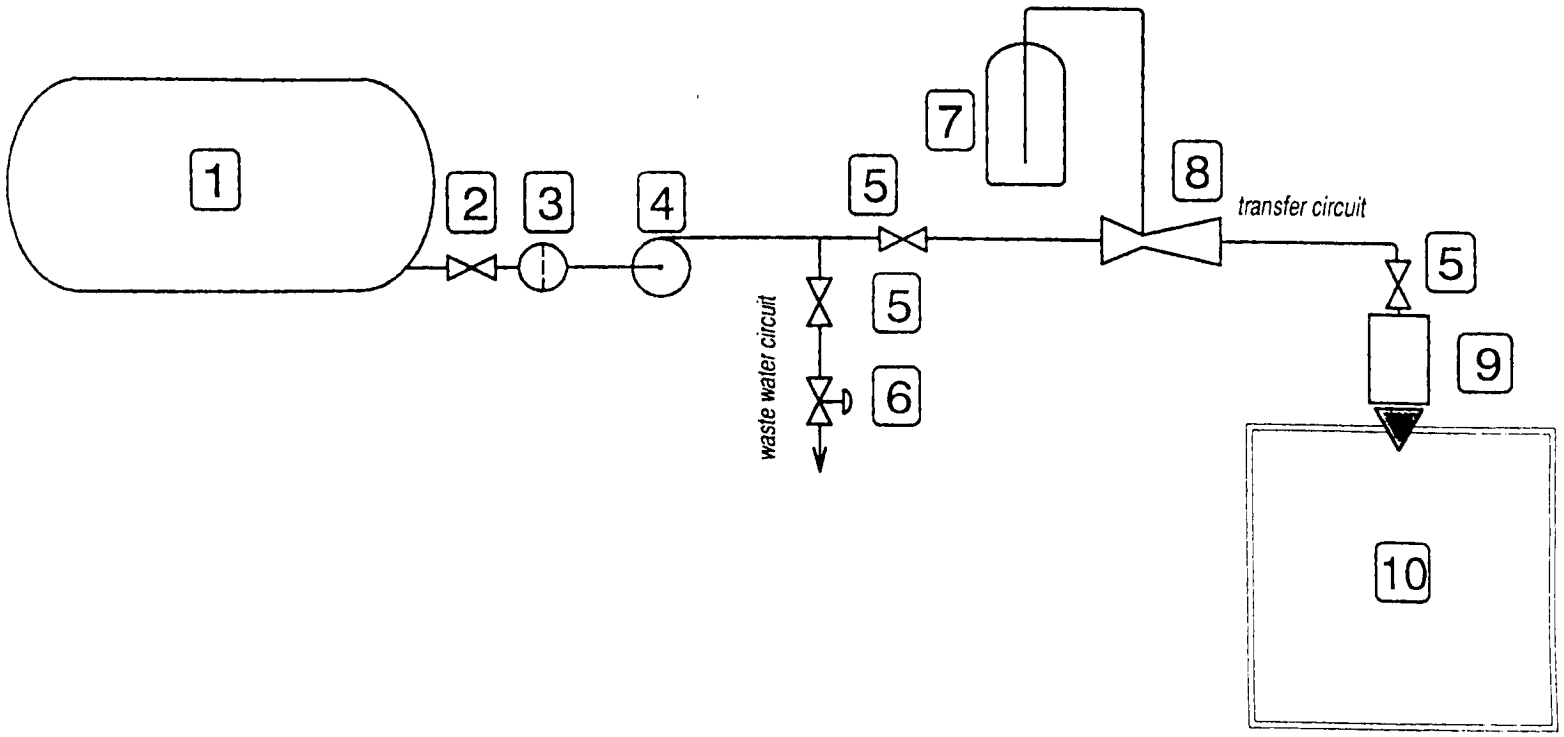
c) start of the foam expansion ratio measuring test.

