NATO INTERNATIONAL STAFF - DEFENCE INVESTMENT DIVISION

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ASSESSMENT
PUBLICATION

AFAP-5
(Edition 3)

NATO REACTION-TO-FIRE TESTS FOR MATERIALS

HEAT RELEASE RATE

AFAP - 5
(Edition 3)

JULY 2010

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AFAP-5

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NORTH ATLANTIC TREATY ORGANIZATION

NATO STANDARDISATION AGENCY (NSA)

NATO LETTER OF PROMULGATION

30 July 2010

1. AFAP-5(Edition 3) – NATO REACTION-TO-FIRE TESTS FOR MATERIALS – HEAT RELEASE RATE is a non classified NATO publication. The agreement of interested nations to use this publication is recorded in STANAG 4602.

2. AFAP-5(Edition 3) is effective on receipt. It supersedes AFAP-5(Edition 2) which shall be destroyed in accordance with the local procedure for the destruction of documents.

3. It is permissible to distribute copies of this publication to Contractors and Suppliers and such distribution is encouraged.

Cihangir AKSIT, TUR Civ
Director, NATO Standardization Agency

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Record of Changes

Change Date	Date Entered	Effective Date	By Whom Entered

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Preface

1. This Allied Publication forms part of a series as follows:

   AFAP-1 NATO reaction-to-fire tests for materials - POLICY FOR THE PRE-SELECTION OF MATERIALS FOR MILITARY APPLICATIONS.

   AFAP-2 NATO reaction-to-fire tests for materials - SMOKE GENERATION

   AFAP-3 NATO reaction-to-fire tests for materials - TOXICITY OF FIRE EFFLUENTS

   AFAP-4 NATO reaction-to-fire tests for materials - SURFACE SPREAD OF FLAME

   AFAP-5 NATO reaction-to-fire tests for materials - HEAT RELEASE RATE

2. The contribution to fire hazard from a particular material, depends on a number of interrelated factors. It is not only influenced by the reaction-to-fire properties of the material, but also by the way in which the material is used in practice and by the fire scenario to which it is exposed. These Allied Publications define methods for the assessment of reaction-to-fire properties of materials, valid under the specific conditions of each test. They provide comparisons between candidate materials, but do not predict the behaviour of the materials, or combinations of materials, in actual fire conditions. Together, they are intended to be used as part of the comparative screening process for the pre-selection of materials on the basis of their fire characteristics.

3. Any enquiries regarding this Allied Publication in relation to an invitation to tender or a contract in which it is incorporated are to be addressed to the Technical Authority.

NATO REACTION-TO-FIRE TESTS FOR MATERIALS

HEAT RELEASE RATE

Warning

This Allied Publication may call for the use of substances and/or procedures that may be injurious to health or damaging to the environment if adequate precautions are not taken. Test operators shall be responsible for implementation of such precautions, in order to ensure the safe operation of the test. The text of this Allied Publication refers only to technical requirements and in no way absolves the user from statutory or other legal obligations relating to health and safety or environment legislation. Full account shall be taken of further health and safety advice/warnings that appear in the normative references and equipment manuals. Where attention is drawn to particular hazards, those quoted may not be exhaustive.

1 SCOPE

This Allied Publication defines a method for measurement of heat release rate from a material, using a cone calorimeter. The procedure is an implementation of ISO 5660-1. This is supplemented to include detailed requirements for specimen preparation for particular types of material, additional details for test and calibration procedures to enhance repeatability/reproducibility and requirements for data presentation.

2 NORMATIVE REFERENCES

2.1. The following documents are referred to in this Allied Publication:

BS 5852 Methods of test for assessment of the ignitability of upholstered seating by smouldering and flaming ignition sources. 2006;

ISO 291 Plastics - Standard atmospheres for conditioning and testing: 2008;

ISO 1514 Paints and varnishes - Standard panels for testing: 2004;

ISO 5660-1 Reaction-to-fire tests - Heat release, smoke production and mass loss rate - Part 1: Heat release (Cone calorimeter method): 2002;

ISO 5660-2 Reaction-to-fire tests - Heat release, smoke production and mass loss rate - Part 2: Smoke production rate (dynamic method): 2002;

STANAG 4602 Fire Assessment of Materials. 2004.

