

RESOLUTION A.653(16) adopted on 19 October 1989
RECOMMENDATION ON IMPROVED FIRE TEST PROCEDURES FOR
SURFACE FLAMMABILITY OF BULKHEAD, CEILING AND DECK FINISH MATERIALS



ASSEMBLY - 16th session
Agenda item 10

IMO

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THE ASSEMBLY,

RECALLING Article 15(j) of the Convention on the International Maritime Organization concerning the functions of the Assembly in relation to regulations and guidelines concerning maritime safety,

RECALLING FURTHER that it adopted, by resolution A.564(14), the Revised Recommendation on Fire Test Procedures for Surface Flammability of Bulkhead, Ceiling and Deck Finish Materials, with reference to the term "low flame spread" in regulations II-2/3.8, II-2/34.3 and II-2/49.1 of the International Convention for the Safety of Life at Sea, 1974, as amended,

RECOGNIZING the need to improve these test procedures in the light of experience gained,

HAVING CONSIDERED the recommendation made by the Maritime Safety Committee at its fifty-seventh session,

1. ADOPTS the Recommendation on Improved Fire Test Procedures for Surface Flammability of Bulkhead, Ceiling and Deck Finish Materials, the text of which is annexed to the present resolution and which supersedes the Revised Recommendation annexed to resolution A.564(14);

W/2724e

2. RECOMMENDS Governments concerned to apply the Recommendation on Improved Fire Test Procedures set out in the Annex, in lieu of the Revised Recommendation as annexed to resolution A.564(14) in conjunction with the guidelines on the evaluation of fire hazard properties of materials set out in resolution A.166(ES.IV).

ANNEX

RECOMMENDATION ON IMPROVED FIRE TEST PROCEDURES FOR SURFACE FLAMMABILITY OF BULKHEAD, CEILING AND DECK FINISH MATERIALS

1 SCOPE

This Recommendation specifies a procedure for measuring fire characteristics of bulkhead, ceiling and deck finish materials as a basis for characterizing their flammability and thus their suitability for use in marine construction.

2 WARNING

2.1 Ignition hazards

The use of this test method involves the generation of very high heat flux levels which are capable of causing ignition of some materials such as clothing following even brief exposures. Precautions should be taken to avoid accidental ignitions of this type.

2.2 Toxic fume hazards

The attention of the user of this test is drawn to the fact that the fumes from burning materials often include carbon monoxide. Other more toxic products may in many instances be produced. Suitable precautions should be taken to avoid any extended exposure to these fumes.

3 DEFINITIONS

Certain terms used in this Recommendation require definition for clarity. Other fire characteristic terms are also used; these are defined hereunder but relate only to the results of measurements by this specific test method.

3.1 Compensating thermocouple

A thermocouple for the purpose of generating an electrical signal representing long-term changes in stack metal temperatures. A fraction of the signal generated is subtracted from the signal developed by the stack gas thermocouples.

3.2 Critical flux at extinguishment

A flux level at the specimen surface corresponding to the distance of farthest advance and subsequent self-extinguishment of the flame on the centreline of a burning specimen. The flux reported is based on calibration tests with a dummy specimen.

3.3 Dummy specimen

A specimen used for standardizing the operating condition of the equipment; it should be roughly 20 mm thickness, $800 \pm 100 \text{ kg/m}^3$ density and should meet the requirements of resolution A.472(XII) as non-combustible.

3.4 Special calibration dummy specimen

A dummy specimen as defined by figure 14 intended only for use in calibration of heat flux gradient along with specimen.

3.5 Fume stack

A box-like duct with thermocouples and baffles through which flames and hot fumes from a burning specimen pass. Its purpose is to permit measurement of the heat release from the burning specimen.

3.6 Heat for ignition

The product of the time from initial specimen exposure until the flame front reaches the 150 mm position and the flux level at this position; this latter obtained in prior calibration of the apparatus.

3.7 Heat release of specimen

The observed heat release under the variable flux field imposed on the specimen and measured as defined by the test method.

3.8 Heat for sustained burning

The product of time from initial specimen exposure until arrival of the flame front and the incident flux level at that same location as measured with a dummy specimen during calibration. The longest time used in this calculation should correspond to flame arrival at a station at least 30 mm prior to the position of furthest flame propagation on the centreline of the specimen.

3.9 Reverberatory wires

A wire mesh located in front of, but close to, the radiating surface of the panel heat source. This serves to enhance the combustion efficiency and increase the radiance of the panel.

3.10 Viewing rakes

A set of bars with wires spaced at 50 mm intervals for the purpose of increasing the precision of timing flame front progress along the specimen.

4 PRINCIPLE OF THE TEST

This test provides methods for evaluating flammability characteristics of 155 mm x 800 mm specimens in vertical orientation. The specimens are exposed to a graded radiant flux field supplied by a gas-fired radiant panel. Means are provided for observing the times to ignition, spread and extinguishment of flame along the length of the specimen as well as for measuring the compensated millivolt signal of the stack gas thermocouples as the burning progresses. Experimental results are reported in terms of: heat for ignition, heat for sustained burning, critical flux at extinguishment and heat release of specimen during burning.

5 FACILITY AND APPARATUS REQUIREMENTS

5.1 General

A detailed description of the facility and apparatus required for conduct of this test is included in the appendix. Compliance with the appendix forms an essential requirement of the test method. The equipment needed may be summarized as follows:

5.1.1 Special test room fitted with fume exhaust system as well as fresh air inlet.

5.1.2 Radiant panel frame fitted with blower or other source of combustion air, a methane* or natural gas supply system with suitable safety controls, and a radiant panel heat source, with reverberatory wires, arranged to radiate on a vertical specimen. Alternatively, an electrically heated radiant source of the same dimensions may be used provided it can expose the specimen to the heat flux distribution shown in table 1. The effective source temperature of any radiant panel is not greater than 1,000°C.

5.1.3 The specimen holder frame, three specimen holders, two parts of pilot burners, specimen holder guides, viewing rakes and a viewing mirror.

5.1.4 A specimen fume stack with both stack gas and stack temperature compensating thermocouples together with a means for adjusting the magnitude of the compensation signal.

5.1.5 Instrumentation comprising a chronograph, digital or sweep second electric clock, a digital millivoltmeter, a two-channel millivolt recorder, gas-flowmeter, heat-fluxmeters, a wide angle total radiation pyrometer and a stopwatch. Use of a data acquisition system to record both panel radiance and the heat release stack signal during test will facilitate data reduction.

* The use of gases other than methane or natural gas is not recommended although with changes in panel-specimen spacing it has been reported possible to use the equipment with propane up to flux levels of 50 kw/m².

6 CALIBRATION

Mechanical, electrical and thermal calibrations should be performed as described in the appendix. These adjustments and calibrations should be performed following initial installation of the apparatus and at other times as the need arises.

6.1 Monthly verification

The calibration of the flux distribution on the specimen and the proper operation of the fume stack with its thermocouple system should be confirmed by monthly tests, or at more frequent intervals if this is found necessary (see 4.3.1 and 4.6 in the appendix).

6.2 Daily verification

As a means of assuring continued proper adjustment of the apparatus, the following tests should be performed on a daily basis, or more frequently if the nature of the specimens makes this necessary.

6.2.1 Adjustment of the pilot burner, the acetylene and air supply should be adjusted to provide a flame length of about 230 mm*. When this has been done, the flame length as viewed in a darkened laboratory will be seen to extend about 40 mm above the upper retaining flange of the specimen holder. The burner spacing from the specimen is adjusted while the radiant source is operating by the use of softwood splines of 3 mm thickness and of 10 mm and 12 mm width. When these splines are moved during a two second exposure along the flame length, between the pilot burner flame and a dummy specimen surface, the 10 mm spline should not be charred but the 12 mm spline should show char. With the specimen in the vertical position, the charring of the 12 mm spline should occur over a vertical distance of at least 40 mm from the upper exposed edge of the specimen (see figure 9 in the appendix).

* It is recommended that, to give increased precision, acetylene rather than other gases be used wherever possible.

6.2.2 The stack gas thermocouples should be cleaned by light brushing at least daily. This cleaning may be required even more frequently, in some instances before each test, when materials producing heavy soot clouds are tested. These thermocouples should also be individually checked for electrical continuity to ensure the existence of a useful thermojunction. Following daily cleaning of the parallel connected stack gas thermocouples, both they and the compensating junction should be checked to verify that the resistance between them and the stack is in excess of 10^6 ohms.

6.3 Continuous monitoring of operation

A dummy specimen should remain mounted in the position normally occupied by a specimen whenever the equipment is in stand-by operation. This is a necessary condition of the continuous monitoring procedure which is accomplished by measuring:

- .1 the millivolt signals from both the stack thermocouples and the total radiation pyrometer mounted securely on the specimen holder frame facing the surface of the radiant panel; or
- .2 the millivolt signals from both the stack thermocouples and a heat-fluxmeter positioned at 350 mm from the exposed hot end of a marine board specimen of about 20 mm thickness (see appendix, paragraph 4.3.2).

Either of these measurement methods would be satisfactory for determining that an appropriate thermal operating level has been achieved. The use of the radiation pyrometer is preferable since it permits continuous monitoring of panel operating level even when tests are in progress. Both signals should remain essentially constant for three minutes prior to the test. The observed operating level of either the radiation pyrometer or the fluxmeter should correspond, within 2%, to the similar required level specified in table 1 and referred to in the calibration procedure mentioned in 6.1 above.

7 SPECIMENS

7.1 Number required

Three specimens should be tested for each different exposed surface of the product evaluated and applied.

7.2 Dimensions

The specimens should be $155 \pm \frac{0}{5}$ mm wide by $800 \pm \frac{0}{5}$ mm long, and should be representative of the product.

7.2.1 Specimen thickness: materials and composites of normal thickness 50 mm or less should be tested using their full thickness, attaching them, by means of an adhesive if appropriate, to the substrate to which they will be attached in practice. For materials and composites of normal thickness greater than 50 mm, the required specimens should be obtained by cutting away the unexposed face to reduce the thickness to $50 \pm \frac{3}{0}$ mm.

7.3 Composites

Assembly should be as specified in 7.2. However, where thin materials or composites are used in the fabrication of an assembly, the presence of an air gap and/or the nature of any underlying construction may significantly affect the flammability characteristics of the exposed surface. The influence of the underlying layers should be recognized and care taken to ensure that the test result obtained on any assembly is relevant to its use in practice.