NOTE. The foam generator should be placed on a rotating table, thereby enabling the generated foam to be discharged outside the impounding area at the beginning of the test. Once the foam generator operates under nominal operating conditions, the rotating table can then be oriented to discharge the foam into the test impounding area.



1 Tank
2 Tank isolating valve
3 Filter
4 Pump
5 Isolating valve
6 Control valve
7 Foam generator
8 Impounding area

Figure A.1 Diagram of generating system with prior preparation of solution



1 Tank
2 Tank isolating valve
3 Filter
4 Pump
5 Isolating valve
6 Control valve
7 Foam concentrate storage
8 Proportioner
9 Foam generator
10 Impounding area

Figure A.2 Diagram of a foam generating system with foam production using a proportioner

Annex B (informative)

Measuring equipment used to quantify foam production

B.1 General remarks

Since all measurements should be recorded, it is recommended that a data acquisition system connected to a computer is provided.

B.2 Measuring devices

The measuring devices necessary to quantify foam production are listed in table B.1

Table B.1 List of the measuring devices

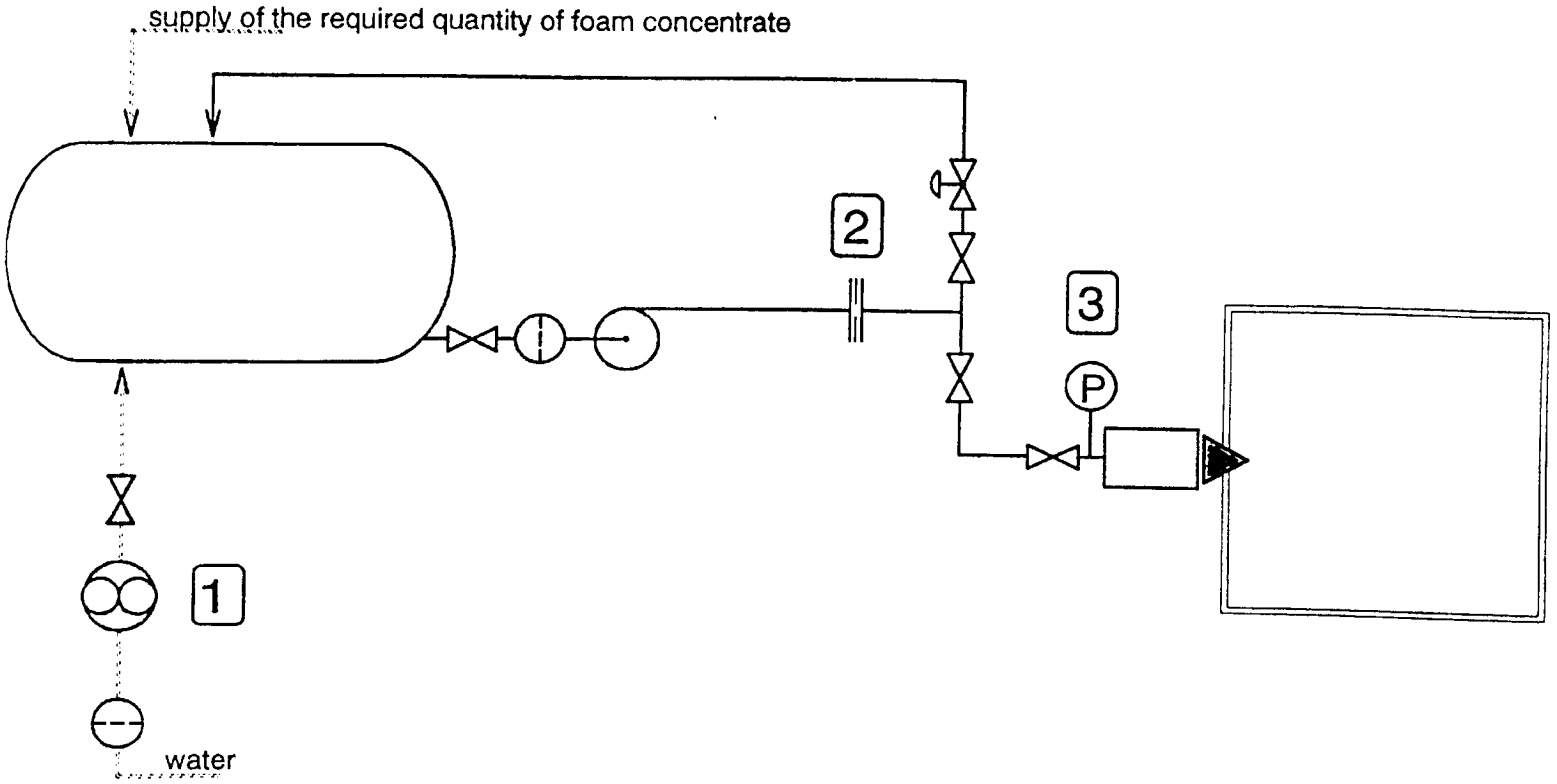
Measuring devices	Measurements
Water meter	Quantity of water used to fill the tank. Only required if using previously mixed solution
Flowmeter	Flow rate of solution
Electronic scales	Weight of foam concentrate used to prepare the solution or when using a proportioner
Pressure measuring device	Pressure at foam generator input