2.2. This Allied Publication has been prepared with reference to the particular versions of the standards specified above, which were current at the time of publication. From time to time, all standards are subject to revision and NATO will keep this prospect under review. Not withstanding this fact, the versions of the standards specified above shall continue to

be used, without amendment, until such time as NATO specifies the use of any amendments or revisions published by the relevant standards organisations.

2.3. National and international standards are available from the relevant national standards body for each nation or from ISO. NATO STANAGs and Allied Publications can be obtained from the NATO STANAG point of contact for each nation.

3 DEFINITIONS

3.1 Technical Authority

The relevant national authority, responsible for providing regulations and guidance on fire reaction of materials associated with procurement and in service support.

4 PRINCIPLE OF THE TEST

This Allied Publication uses the cone calorimeter test specified in ISO 5660-1 to assess the heat released by horizontal test specimens when exposed to specified levels of irradiance 25 or 50 kW/m^2 as required by AFAP-1.

5 GENERAL

5.1 Conduct of tests

Carry out the tests in accordance with ISO 5660-1 supplemented and amended by the provisions of this Allied Publication. Where the provisions of ISO 5660-1 conflict with the provisions of this Allied Publication, the provisions of this Allied Publication shall be applied. Where no information is given in this Allied Publication all of the provisions of ISO 5660-1 shall be applied.

5.2 Additional information

Only the information that is additional to ISO 5660-1 is included in this document. All remaining information appears in ISO 5660-1 and in order to carry out the test specified by this Allied Publication it must be read in conjunction with a copy of ISO 5660-1.

5.3 Smoke production measurements

For generic materials, in addition to data on heat release rate, it is optional to measure and to record smoke production rate by using the supplementary apparatus and procedures specified in ISO 5660-2.

Smoke measurements are mandatory for evaluating furniture and other components as "fire-restricting materials" for Ship Type (H) (see AFAP-1 Annex 4).

Note: The smoke production measurements from AFAP-5 and AFAP-2 cannot be directly compared and may rank materials in a different order.

6 APPARATUS

6.1 Gas sampling apparatus *(ISO 5660-1 Sect 6.8)*

For the purposes of this Allied Publication the preferred arrangement is to use a gas sampling system in which CO_2 is removed from the gas sample in a chemical scrubber before O_2 is measured as shown in Figure 6 of ISO 5660-1. The use of optional analysers for CO_2 and CO is not recommended. (See also Section 10.1 of this Allied Publication).

6.2 Heat flux meters *(ISO 5660-1 Section 6.12)*

6.1.1 Calibration of the working heat flux meter

Calibration of the working heat flux meter used to set radiator cone at 25 kW/m^2 or 50 kW/m^2 at the start of each testing day (ISO 5660-1 Section 10.2.5) shall be traceable by no more than 4 steps, to the primary standard maintained by LNE - France or SP - Sweden (see below). Details of how to obtain such a calibration may be obtained from the Technical Authority.

Note: Technical enquiries, on this subject, may also be directed to:

LNE Laboratoire National de Metrologie et d'Essais
Centre for Metrology and Instrumentation
Division for Optical Radiation Metrology
and Thermal Properties of Materials
29, Avenue Roger Hennequin
78197 Trappes Cedex
France
Tel : +33 1 30 69 10 00
Fax : +33 1 30 69 12 34
e-mail: info@lne.fr

SP Technical Research Institute of Sweden
Fire Technology
Box 857
SE-501 15 Boras
Sweden
Tel.: + 46 10 516 50 00
Fax : + 46 33 13 55 02
e-mail: info@sp.se

6.1.2 Transfer calibrations

Transfer calibrations shall be made using the radiator cone an ISO 5660-1 cone calorimeter, according to the procedures described in Annex 3 of this Allied Publication. (Steps 2 and 3 in Figure 1 of Annex 3).