7.4 Metallic facings

If a bright metallic faced specimen is to be tested, it should be painted with a thin coat of flat black paint prior to conditioning for test.

7.5 Marking specimens

A line should be marked centrally down the length of the tested face of each specimen. Caution should be exercised to avoid the use of a line which would influence specimen performance.

7.6 Conditioning of specimens

Before test, the specimens should be conditioned to constant moisture content, at a temperature of $23 \pm 2^{\circ}\text{C}$, and a relative humidity of $50 \pm 10\%$. Constant moisture content is considered to be reached when, following two successive weighing operations, carried out at an interval of 24 hours, the measured masses do not differ by more than 0.1% of the mass of the specimen.

8 TEST PROCEDURE

8.1 General considerations

The test method involves mounting the conditioned specimen in a well-defined flux field and measuring the time of ignition, spread of flame, its final extinguishment together with a stack thermocouple signal as an indication of heat release by the specimen during burning.

8.1.1 Prepare a properly conditioned specimen for test in a cool holder away from the heat of the radiant panel. Prior to insertion in the specimen holder, the back and edges of the specimen should be wrapped in a single sheet of aluminium foil of 0.02 mm thickness and dimensions of $(175 + a)$ mm x $(820 + a)$ mm where "a" is twice the specimen thickness. When inserted in the specimen holder each specimen should be backed by a cool 10 ± 2 mm board of non-combustible refractory insulating material with the same lateral dimensions and density as the dummy specimen. When mounting non-rigid specimens in the holder, shims should be placed between specimen and holder flange to ensure that the exposed specimen face remains at the same distance from the pilot flame as a rigid specimen. For such materials, the shims may often only be required for a 100 mm length at the hot end of the specimen.

8.1.2 The dummy specimen in a specimen holder should be mounted in position facing the radiant panel. The equipment fume exhaust system should be started.

8.1.3 The radiant panel is operated to realize the test conditions as specified in 6.3. Start the millivolt recorder recording the output signal of the stack thermocouples, as well as signal from the total radiation pyrometer or heat-fluxmeter positioned, as described in 6.3.2.

8.1.4 When the radiant panel and stack signals have attained equilibrium, after the preheat period, light the pilot flame, adjust its fuel flow rate and observe both signals for at least three minutes and verify continued signal stability.

8.1.5 After both signals reach stable levels, remove the dummy specimen holder and insert the specimen in the test position within 10 s. Immediately start both the clock and chronograph.

8.1.6 Operate the event marker of the chronograph to indicate the time of ignition and arrival of the flame front during the initial rapid involvement of the specimen. The arrival at a given position should be observed as the time at which the flame front at the longitudinal centreline of the specimen is observed to coincide with the position of two corresponding wires of the viewing rakes. These times are recorded manually both from measurement on the chronograph chart and from observations of the clock. As far as possible, the arrival of the flame front at each 50 mm position along the specimen should be recorded. Record both the time and the position on the specimen at which the progress of flaming combustion ceases. The panel operating level, as well as stack signals, should be recorded throughout the test and continued until test termination.

8.1.7 Throughout the conduct of the test, no change should be made in the fuel supply rate to the radiant panel to compensate for variations in its operating level.

8.2 Duration of test

The test should be terminated, the specimen removed, and the dummy specimen in its holder reinserted when any one of the following is applicable:

- .1 the specimen fails to ignite after a 10 min exposure;
- .2 3 min have passed since all flaming from the specimen ceased;
- .3 flaming reaches the end of the specimen or self-extinguishes and thus ceases progress along the specimen. This criterion should only be used when heat release measurements are not being made.

8.2.1 Operations 8.1.1 to 8.1.7 should be repeated for two additional specimens (see 8.3).

8.3 Conditions of retest

In the event of failure, during test of one or more specimens, to secure complete flame spread times or a reasonable heat release curve, the data secured should be rejected and a new test or tests performed. Such failures might involve, but not be limited to, incomplete observational data or malfunction of data logging equipment. Excessive stack signal baseline drift should also require further equipment stabilization and retest.

8.3.1 In the event that the first two or three specimens do not ignite following exposure for 10 min, at least one specimen should be tested with the pilot flame angled to impinge on the upper half of the specimen. If this specimen ignites, two additional tests should be run under the same conditions.

8.3.2 If a specimen shows extensive loss of incompletely burned material during test, at least one additional specimen, restrained in the testing frame by poultry netting, should be tested and the data secured reported separately.

8.4 Observations

In addition to the recording of the experimental data, observations should be made and recorded on general behaviour of the specimen including: glowing, charring, melting, flaming drips, disintegration of the specimen, etc.

9 DERIVED FIRE CHARACTERISTICS

Experimental results should be reported in terms of the thermal measurements of incident flux measured with a dummy specimen in place.

The results should not be adjusted to compensate for changes in the thermal output of the radiant panel during the conduct of the test. The following data should be derived from the test results.

9.1 Heat for ignition

As defined in 3.6.

9.2 Heat for sustained burning

A list of the values of this characteristic as defined in paragraph 3.8.

9.3 Average heat for sustained burning

An average of the values for the characteristic defined in 3.8 measured at different stations, the first at 150 mm and then at subsequent stations at 50 mm intervals through the final station or the 400 mm station, whichever value is the lower.

9.4 Critical flux at extinguishment

A list of the values of this characteristic for the specimens tested and the average of these values.

9.5 Heat release of the specimen

Both a heat release time curve and a listing of the peak and total integrated heat release should be secured from the experimental data. They should be corrected for the non-linearity of the heat release calibration curve.

The curve of the millivolt signal from the stack thermocouples should include at least 30 s of the initial 3 min steady state verification period as well as the starting transient just prior to and following specimen insertion. In converting millivolt signals to heat release rate, the zero release level of the calibration curve should be set at the level of the initial steady state just prior to test of the specimen involved. See figure 13.

9.5.1 Total heat release

The total heat release is given by integration of the positive part of the heat release rate during the test period (see figure 13).

9.5.2 Peak heat release rate

The peak heat release rate is the maximum of the heat release rate during the test period (see figure 13).

10 CLASSIFICATION

Materials giving average values for all of the surface flammability criteria not exceeding those listed in the following table, are considered to meet the requirement for low flame spread in compliance with regulations II-2/3.8, II-2/34 and II-2/49 of the International Convention for the Safety of Life at Sea, 1974, as amended.

SURFACE FLAMMABILITY CRITERIA

Bulkhead, wall and ceiling linings				Floor coverings			
CFE kW/m ²	Q _{sb} MJ/m ²	Q _t MJ	Q _p kW	CFE kW/m ²	Q _{sb} MJ/m ²	Q _t MJ	Q _p kW
≥20.0	≥1.5	≤0.7	≤4.0	≥7.0	≥0.25	≤1.5	≤10.0

Where CFE = Critical flux at extinguishment

Q_{sb} = Heat for sustained burning

Q_t = Total heat release

Q_p = Peak heat release rate

11 TEST REPORT

The test report should include both the original data, observations made on each specimen tested and the derived fire characteristics. The following information should be supplied:

- .1 Name and address of testing laboratory.
- .2 Name and address of sponsor.
- .3 Name and address of manufacturer/supplier.
- .4 Full description of the product tested including trade name, together with its construction, orientation, thickness, density and, where appropriate, the face subjected to test. In the case of specimens which have been painted or varnished, the information recorded should include the quantity and number of coats applied, as well as the nature of the supporting materials.
- .5 Data from the test including:
 - .5.1 number of specimens tested;
 - .5.2 type of pilot flame used;
 - .5.3 duration of each test;
 - .5.4 observations recorded in accordance with 8 above;
 - .5.5 other relevant observations from the test, such as flashing, unstable flame front, whether or not pieces of burning materials fall off, separations, fissures, sparks, fusion, changes in form;
 - .5.6 derived fire characteristics as described in 9 above;
 - .5.7 classification of the material.

.6 A limiting use statement.

Note: The test results relate only to the behaviour of the test specimens of a product under the particular conditions of the test; they are not intended to be the sole criterion for assessing the potential fire hazard of the product in use.

APPENDIX

This appendix provides technical information intended to permit construction, erection, alignment and calibration of the physical equipment required for the conduct of tests by this procedure.

1 TEST EQUIPMENT FABRICATION

Figures 1 to 5 show photographs of the equipment as assembled ready for test. Detailed drawings and a parts list are available from the IMO Secretariat. These provide engineering information necessary for the fabrication of the main frame, specimen holders, stack and other necessary parts of the equipment.

1.1 Brief parts list for the test equipment assembly includes:

- .1 The main frame (figure 1) which comprises two separate sections, the burner frame and the specimen support frame. These two units are bolted together with threaded rods permitting flexibility in mechanical alignment.
- .2 Specimen holders which provide for support of the specimens during test. At least two of these are required. Three prevent delays resulting from required cooling of holders prior to mounting specimens.
- .3 A specimen fume stack fabricated of stainless steel sheet of 0.5 ± 0.05 mm thickness complete with gas and stack metal compensating thermocouples.
- .4 The radiant panel which has radiating surface dimensions of 280 mm x 483 mm. It has been specially fabricated for use with this equipment through use of commercially available porous refractory tiles.

- .5 The blower for combustion air supply, radiant panel, air flow metering device, gas control valves, pressure reducer and safety controls which are all mounted on the burner frame (figure 3). Requirements are summarized below:
- .5.1 Air supply of about $30 \text{ m}^3/\text{h}$ at a pressure sufficient to overcome the friction losses through the line, metering device and radiant panel. The radiant panel drop amounts to only a few millimetres of water.
- .5.2 The gas used may be either natural gas or methane. The use of gas other than methane or natural gas is not recommended*, although with changes in panel-specimen spacing, it is possible to use the equipment with propane at flux levels of 50 kW/m^2 . A pressure regulator should be provided to maintain a constant supply pressure. Gas is controlled by a manually adjusted needle valve. No venturi mixer is necessary. Safety devices include an electrically operated shutoff valve to prevent gas flow in the event of electric power failure, air pressure failure and loss of heat at the burner surface. The gas flow requirements are roughly $1.0 \text{ m}^3/\text{h}$ to $3.7 \text{ m}^3/\text{h}$ for natural gas or methane at a pressure to overcome line pressure losses.
- .6 The specimen holder, pilot flame holder, fume stack, flame front viewing rakes, radiation pyrometer and mirror are all assembled on the specimen support frame. The arrangement of parts on this frame is shown in figures 1 and 2.
- .7 A dummy specimen approximately 20 mm thick, made of non-combustible refractory board of $800 \pm 100 \text{ kg/m}^3$ density should be continuously mounted on the apparatus in the position of the specimen during operation of the equipment. This dummy specimen should only be removed when a test specimen is to be inserted.