B.3 Layout of measuring devices in test rig

Measuring devices should be positioned in accordance with the diagram shown:

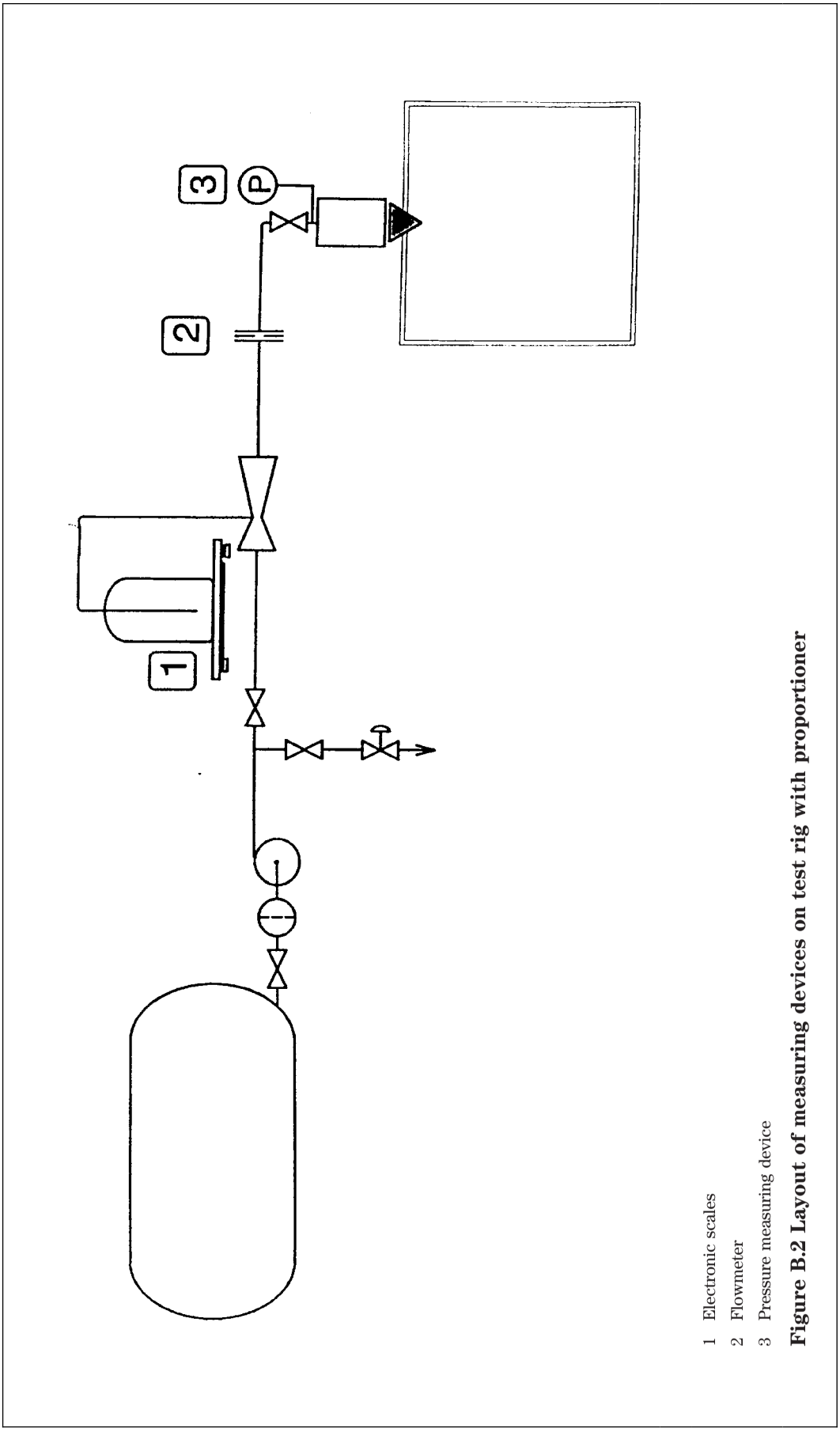
– on figure B.1 for a test rig with prior preparation of solution;