7 SUITABILITY OF A PRODUCT FOR TESTING *(ISO 5660-1, SECT 7)*

7.1 Asymmetrical products *(ISO 5660-1, Section 7.2)*

In cases where materials submitted for evaluation have faces which differ or contain laminations of different materials arranged in a different order in relation to the two faces, the Technical Authority shall determine which of the faces are required to be tested. Where both faces are to be exposed in practice both faces may be required to be tested. Each set of test results shall only be valid for the particular face tested.

7.2 Materials of short burning time *(ISO 5660-1 Section 7.3 & 11.3.1)*

For the purposes of this Allied Publication the preferred data sampling interval is 2 seconds for all specimens regardless of burn time (see Section 9.3 of this Allied Publication).

7.3 Materials that decompose explosively

It is known that some materials can explosively decompose when exposed to heat (e.g. some types of phenolic resin composites delaminate explosively, due to expansion of trapped moisture). This is a safety hazard and has been known to damage the apparatus by throwing off the edge frame from the specimen holder. Where this is likely, it is particularly important that the means of securing the edge frame to the specimen holder (e.g. retaining screws/bolts etc) is sufficiently strong to prevent this from happening (see ISO 5660-1 Section 6.6).

8 SPECIMEN CONSTRUCTION AND PREPARATION *(ISO 5660-1, SECT 8)*

8.1 Form of test specimens

The test specimen form shall be determined in accordance with ISO 5660-1, with reference to Annex 1 & 2 of this Allied Publication.

8.2 Conditioning

Condition the test specimens to constant mass as described in ISO 5660-1 Section 8.2.

For the purposes of this Allied Publication, Class 2 conditions in accordance with ISO 291 : 1997 are accepted (23 ± 2) °C, (50 ± 10) %R.H.

9 TEST PROCEDURE

9.1 Irradiance

Test 3 specimens at the required irradiance (see AFAP-1): 25 kW/m^2 or 50 kW/m^2.

9.2 Drying agent *(ISO 5660-1 Section 11.2.1)*

Ensure that the drying agent (sorbent) in the moisture trap(s) (as described in ISO 5660-1 Section 6.8 and Figure 6) is sufficiently fresh at the start of each test, so that it will continue to absorb all moisture from the gas sample entering the oxygen analyser for the full duration of the test.

Note 1: This is likely to require that it is changed several times during the course of a testing day, although the actual frequency required may vary due to the nature of the materials being tested (amount of moisture generated in the combustion products) and the particular design of the apparatus (size of traps containing drying agent).

Note 2: It is advisable to use new (previously unused) drying agent each time the trap is refilled and to discard the used material. Regeneration of the drying agent by heating is not advised, as it is known that some types of drying agent loose absorbency after a relatively small number of heating/regeneration cycles.

9.3 Scan interval *(ISO 5660-1 Section 7.3 & 11.3.1)*

For the purpose of this Allied Publication use a scan interval of 2 seconds or less for all specimens, unless otherwise agreed with the Technical Authority.

9.4 End of test *(ISO 5660-1 Section 11.3.5)*

For the purposes of this Allied Publication collect all data until:

.1 22 min after the time to sustained flaming (the 22 min consist of a 20-min test period and an additional 2-min post-test period to collect data that will be time shifted);

.2 20 min have elapsed and the specimen has not ignited;

.3 X_{O_2} returns to the pre-test value within 100 parts per million of oxygen concentration for 10 min; or

.4 the mass of the specimen becomes zero;

whichever occurs first, but in any case, minimum test duration shall be 5 min. Observe and record physical changes to the sample such as melting, swelling and cracking.

10 CALCULATIONS *(ISO 5660-1, SECT 12)*

10.1 Heat Release Rate

For the purposes of this Allied Publication the preferred method is that carbon dioxide (CO_2) is removed from the gas stream before the oxygen analyser (see Section 6.1 of this Allied Publication), so that the calculations given in Section 12 of ISO 5660-1 are used to calculate heat release rate data.