* Flashback limits the maximum operating level with propane.

2 INSTRUMENTATION

2.1 Total radiation pyrometer

This should have a sensitivity substantially constant between the thermal wave lengths of $1\text{ }\mu\text{m}$ and $9\text{ }\mu\text{m}$ and should view a centrally-located area on the panel of about $150\text{ mm} \times 300\text{ mm}$. The instrument should be mounted on the specimen support frame in such a manner that it can view the panel surface.

2.2 Heat fluxmeters

It is desirable to have at least two fluxmeters for this test method. They should be of the thermopile type with a nominal range of 0 kW/m^2 to 50 kW/m^2 and capable of safe operation at three times this rating. One of these should be retained as a laboratory reference standard. They should have been calibrated to an accuracy of within $\pm 5\%$. The target sensing the applied flux should occupy an area not more than 80 mm^2 and be located flush with and at the centre of the water-cooled 25 mm circular exposed metallic end of the fluxmeter. If fluxmeters of smaller diameter are to be used, these should be inserted into a copper sleeve of 25 mm outside diameter in such a way that good thermal contact is maintained between the sleeve and water-cooled fluxmeter body. The end of the sleeve and the exposed surface of the fluxmeter should lie in the same plane. Radiation should not pass through any window before reaching the target.

2.3 Timing devices

Both a chronograph and either an electric clock with a sweep second hand or a digital clock should be provided to measure time of ignition and flame advance. The chronograph for timing ignition and initial flame advance may comprise a strip chart recorder with paper speed of at least 5 mm/s and an event marker pen. Both the chronograph paper drive and the electric clock should be operated through a common switch to initiate simultaneous operation when the specimen is exposed. This may be either hand operated or actuated automatically as a result of complete specimen insertion.

2.4 Recording millivoltmeter

A two-channel strip chart recording millivoltmeter having at least one megohm input resistance should be used to record signals from the fume stack thermocouples and the output from the radiation pyrometer. The signal from the fume stack will in most instances be less than 15 mV but in some cases this may be exceeded by a small amount. The sensitivity of the other channel should be selected to require less than full scale deflection with the total radiation pyrometer or fluxmeter chosen. The effective operating temperature of the radiant panel should not normally exceed 935°C.

2.5 Digital voltmeter

A small digital millivoltmeter will be found convenient for monitoring changes in operating conditions of the radiant panel. It should be capable of indicating signal changes of 10 μ V or less.

3 SPACE FOR CONDUCTING TESTS

3.1 Special room

A special room should be provided for performance of this test. The dimensions of it are not critical but it may be roughly 45 m³ volume with a ceiling height of not less than 2.5 m.

3.2 Fume exhaust system

An exhaust system should be installed above the ceiling with a capacity for moving air and combustion products at a rate of 30 m³/min. The ceiling grill opening to this exhaust system should be surrounded by a 1.3 m x 1.3 m refractory fibre fabric skirt hanging from the ceiling down to 1.7 \pm 0.1 m from the floor of the room. The specimen support frame and radiant panel should be located beneath this hood in such a way that all combustion fumes are withdrawn from the room.

3.3 The apparatus

This should be located with a clearance of at least one metre separation between it and the walls of the test room. No combustible finish material of ceiling, floor or walls should be located within 2 m of the radiant heat source.

3.4 Air supply

Access to an exterior supply of air, to replace that removed by the exhaust system, is required. This should be arranged in such a way that the ambient temperature remains reasonably stable (for example: the air might be taken from an adjoining heated building).

3.5 Room draughts

Measurements should be made of air speeds near a dummy specimen while the fume exhaust system is operating but the radiant panel and its air supply are turned off. At a distance of 100 mm the air flow perpendicular to the lower edge at midlength of the specimen should not exceed 0.2 m/s in any direction.

4 ASSEMBLY AND ADJUSTMENT

4.1 General

The test conditions are essentially defined in terms of the measured heat flux incident on a dummy specimen during calibration. Radiation transfer will predominate, but convection transfer will also play a part. The flux level incident at the specimen surface is a result of the geometrical configuration between the radiant panel and the specimen, as well as the thermal output from the radiant panel.

4.1.1 Both in original adjustment of test operating conditions and periodic verification of this adjustment, the measured heat flux at the surface of the specimen is the controlling criterion. This heat flux is measured by a fluxmeter (see 2.2) mounted in a special dummy specimen (figure 14).

4.1.2 Between consecutive tests, the operating level should be monitored either by use of a fluxmeter mounted in a dummy specimen as defined in paragraph 3.3 of the Recommendation under "Definitions" or preferably by use of a radiation pyrometer which has been previously periodically calibrated on the basis of the readings of such a fluxmeter. This radiation pyrometer should be rigidly fixed to the specimen-holder frame in such a manner that it continuously views the radiating panel surface (see 2.1).

4.2 Mechanical alignment

Most of the adjustments of the components of the test apparatus may be conducted in the cold condition. The position of the refractory surface of the radiant panel with respect to the specimen must correspond with the dimensions shown in figure 6. These relationships can be achieved by appropriate use of shims between the panel and its mounting bracket, adjustment or separation between the two main frames, and adjustment of the position of the specimen holder guides. Detailed procedures for making these adjustments are suggested in paragraph 5.

4.2.1 The fume stack for heat release measurements should be mechanically mounted on the specimen support frame in the position shown in figure 7. The method of mounting should ensure the relative positions shown but should allow easy stack removal for cleaning and/or repair. The compensating thermocouple should be mounted in such a manner that good thermal contact is achieved while ensuring greater than one megohm electrical resistance from the stack metal wall.

4.3 Thermal adjustment of panel operating level

Thermal adjustment of the panel operating level is achieved by first setting an air flow of about $30 \text{ m}^3/\text{h}$ through the panel. Gas is then supplied and the panel ignited and allowed to come to thermal equilibrium with a dummy specimen mounted before it. At proper operating condition, there should be no visible flaming from the panel surface except when viewed from one side parallel to the surface plane. From this direction, a thin blue flame very close to the panel surface will be observed. An oblique view of the panel after a 15 min warm-up period should show a bright orange radiating surface.

4.3.1 With a water-cooled* fluxmeter mounted in a special dummy specimen, the flux incident on the specimen should correspond to the values shown in table 1. Compliance with this requirement is achieved by adjustment of the gas flow. If necessary, small changes in air flow can be made to achieve the condition of no significant flaming from the panel surface. Precise duplication of the flux measurements specified in table 1 for the 50 mm and 350 mm positions on the basis of the fluxmeter calibration used will fix the flux at the other stations well within the limits called for. This does not mean that all other flux levels are correct, but it does ensure that a fixed configuration or view geometry between the panel and specimen has been achieved. To meet these requirements, it may be necessary to make small changes in the specimen longitudinal position shown in figure 6. A plot and smooth curve should be developed on the basis of the eight flux measurements required. The shape of the curve should be similar to that defined by the typical data shown in table 1. These measurements are important, since the experimental results are reported on the basis of these flux measurements. If a total radiation pyrometer is to be used to monitor panel operation, records of its signal should be kept following successful completion of this calibration procedure. If a change in panel-specimen axial position is necessary to meet the requirements for flux at the 50 mm and 350 mm positions, this should be accomplished by adjusting the screws connecting the two frames. In this way, the pilot position with respect to the specimen will remain unchanged. The specimen stop screw adjustment may be changed to meet the flux requirements in the standard and then the position of the pilot burner mount may require adjustment to maintain the 10 ± 2 mm pilot spacing.

* Water cooling of the fluxmeter is required to avoid erroneous signals at low flux levels. The temperature of the cooling water should be controlled in such a manner that the fluxmeter body temperature remains within a few degrees of room temperature. If this is not done, correction of the flux measurement should be made for temperature difference between the fluxmeter body and room temperature. Failure to supply water-cooling may result in thermal damage to the thermal sensing surface and loss of calibration of the fluxmeter. In some cases repairs and recalibration are possible.

4.3.2 Once these operating conditions have been achieved, all future panel operation should take place with the established air flow with gas supply as the variable to achieve the specimen flux level as calibrated. This level should be monitored with use of either a radiation pyrometer fixed to view an area of the source surface or a fluxmeter mounted in a dummy specimen, as defined in paragraph 3.3 under "Definitions", at the 350 mm position. If the latter method is used, the assembly of dummy specimen and fluxmeter should remain in place between tests.

4.4 Adjustments and calibrations - general

The following adjustments and calibrations are to be achieved by burning methane gas from the line heat source located parallel to, and in the same plane as, the centreline of a dummy specimen located in position and without fluxmeters. This line burner comprises a 2 m length of pipe of 9.1 mm internal diameter. One end is closed off with a cap and a line of 15 holes of 3 mm diameter are drilled at 16 mm spacing through the pipe wall. The gas burned as it flows through this line of vertically positioned holes flames up through the stack. The measured flow rate and the net or lower heat of combustion of the gas serve to produce a known heat release rate which can be observed as a compensated stack millivolt signal change. Prior to performing calibration tests, measurements must be conducted to verify that the stack thermocouple compensation has been properly adjusted.

4.5 Compensation adjustment

The fraction of the signal from the compensator thermocouple which is subtracted from the stack thermocouple output should be adjusted by means of the resistance of one leg of the potential divider shown in figure 10. The purpose of this adjustment is as far as practical, to eliminate from the stack signal the long-term signal changes resulting from the relatively slow stack metal temperature variations. Figure 11 shows the curves resulting from under-compensation, correct compensation, and over-compensation. These curves were obtained by abruptly placing the lighted gas calibration burner adjacent to the hot end of a dummy specimen and then extinguishing it. For this adjustment, the calibration gas feed rate should be set to correspond to a heat rate of one kW. The compensator potential divider should be adjusted to yield curves that show a rapid rise to a steady state signal which is essentially constant over a 5 min period following the first minute of

transient signal rise. When the calibration burner is shut off, the signal should rapidly decrease and reach a steady state value within two minutes. Following this, there should be no long-term rise or fall of the signal. Experience has shown that between 40% and 50% of the compensation thermocouple signal should be included in the output signal to achieve this condition. When properly adjusted, a square thermal pulse of 7 kW should show not more than approximately 7% overshoot shortly after application of the calibration flame (see figure 11).