– on figure B.2 for a test rig with a proportioner.



1 Water meter _____ production of solution
2 Flowmeter
3 Pressure measuring device ..... preparation of solution

Figure B.1 Layout of measuring devices on test rig with prior preparation of solution



1 Electronic scales
2 Flowmeter
3 Pressure measuring device

Figure B.2 Layout of measuring devices on test rig with proportioner

Annex C (normative)
Measuring equipment used to determine fire conditions

C.1 General remarks

Since the execution of the LNG fire test requires real time processing of the measurements, a data acquisition system connected to a computer shall be used.

C.2 Type and layout of sensors

The sensors required to evaluate the fire activity shall be as listed in **4.3.2**.

Sensor layout shall fulfill the following requirements:

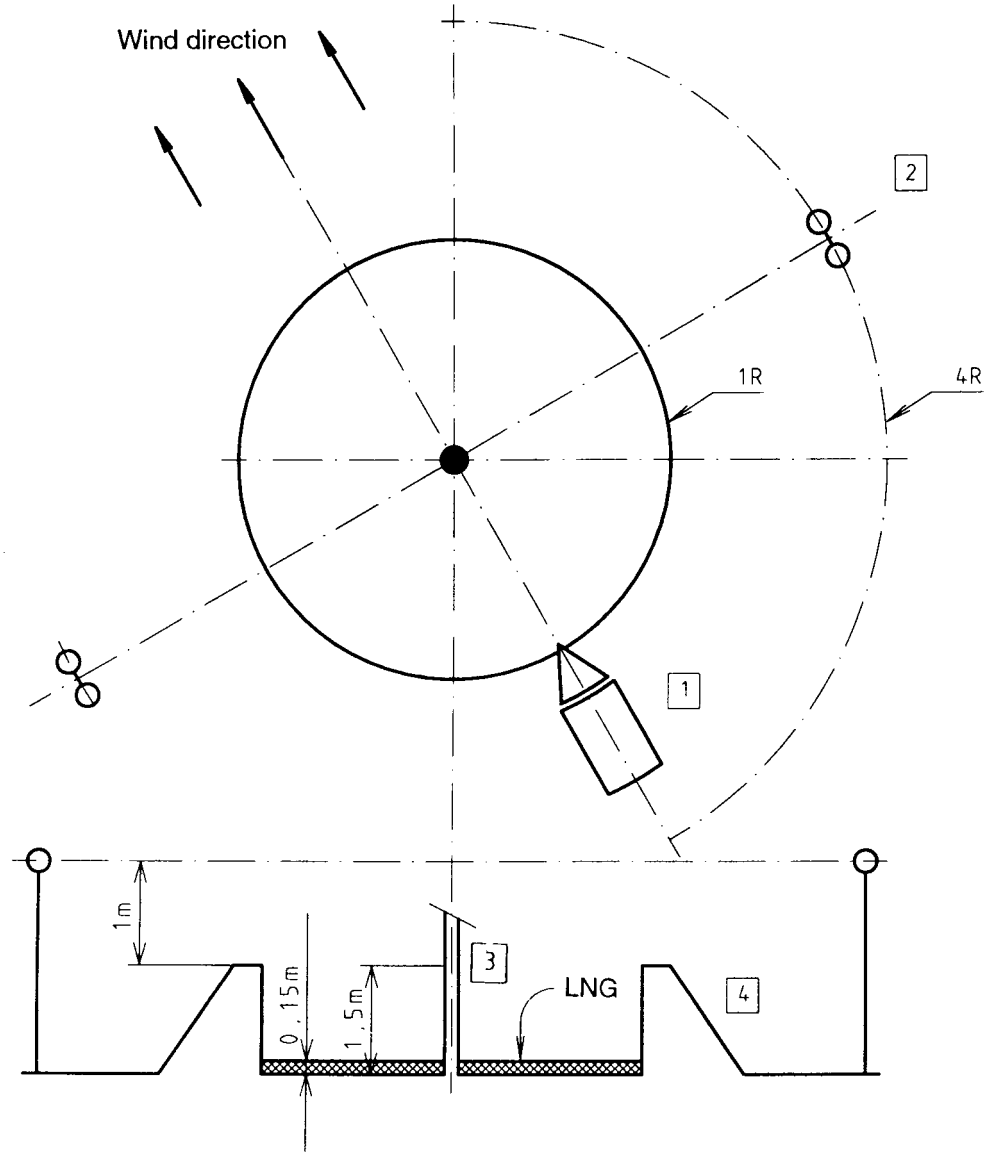
– radiometers shall be positioned 1 m above the open surface of the impounding area;

– thermocouples shall be positioned below the open surface of the impounding area in order to measure the foam destruction rate.

The position of sensors in relation to the bund shall be as specified on table C.1 and on figure C.1.

Table C.1 Position of thermocouples

Reference of thermocouple	Location of thermocouple from the base of the bund mm
T1	250
T2	420
T3	580
T4	750
T5	920
T6	1070
T7	1250
T8	1420



1 Foam generator
2 Radiometer
3 Temperature mast
4 Impounding area