10.2 Additional calculations – MARHE, *HRR30max*, *SPR30max*

When evaluating generic materials and assembled upholstery furniture composite specimens (see AFAP-1 Annex 4) calculate MARHE, the Maximum Average Rate of Heat Emission, recorded during the test as follows:

10.2.1 ARHE

ARHE(t), the Average Rate of Heat Emission at time t, is defined as the cumulative heat emission per unit area of exposed specimen, from t = 0 to t = t, divided by t.

Calculate ARHE, for each data point using the following equation:

$$ARHE(t_n) = \frac{\sum_{2}^{n}\left((t_n - t_{n-1}) \times \left(\frac{\dot{q}_n + \dot{q}_{n-1}}{2}\right)\right)}{(t_n) \times A_S} \quad (kW/m^2)$$

Where,

t_n is the time (in seconds) at the n[th] scan interval,

$\dot{q}$ is the heat release rate (in kW) at the n[th] scan interval;
(the first data point is $(t_1, \dot{q}_1)$, where $t_1 = 0, \dot{q}_1 = 0$ or t is rescaled to meet this condition)

A_S is the initially exposed specimen area (in m^2) (usually 0.0088)

Note The equation uses the trapezium rule assumption to calculate the cumulative heat emission.

10.2.2 MARHE

Determine MARHE as the maximum value of ARHE during the time period t = 0 to t = t_{end} expressed in kW/m^2.

10.2.3 *HRR30* and *SPR30*

When evaluating materials for furniture and other components as "fire-restricting materials" for Ship Type(H) (see AFAP-1 Annex 4), calculate *HRR30max* and *SPR30max* as follows:

Note: *HRR* = Heat release rate per unit area ($\dot{q}_A$ in ISO 5660-1) in kW/m^2 and *SPR* = smoke production rate (P_s in ISO 5660-2) in $m^2 \cdot s^{-1}$.

Using a scan interval of 2 seconds, calculate the 30-second sliding average of heat release rate, HRR is performed as follows:

HRR30(t) is the average of 15 records (30 seconds) of *HRR(t)*.

$$HRR30(t) = \frac{HRR(t-14s) + HRR(t-12s) + ... + HRR(t+12s) + HRR(t+14s)}{15}$$

For all values of $(t - x) < 14$ $HRR(t - x) = 0$
For all values of $(t + x) > 1200$ $HRR(t + x) = HRR(1200)$

SPR30 is calculated using the directly equivalent equation. If other scan interval is used the above equation shall be adapted.

10.2.4 HRR30max and SPR30max

Determine *HRR30max* and *SPR30max* as the maximum value of *HRR30* (kW/m^2) and *SPR30* (m^2·s^{-1}) respectively, during the time period t = 0 to t = t_{end}.

11 TEST REPORT *(ISO 5660-1, SECT 13)*

The test report shall include a reference to this Allied Publication together with the following information:

Note: Some of the following information may be required by the Technical Authority for input to the database described in AFAP-1.

a) the name and address of the laboratory undertaking the test;

b) the name and address of the supplier and where different, of the manufacturer (original source) of the material tested;

c) the date(s) of the test;

d) a full description of the material tested including, where applicable and/or known;

name

application

type of material (chemical composition)

type of product (form or shape e.g. sheet or tube etc.)

essential dimensions, including mass or density, sheet size/thickness, diameters and wall thickness of pipes/tubes, etc. If the material has been reduced in thickness for testing (see ISO 5660-1 Section 8.1.4), report both the thickness tested and the original thickness of the material as received;

colour (facing colour)

details of any coatings (including substrates, surface preparation techniques, no. of layers, colour, coverage rates, etc.)