4.6 Fume stack calibration

With the adjustment described in 4.5 completed and a steady state base signal having been achieved, stack calibration should be carried out with the radiant panel operating at 50.5 kW/m^2 and the pilot burner not lit. The calibration of the stack millivolt signal rise should be made by introducing and removing the line burner, as described in 4.4. The flow rate of methane gas of at least 95% purity should be varied over the range of about $0.004 \text{ m}^3/\text{min}$ to $0.02 \text{ m}^3/\text{min}$ in sufficient increments to permit plotting the data in a well defined curve of stack compensated millivolt signal rise against the net or lower heat input rate. A similar calibration should be performed with the calibration burner located at the cool end of the specimen. The two curves should show agreement in indicated heat release rate within about 15%. A typical curve is shown in figure 12. The curve for the calibration burner at the hot end of the specimen should be the one used for reporting all heat release measurements. This completes the calibration and the test equipment is ready for use.

5 ASSEMBLY AND MECHANICAL ADJUSTMENT OF THE FLAMMABILITY TEST APPARATUS

The following instructions assume that parts of the flammability test apparatus have been made according to the drawings. The radiant panel subassembly has been completed with the exception of the support brackets and reverberatory screen. The equipment can be assembled to permit test of specimens of thickness up to 50 mm or 75 mm. Unless there is a real need for test of thicker specimens, assembly for 50 mm specimens is preferable.

5.1 The panel frame should be placed upright on a level floor, preferably in the location in which the equipment will be used.

5.2 The rotating ring should be mounted on its three guide bearings.

5.3 The panel mount frame should be bolted together, and to the ring, by four bolts.

5.4 A check should be made that the ring lies in a vertical plane. If the error is large, an adjustment of the upper ring support-bearing location may be necessary. Prior to making such an adjustment, it should be determined whether the error is due to excessive clearance between the ring and bearing rollers. If this is the case, rollers of larger diameter may correct the problem.

5.5 The four panel support brackets should be fastened to the radiant panel at four corners. Do not use too much force in bolting these brackets in place. Prior to mounting these brackets, one 35 mm M9 cap screw is placed in the hold that will be farthest from the panel end. These screws provide a means for mounting the panel.

5.6 Four washers should be placed on each of the panel mounting screws and the panel assembled on the mount bracket.

5.7 The angularity of the radiant panel surface with the plane of the mounting ring should be checked. This can be accomplished by means of a carpenter's square and measurements to the refractory tile surface at both ends of the panel. Any deviation from the required 15° angle may be adjusted by increasing or reducing the number of washers on the mounting screws.

5.8 The radiant panel should be rotated to face a specimen mounted in a vertical plane.

5.9 The panel surface should be checked with a level to ensure that it also lies in a vertical plane.

5.10 The specimen frame with specimen support rails on side and bottom positions and pilot burner holders assembled in approximate positions should be brought up to the burner frame and the two frames fastened together with two bolts and six nuts or two threaded rods and eight nuts. The spacing between the frames is roughly 100 mm.

5.11 The spacing of the two sides of the frames is adjusted to ensure that the specimen support frame longitudinal members are at a 15° angle to the radiant panel surface.

5.12 The single specimen holder side guide rail for vertical specimen orientation should be adjusted so that it is at the required 15° angle to the radiant panel surface.

5.13 An empty specimen holder should be slid into position on the rail and the position of the upper guide fork adjusted to ensure that when a specimen is inserted in the holder its surface will lie in a vertical plane.

5.14 The stop screw determining the axial position of the specimen holder should be adjusted to ensure that the axis of the pilot burner is 10 ± 2 mm from the closest exposed edge of the specimen. This adjustment should again be made by use of an empty specimen holder and substitution of a 6 mm steel rod of 250 mm length for the pilot burner ceramic tube. When viewed from the back of the specimen holder, the spacing between rod axis and the edge of the specimen retaining flange of the holder should be 10 ± 2 mm.

5.15 With the specimen holder still in place against the top screw, the spacing between the panel and specimen support frames should be adjusted to make dimension B, figure 6, equal to about 125 mm. This adjustment is made by means of the two screws fastening the frames together. In making this adjustment, it is important to make equal adjustments on each side to maintain the angular relationship called for in adjustments 5.11 and 5.12.

5.16 The nuts supporting the specimen holder side guide rail should be adjusted to ensure that dimension A, figure 6, is 125 ± 2 mm. Again, equal adjustments to the two mounting points are required. When doing this, a check should be made to ensure that the guide rail and edge of the specimen holder are in a horizontal plane. In making this adjustment, it is important to ensure that the 45 mm stack position dimension shown in figure 7 is maintained. Another way of adjustment to dimension A is through changes in the number of washers mentioned in 5.6.

5.17 If necessary, procedure 5.13 should be repeated.

5.18 The reverberatory screen should be mounted on the radiant panel. This must be done in such a manner that it is free to expand as it heats up during operation.

5.19 The viewing rake with 50 mm pins is mounted on an angle fastened to the specimen holder guide rail. Its position is adjusted so that pins are located at multiples of 50 mm distance from the closest end of the specimen exposed to the panel. It should be clamped in this position.

TABLE 1
CALIBRATION OF FLUX TO THE SPECIMEN

Typical flux incident on the specimen and specimen positions at which the calibration measurements are to be made. The flux at the 50 mm and 350 mm positions should be matched. Calibration data at other positions should agree with typical values within 10%.

Distance from exposed end of the specimen	Typical flux levels at the specimen	Calibration position to be used
0 mm	49.5 kW/m ²	
50	50.5	50.5 kW/m ²
100	49.5	
150	47.1	X
200	43.1	
250	37.8	X
300	30.9	
350	23.9	23.9
400	18.2	
450	13.2	X
500	9.2	
550	6.2	X
600	4.3	
650	3.1	X
700	2.2	
750	1.5	X