R Radius of the impounding area

Figure C.1 Positioning of sensors for determination of fire conditions

Annex D (normative)
Method of calculating the parameters used to determine the efficiency of the foam concentrate

D.1 Fire containment time

The fire containment time, t_c, shall correspond to the time interval elapsed between the instant when the foam starts being discharged into the impounding area and the instant when the reduced radiation is less than or equal to 10 % of the mean initial radiation over a completed period of 10 s.

$$t_c = t_{f10\,\%} - t_g \qquad \text{(D.1)}$$

where:

t_g is the instant when foam discharge starts, in seconds;

$t_{f10\,\%}$ is the instant when the reduced radiation is less than or equal to 10 % of the mean initial radiation over a completed period of 10 s.

D.2 Volume of foam concentrate required to contain the fire

D.2.1 *Test rig with prior preparation of solution in a tank*

The volume of foam concentrate per surface unit V_{em} shall be derived from the flow rate of the solution Q_{sol} in cubic metres per second, and calculated as follows:

$$V_{sol} = \frac{1}{S} \int_{t_g}^{t_{f10\,\%}} Q_{sol}\, dt \qquad \text{(D.2)}$$

where:

S is the surface area of the impounding area, in square metres;

V_{sol} is the volume of solution used per surface unit, in cubic metres per square metre.

$$V_{em} = \tau \cdot V_{sol} \qquad \text{(D.3)}$$

where:

τ is the foam concentrate ratio.