details of upholstery construction (including number, type and thicknesses of each covering, interliner and padding layer, etc)

specifications

NATO Stock No.s or other Unique Identification No.s

details of any previous tests known

other relevant technical data

e) a full test report in accordance with ISO 5660-1: 2002; including a full description of the specimen construction and preparation (e.g. including where relevant, substrate, use of grid, coating layers, tube or pipe, details of upholstery layers included in the specimen and any water soak or cleaning procedures, etc.);

f) individual values of MAHRE or *HRR30max* and *SPR30max* as appropriate and for each specimen determined in accordance with Section 10.2 of this Allied Publication and their average values for the sets of 3 specimens tested each heat flux;

g) if the additional measurements for smoke production rate have been made (see Section 5.3 of this Allied Publication), a full test report in accordance with ISO 5660-2: 2002;

h) additional experimental details;

Gas sampling apparatus / heat release calculations used (AFAP-5 Sections 6.1 & 10.1)

Details of heat flux meter traceability (AFAP-5 Section 6.2)

Dimensionally unstable materials - details of increased separation and/or restraining wires (ISO 5660-1 Section 7.5)

Scan interval (AFAP-5 Section 9.3)

i) the statement: "These results relate only to the behaviour of the specimens of the material under the particular conditions of test."

Note: The Materials Fire Characteristics Data Sheets from the STANAG 4602 database described in AFAP-1 may, optionally, be used for recording some of the test results. (Copies are shown in Annex 4 of this Allied Publication).

ANNEX 1 - PREPARATION OF TEST SPECIMENS

A – Paint/coating

A.1 Paint/coating test specimens shall consist of mild steel panels[1], of nominal thickness 3 mm, coated on the upper (i.e. exposed) face with the paint system under test.

A.2 The dimensions of the test panels shall be 100 $^{+0}/_{-2}$ mm x 100 $^{+0}/_{-2}$ mm (as specified in ISO 5660-1 Section 8.1.2).

A.3 Prepare the surface of each test panel and apply the paint/coating system to the required thickness, according to the manufacturer's instructions that will be used in the end use application. The method of surface preparation shall be recorded in the test report. The back and edges of the panel shall not be coated.

A.4 In the absence of specific instructions on surface preparation from the manufacturer, the method of surface preparation shall be as specified by the Technical Authority.

Note: Examples of suitable surface preparation techniques can be found in ISO 1514.

A.5 Dry (or heat cure) each coated test panel for the manufacturers specified time under the specified conditions, and then, condition them at (23 ± 2) °C, (50 ± 10) % R.H. for 7 days, with free circulation of air and without exposing them to direct sunlight.

A.6 The cone calorimeter test procedure shall then be carried out within 7 days.

[1] Where the end use application of a paint/coating is on mild steel of less than 3 mm thickness, or on a different non-combustible substrate material, which has lower heat absorption, the smoke generation may be greater and/or more rapid. In such cases the Technical Authority may require that the material is tested on the end use substrate. If paint/coating is applied on a combustible substrate it shall be tested as part of the end use composite.

B - Tubes and pipes

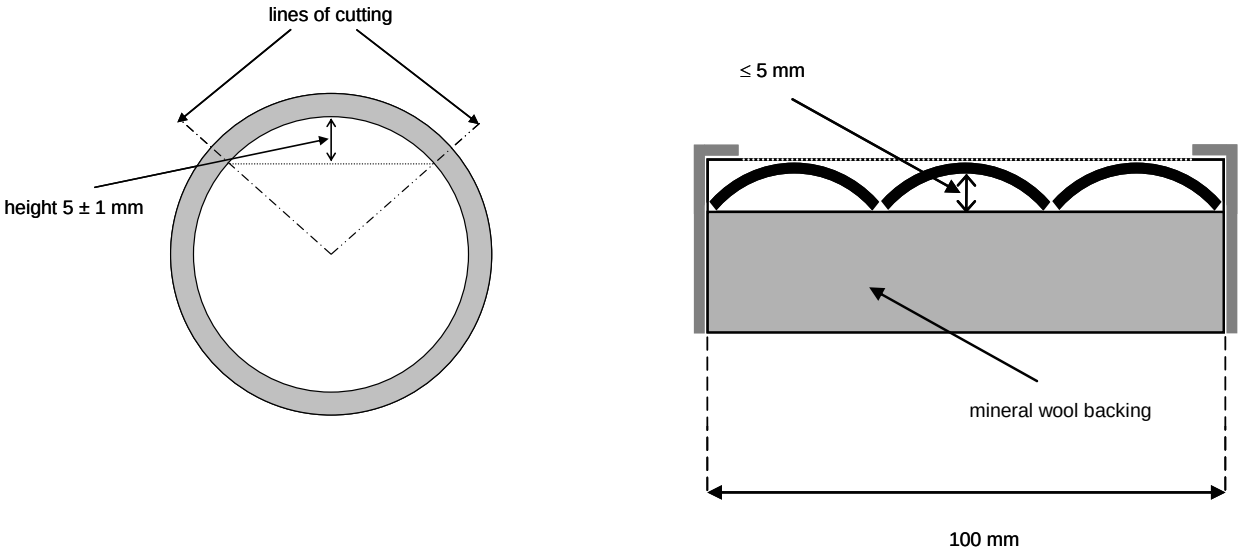
Specimens shall be prepared as required in any relevant material/product specification as directed by the Technical Authority. In the absence of a material/product specification, specimens shall be prepared, without a substrate, as follows;