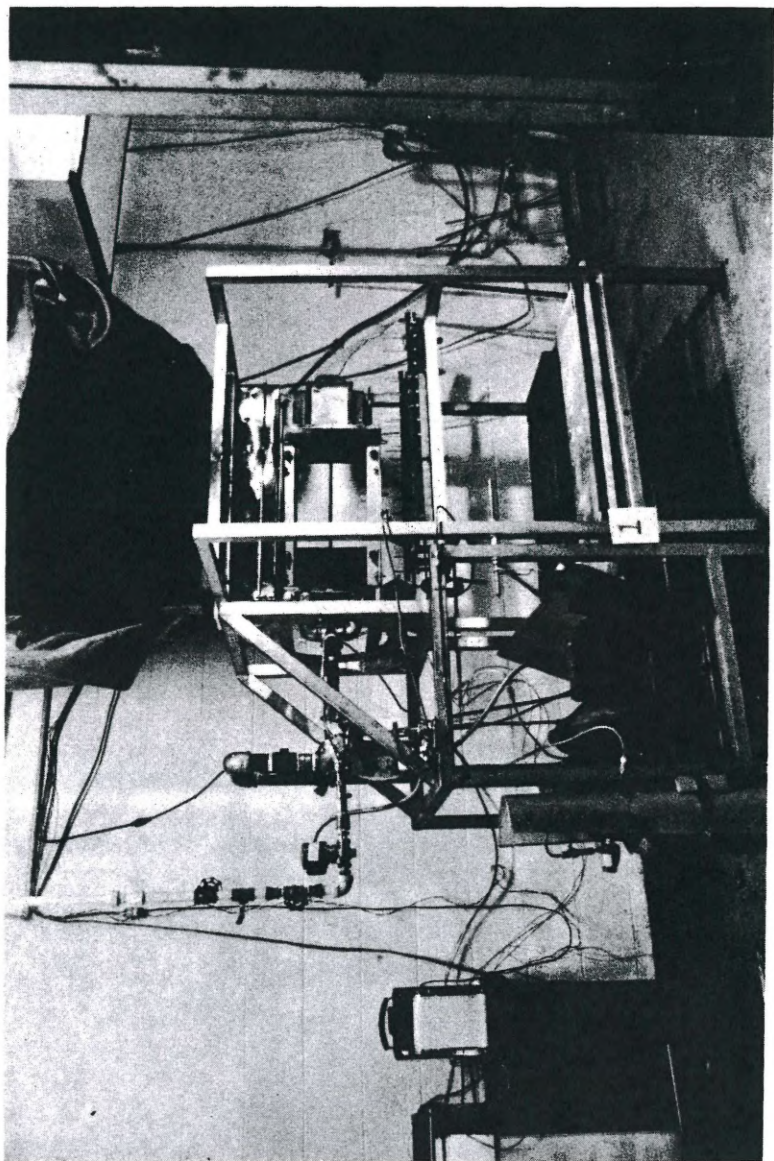


Figure 1 — General view of the apparatus

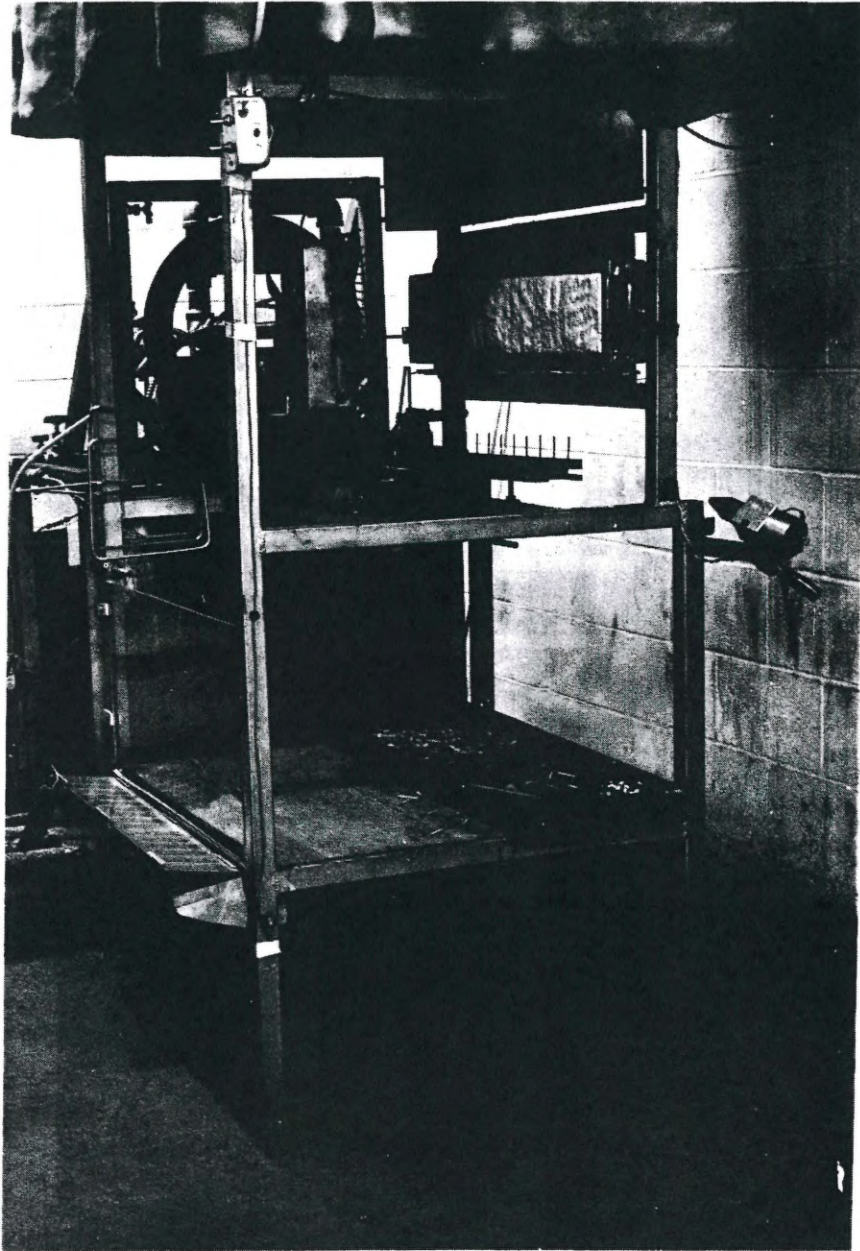


Figure 2 — *View from specimen end*

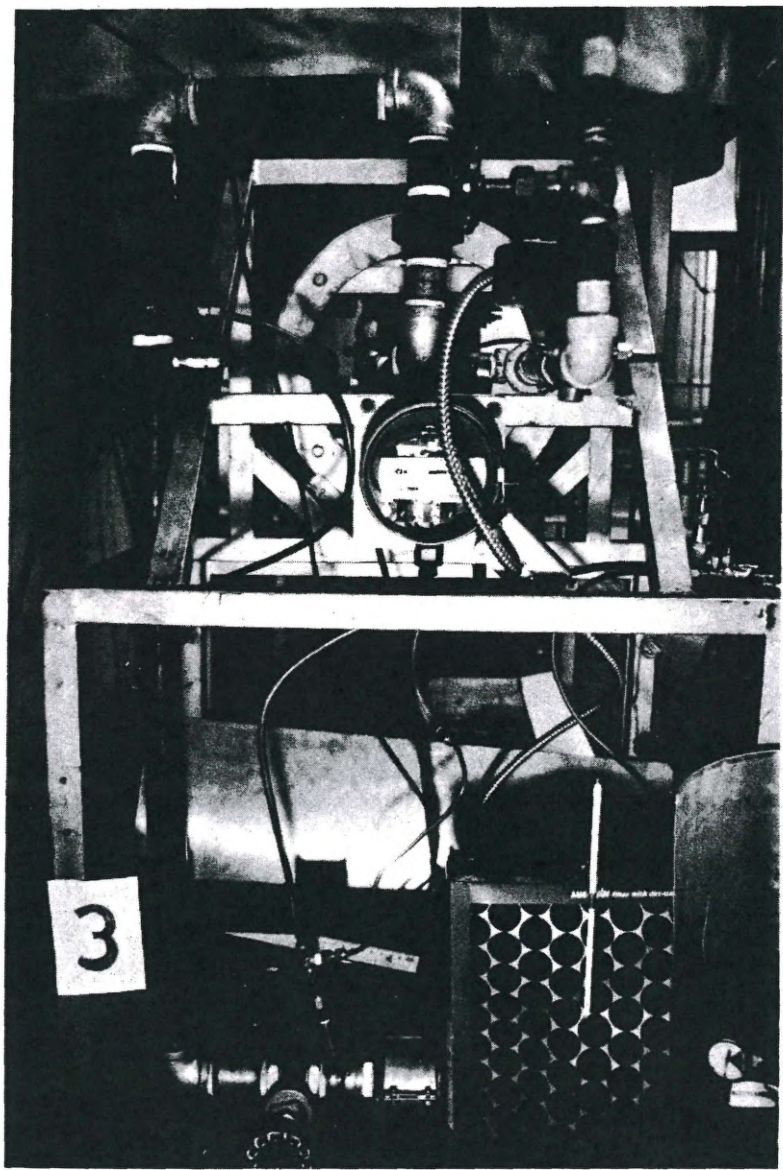


Figure 3 — *View from radiant panel end*

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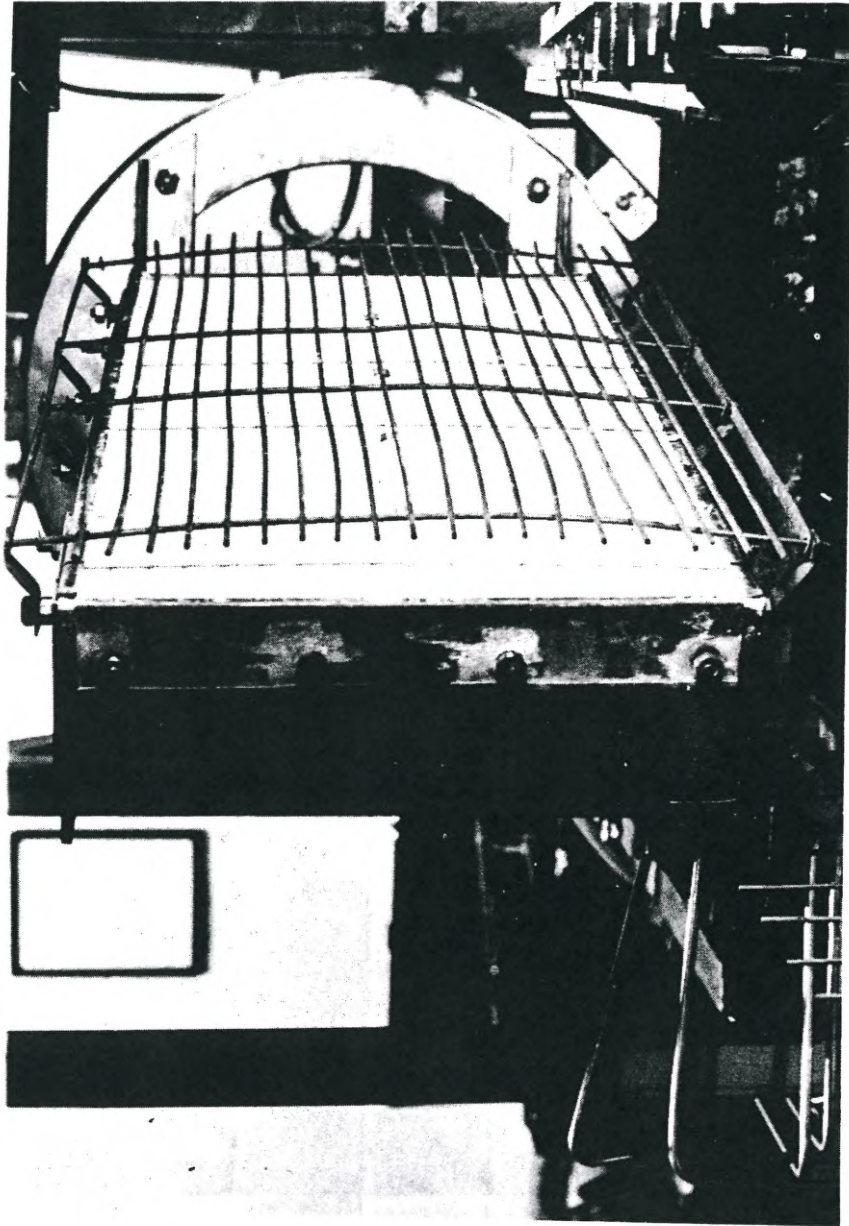


Figure 4 — *Radiant panel with reverberatory wires viewed through specimen mount frame*