D.2.2 *Test rig with proportioner*

The volume of foam concentrate per surface unit V_{em} shall be derived from continuous weighing of the foam concentrate container:

$$V_{em} = \frac{1}{S} \cdot \frac{1}{\rho_{em}} \cdot (M_g - M_{f10\,\%}) \qquad \text{(D.4)}$$

where:

M_g is the mass of foam concentrate stored at time t_g, in kilograms;

$M_{f10\,\%}$ is the mass of foam concentrate remaining at time $t_{f10\,\%}$, in kilograms;

ρ_{em} is the density of the foam concentrate, in kilograms per cubic metre.

D.3 Height of foam required for fire containment

The required height of foam H_m, in metres, shall be determined on the basis of an analysis of the temperatures measured by the thermocouples arranged on the mast positioned at the centre of the impounding area:

$$H_m = H_{th_i} + \frac{H_{th_{i+1}} - H_{th_i}}{2} \qquad \text{(D.5)}$$

where:

H_{th_i} is the position of the highest thermocouple th_i showing a temperature below 100 °C during the continuous 10 s period during which the reduced radiation is less than or equal to 10 % of the initial radiation, in metres;

$H_{th_i} + 1$ is the height of thermocouple th_{i+1} positioned above thermocouple th_i, in metres.

D.4 Foam concentrate consumption required for fire control

D.4.1 *Test rig with prior preparation of solution in a tank*

The consumption rate of foam concentrate C_{em} shall be derived from the solution flow rate Q_{sol} and calculated as follows:

$$V_{sol} = \frac{1}{S} \int_{t_1}^{t_2} Q_{sol} dt \qquad \text{(D.6)}$$

where:

t_1 is the instant, in seconds, at the end of the first foam discharge, when the reduced radiation is less than or equal to 10 % of the mean initial radiation over a completed period of 10 s;

t_2 is the instant, in seconds, at the end of the last foam discharge, when the reduced radiation is less than or equal to 10 % of the mean initial radiation over a completed period of 10 s.

$$C_{em} = \frac{\tau \cdot V_{sol}}{t_2 - t_1} \qquad \text{(D.7)}$$

where:

τ is the foam concentrate ratio.

D.4.2 *Test rig with proportioner*

The consumption rate of foam concentrate C_{em} shall be derived from continuous weighing of the foam concentrate container:

$$C_{em} = \frac{1}{S} \cdot \frac{1}{\rho_{em}} \cdot \frac{M_{t_1} - M_{t_2}}{t_2 - t_1} \qquad \text{(D.8)}$$

where:

M_{t_1} is the mass of foam concentrate initially stored at time t_1, in kilograms;

M_{t_2} is the mass of foam concentrate remaining at time t_2, in kilograms.

D.5 Rate of foam destruction

The foam destruction rate V_{dest} expressed in m/s shall be determined by analysing, after the last foam discharge, the temperatures measured by the thermocouples arranged on the vertical mast positioned at the centre of the impounding area, as a function of time. The destruction rate shall be calculated as follows:

$$V_{dest} = \frac{0{,}5}{t_{th_{0{,}75\ m}} - t_{th_{1{,}25\ m}}} \qquad \text{(D.9)}$$