B.1 Flexible materials

If the material is sufficiently flexible, cut the tube or pipe lengthwise into strips and construct flat specimens, 100 $^{+0}/_{-2}$ mm x 100 $^{+0}/_{-2}$ mm.

B.2 Rigid materials

If the material is rigid, the test specimen shall be composed of strips cut from the tube/pipe, 100 $^{+0}/_{-2}$ mm in length. A sufficient number of identical whole strips shall be provided to obtain a test specimen 100 $^{+0}/_{-2}$ mm wide. The combination of the number and the width of the strips shall be chosen such that a whole number of strips, when placed together as shown, fill the overall specimen width of 100 $^{+0}/_{-2}$ mm and the height under the curve is $\leq$ 5 mm[1]. All cuts shall be made normal to the wall of the tube/pipe. The spaces beneath the unexposed concave surfaces shall be left void.



[1] The exception to this is that if the internal diameter is $\leq$ 10 mm the tube/pipe strips shall be cut with a semi-circular cross section.

C – UPHOLSTERED FURNITURE

INCLUDING MATTRESSES

C.1 General

Where upholstered furniture items are to be evaluated by testing an assembled upholstered composite, the test specimen shall consist of layers of all of the covering(s), interliner(s) and padding material(s) (usually foam or other compliant material) arranged in the order that they occur in the finished item, assembled as described below.

Note: To ensure repeatability/reproducibility it is important that the masses of the blocks of padding material are consistent and the fabric pieces are uniform.

C.1.1 Overall thickness

Where the total thickness of the upholstery on the finished item of furniture [padding(s) + interlayer(s) + covering(s)] is less than or equal to 50 mm, all of the component layers shall be included in the test specimen at their original thickness.

Where the total thickness of the upholstery on the finished item of furniture [padding(s) + interlayer(s) + covering(s)] is greater than 50 mm, include any padding layers thinner than 8 mm in their original thicknesses. Include each of the remaining layers (i.e. those > 8 mm in thickness) at reduced thickness, so proportioned that their relative thickness in the remaining specimen depth (50 mm minus the thin layers) is in the same proportion as is found for those layers in the finished item of furniture.

C.2 CUTTING AND WEIGHING

C.2.1 Dimensions

Cut nine square pieces of each component material, $100\ ^{+0}/_{-2}$ mm x $100\ ^{+0}/_{-2}$ mm.

C.2.2 Fabrics

Do not cut fabrics on the bias.

If the fabric weave is such that the threads in the two directions do not lie at 90° to each other, do not cut the sample along threads in both directions, since a skew specimen would result. Preferably

Cut the fabric pieces from a position away from the edge of the supplied sample (if possible, at least 250 mm from any edge).

Material cut from the selvage (i.e. the finished edge of the fabric roll, which often has a different weave pattern and/or thickness) shall not be used.