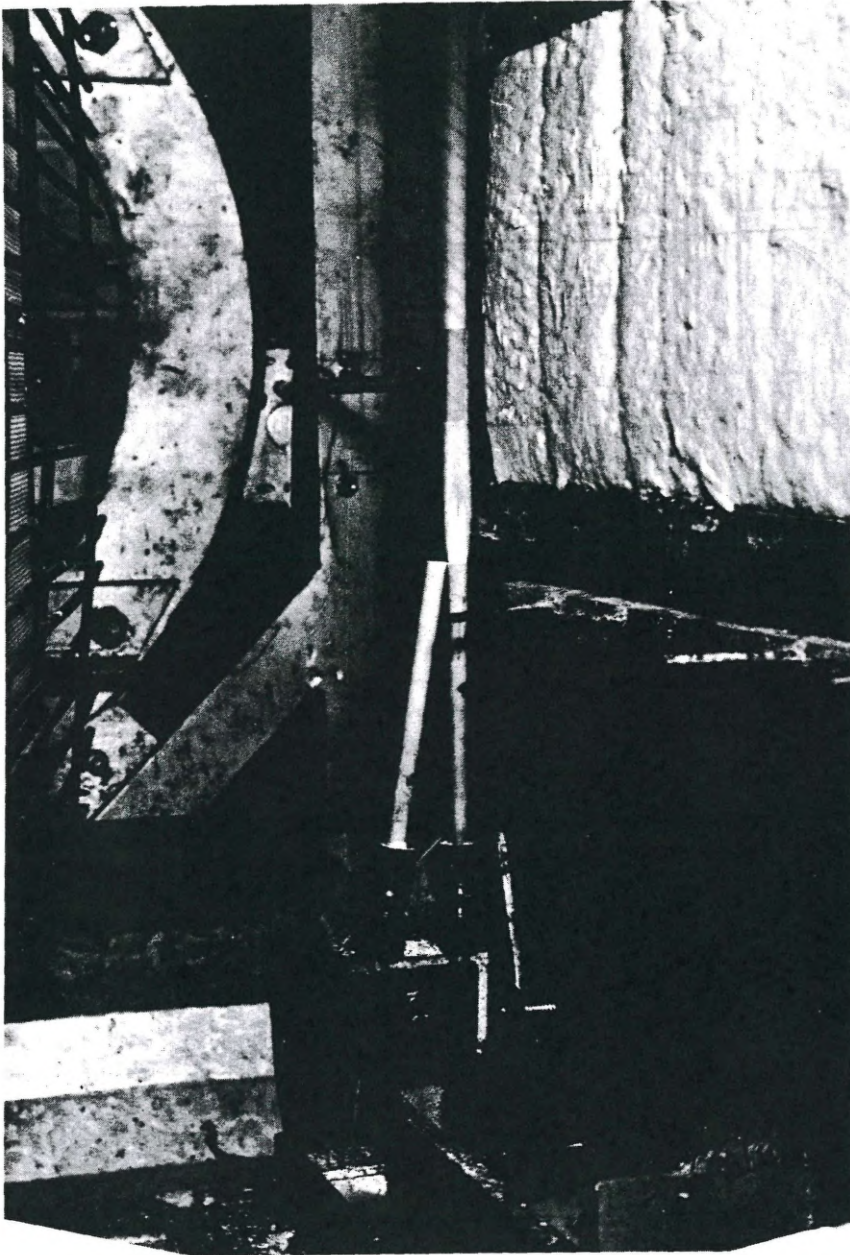


Figure 5 — *Pilot burner and mount*

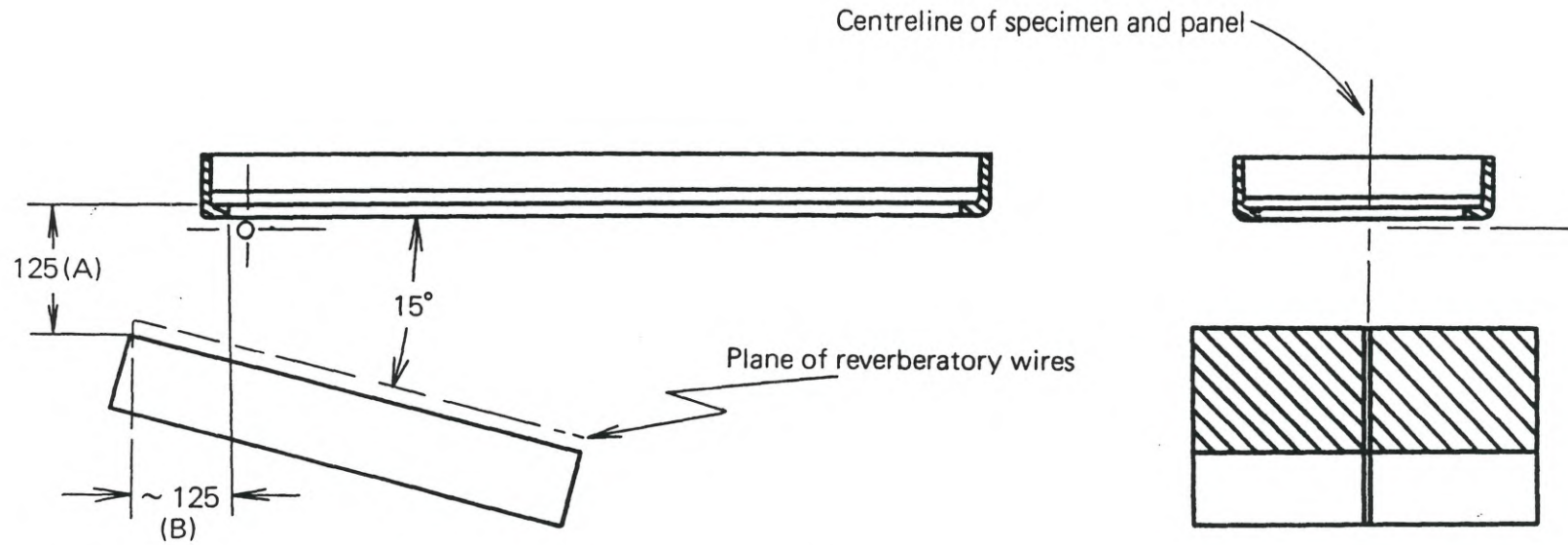


Figure 6 — Specimen — panel arrangement

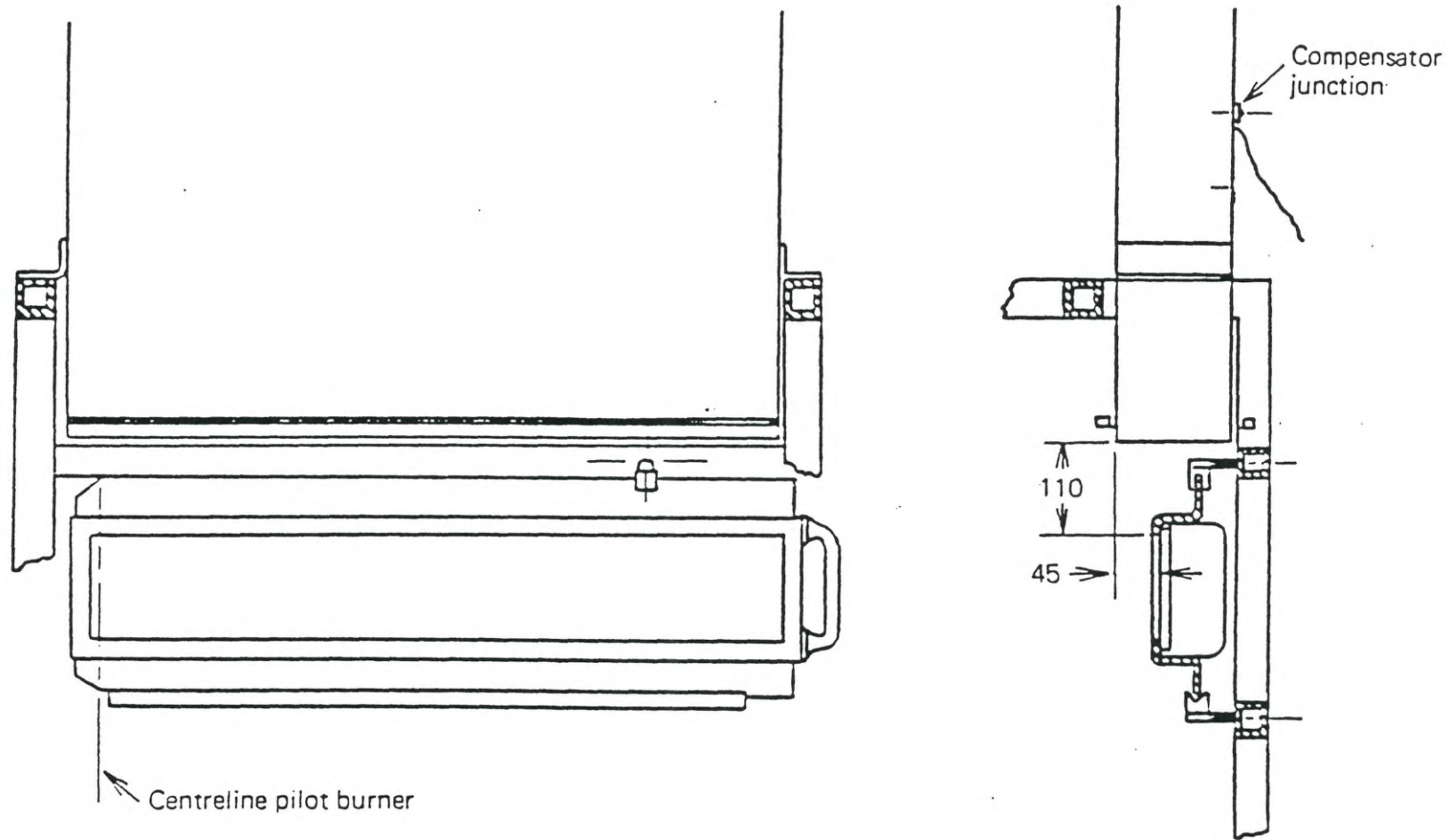


Figure 7 — Stack — specimen position dimensions

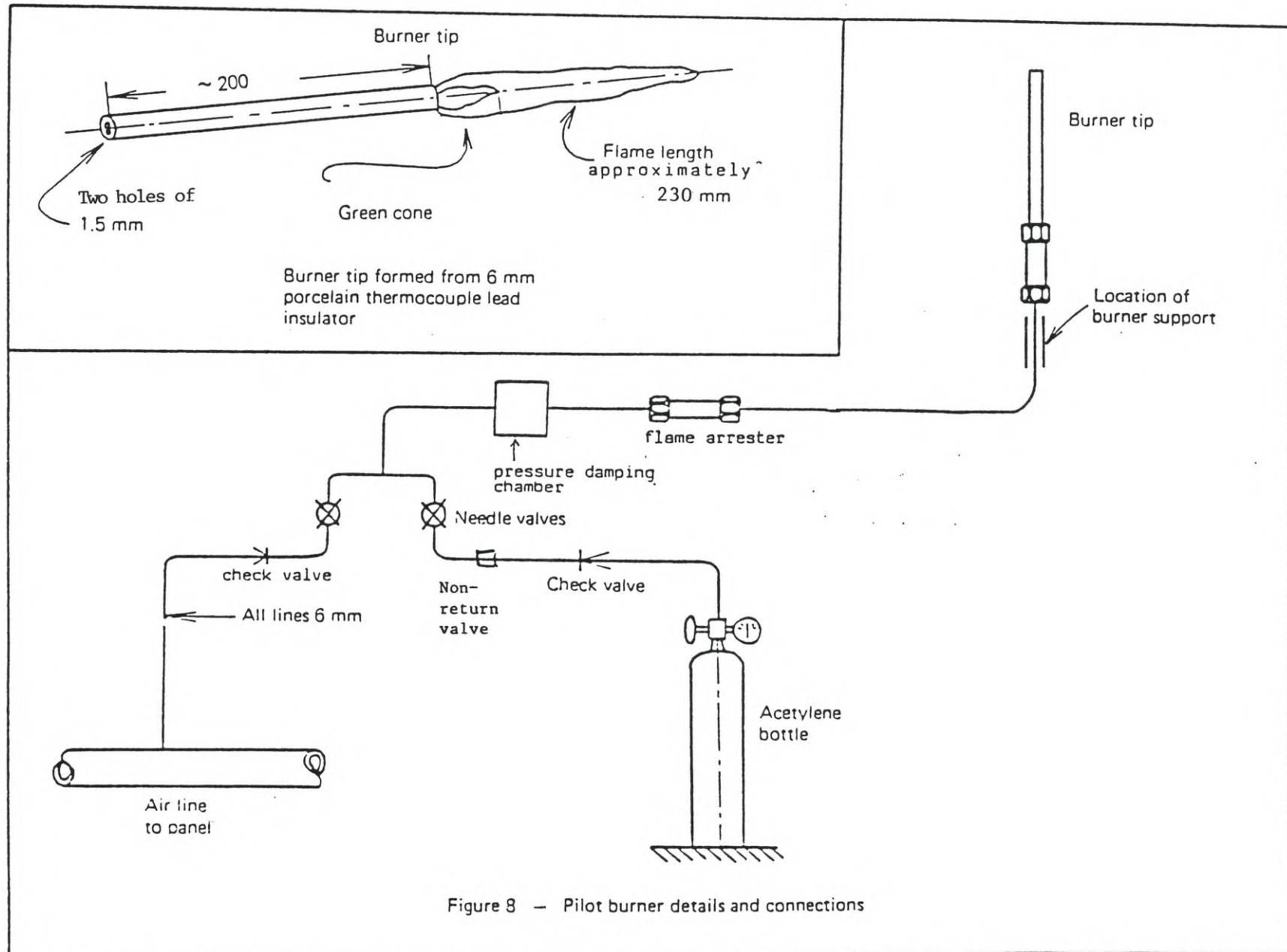


Figure 8 — Pilot burner details and connections

Figure 9 — Position of pilot flame

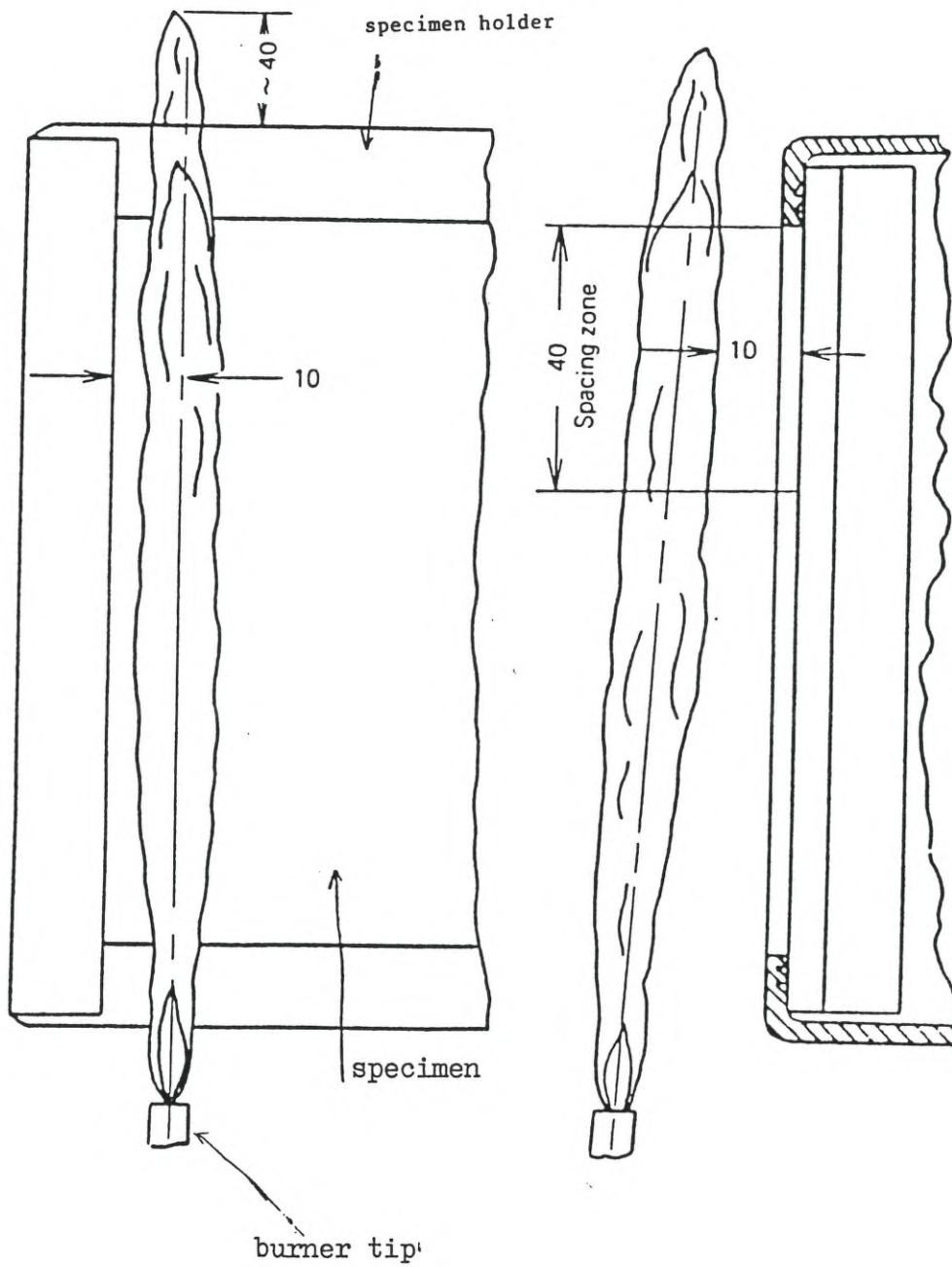


Figure 10 — Diagrammatic sketch of thermocouple circuit