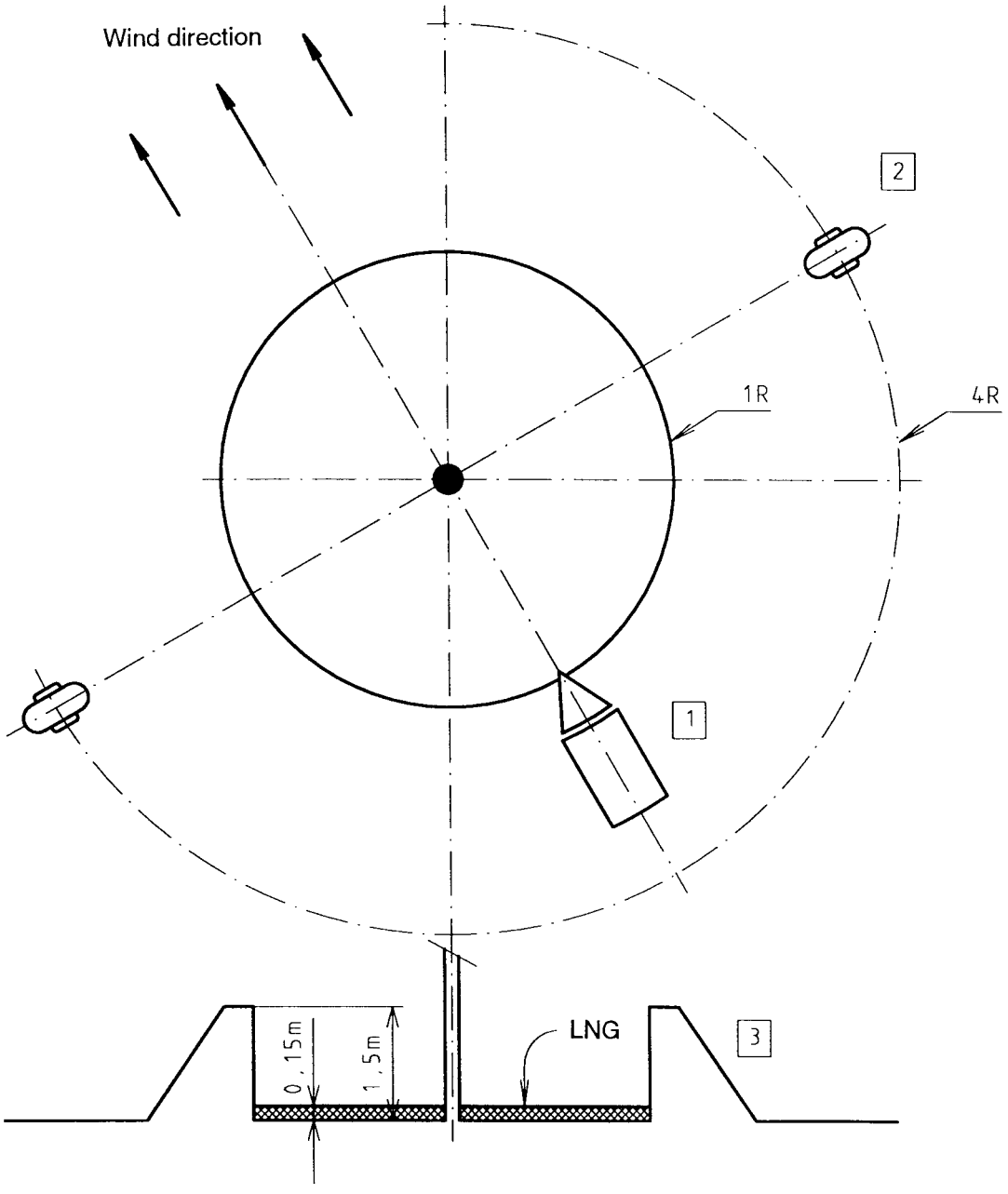
where:

$t_{th_{1,25\ m}}$ is the time, expressed in seconds, when the thermocouple located 1,25 m from the base of the impounding area is no longer immersed in foam and detects a temperature greater than or equal to 100 °C;

$t_{th_{0,75\ m}}$ is the time, expressed in seconds, when the thermocouple located 0,75 m from the base of the bund is no longer immersed in foam and detects a temperature greater than or equal to 100 °C.

Annex E (normative)

Special test rig required to test the compatibility between foam and extinguishing powder



1 Foam generator

2 Extinguishers

3 Impounding area

R Radius of the impounding area

Figure E.1 Test rig configuration

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