Two sets of thermocouples and lead wires are required. The wire size and lengths within the fume T.C. group must be the same to ensure proper signal averaging. The parallel connection of the couples may be achieved at the mixing box by plug connection of the leads. This allows quick removal and checks for continuity and grounding problems with minimum delay. No cold junction should be used but the signal mixing box shall be shielded from panel radiation.

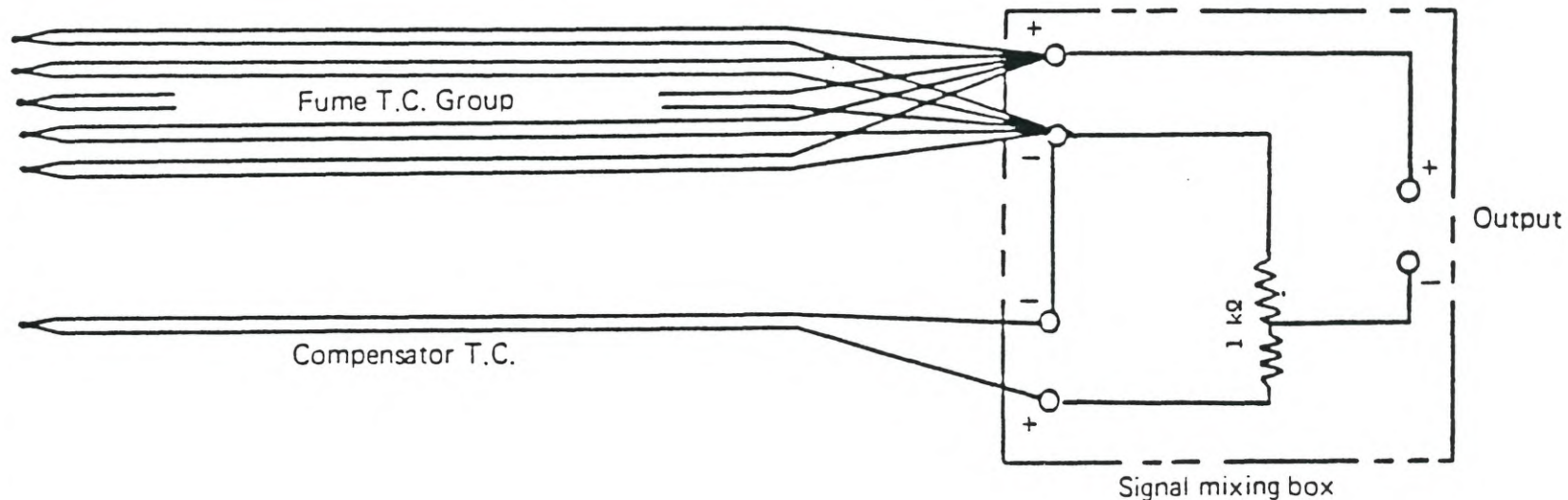
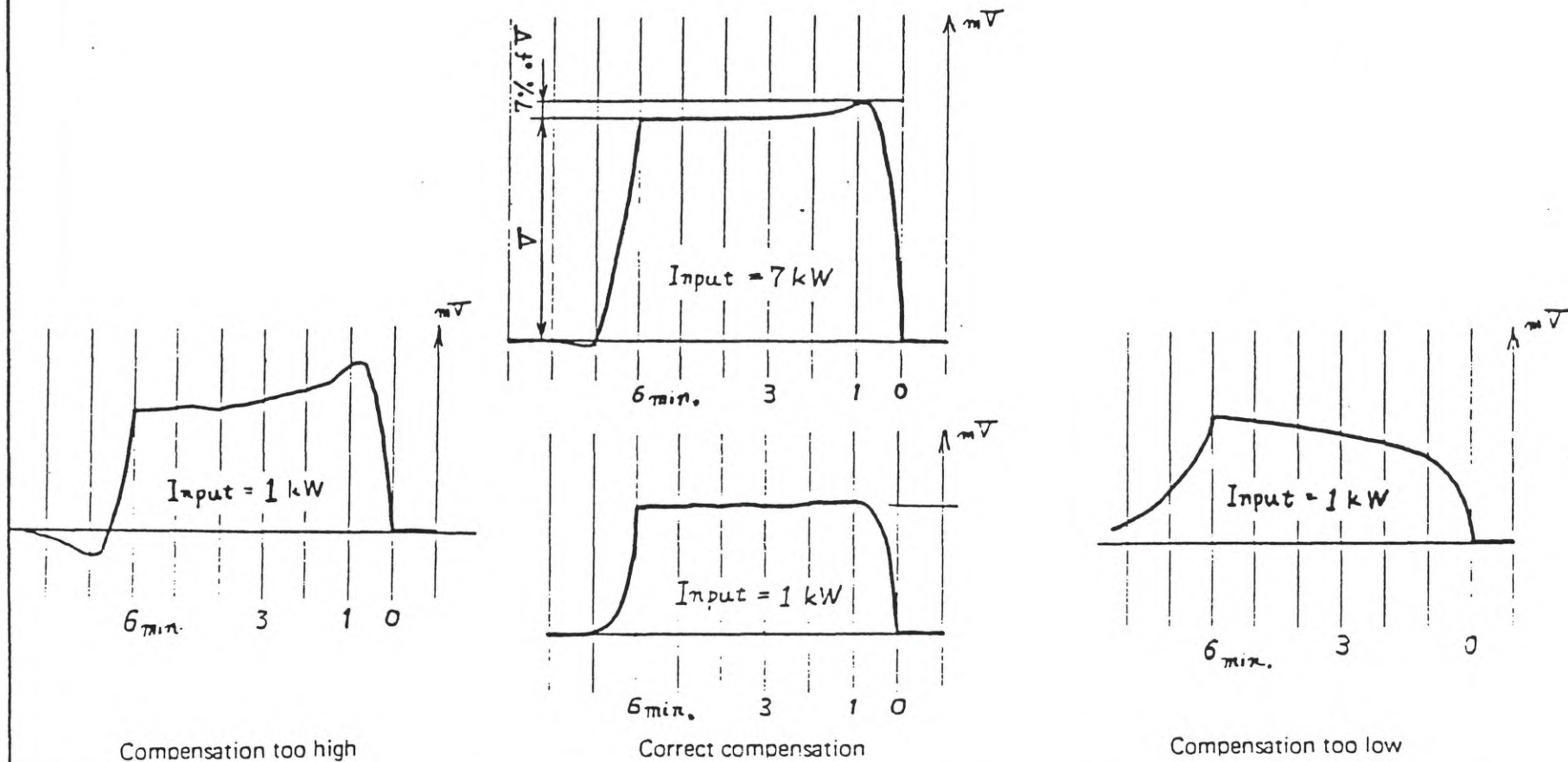


Figure 11 — Response-behaviour of heat release signal to a square wave thermal pulse

The four curves shown illustrate changes in the indicated \overline{mV} signal rise for three different levels of inverse feedback or compensation level.



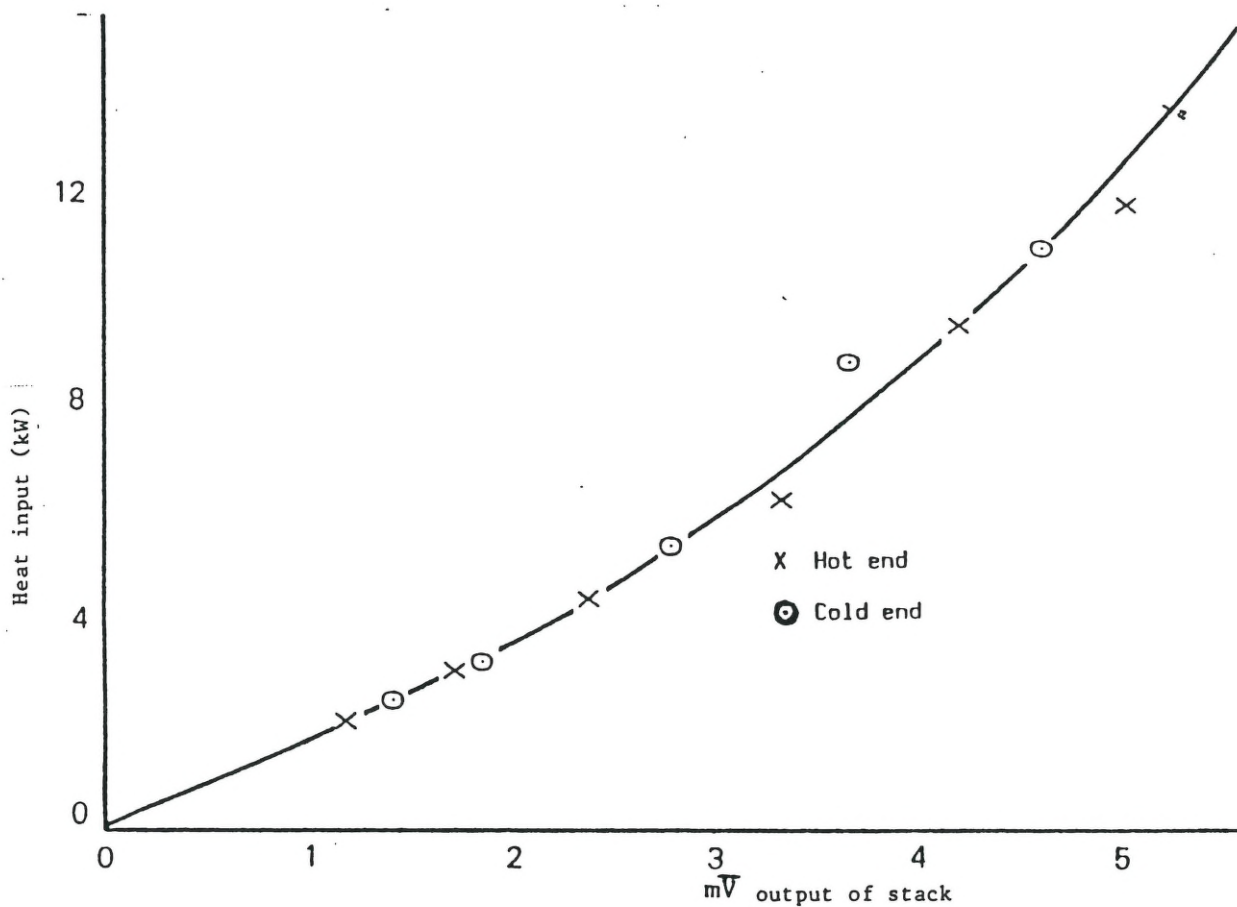


Figure 12 — Typical stack calibration

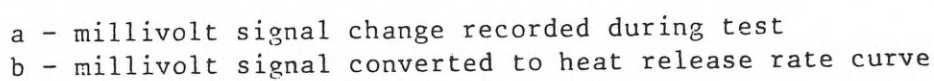
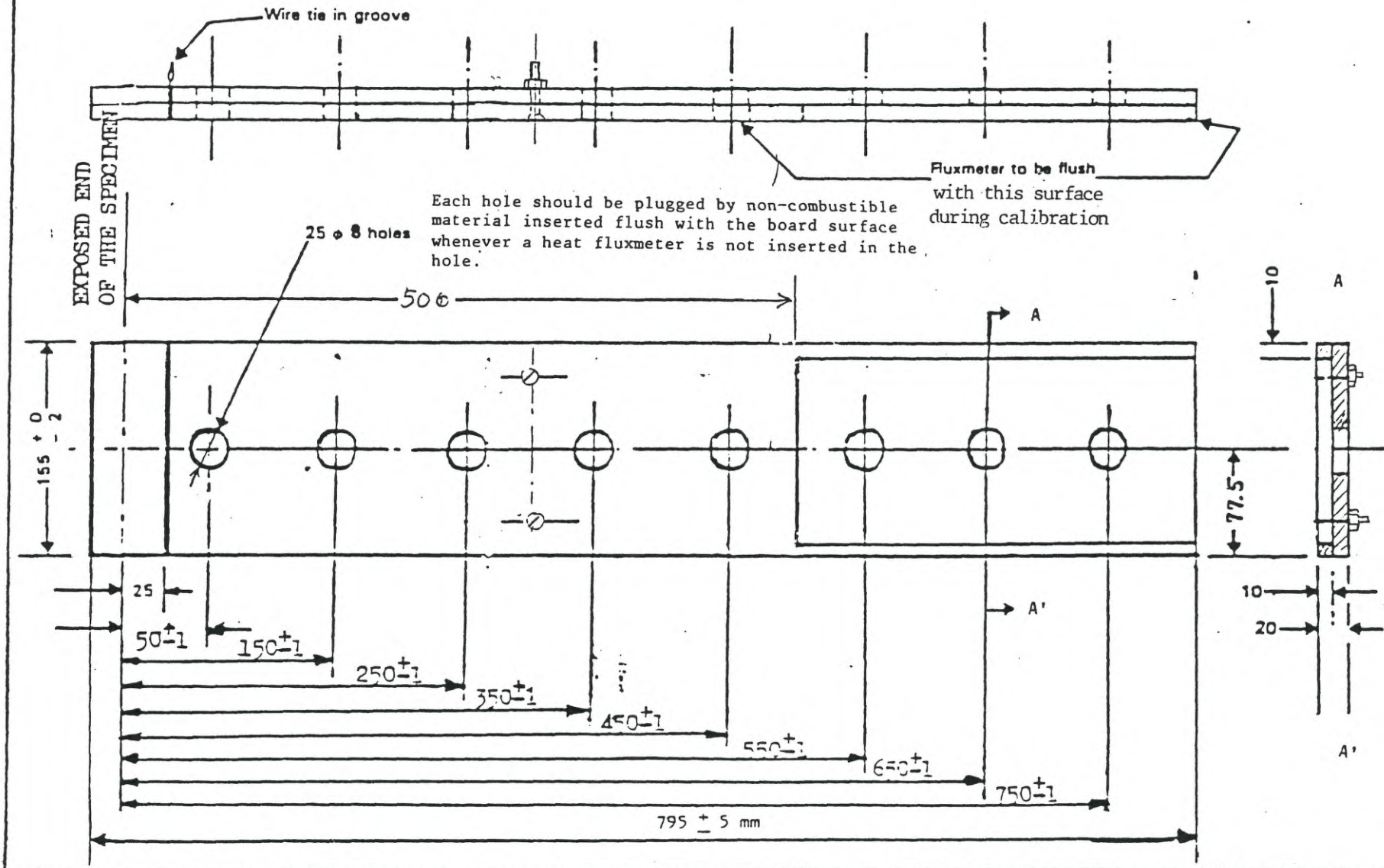


Figure 14 — Special calibration dummy specimen for flux gradient calibration



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