C.2.2 Mass tolerance

Weigh each square and for each material, calculate the mean of the set of nine.

There shall be no piece that has a mass greater than 105%, nor any less than 95% of the mean. If necessary, check and adjust the dimensions of any over sized pieces and/or cut and weighed further pieces as necessary until the required tolerance is achieved.

Mark each accepted square for traceability and report the mass of each piece along with information about the corresponding test run.

C.3 PREPARATION OF THE TEST SPECIMEN

C.3.1 Water Soak

All outer covers and inner covers that have been chemically treated to reduce their ignitability shall be subjected to the water soaking and drying procedure described in Annex E of BS 5852.

For blankets, quilts, pillows, thin light mattresses or removable covers, that may be subject to regular washing, the Naval Administration may require further cleaning procedures appropriate to end use.

Note: Water soak or washing procedures are only required for assessment of heat release rate in accordance with AFAP-5 and shall not be undertaken for tests according to AFAP-2 or AFAP-3.

C.3.2 Assembly of composite specimen

Weigh the combined components of each test specimen [padding(s) + interlayer(s) + covering(s)] and report the mass along with information about the corresponding test run.

Cut a square of aluminium foil, 210 mm x 210 mm.

With the dull side of the foil facing upwards (towards specimen), stack the components at the centre on the foil. Start with the material from unexposed side (usually padding), progressing in the order the layers occur in the finished furniture item, placing each layer oriented with the exposed side facing upwards.

Hold the block firmly in place and pull each side of the foil up to create the bottom foil. Form the corners by holding the foil firmly in contact with the corner of the specimen. Stretch the corner of the foil and make a 45° fold at each corner. Finally, pull the corners flat against two sides of the specimen and pat all sides down flat against the specimen.

Weigh each specimen with aluminium foil and report the mass along with information about the corresponding test run.

After mounting the test specimen in its holder, cut away excess aluminium foil. The central exposed specimen area is 94 mm by 94 mm.

NOTE If in the end use application the component layers are glued together over a substantial area, the Technical Authority may require that the component layers of the test specimen are glued using the appropriate adhesive. For test specimens with glued parts, it may be convenient for the producer to prepare the specimens.

ANNEX 2 - FORM OF TEST SPECIMENS

Material type	Form of test specimen
INTERIOR PAINT SYSTEMS, WET AND DRY SPACES	Full system including primer(s), undercoat(s) finish(s) etc. as recommended by the manufacturer for initial application. Applied in accordance with Annex 1 of this Allied Publication. Test with the painted face exposed to the cone heater.
INTERIOR DECK COVERING	End use thickness[1]. Test alone, with the upper face exposed to the cone heater. No application of adhesive, underlay or substrate.
THERMAL INSULATION (STRUCTURE)	Insulation at end use thickness[1], with glass cloth facing bonded with the adhesive used in manufacture of the final product. Test with the glass cloth side exposed to cone heater. No application of installation adhesive, vapour barrier coating or substrate, etc.
DECORATIVE LININGS	End use thickness[1]. Test alone, with the outer face exposed to the cone heater. No application of installation adhesive, coatings, fixings or substrate, etc.
UPHOLSTERED FURNITURE INCLUDING MATTRESSES	Assembled upholstered composite test specimens, prepared in accordance with Annex 1 of this Allied Publication.
UPHOLSTERY COMPONENT LAYERS	Some Technical Authorities may require tests on individual components, such as coverings, interliners or padding materials (e.g. core or barrier foams). In such cases the materials shall be tested in their end use thickness[1], without a substrate or facing.

[1] Materials with a thickness greater than 50 mm shall be cut to give a specimen thickness of 50 mm as described in ISO 5660-1 Section 8.1.4.

ANNEX 3 - HEAT FLUX METER CALIBRATIONS

Introduction

Most laboratories operate a procedure for calibration of heat flux meters that requires a "transfer" or "secondary" method of calibration (see Figure 1). This is to reduce the cost burden of having all heat flux meters calibrated by a primary method.

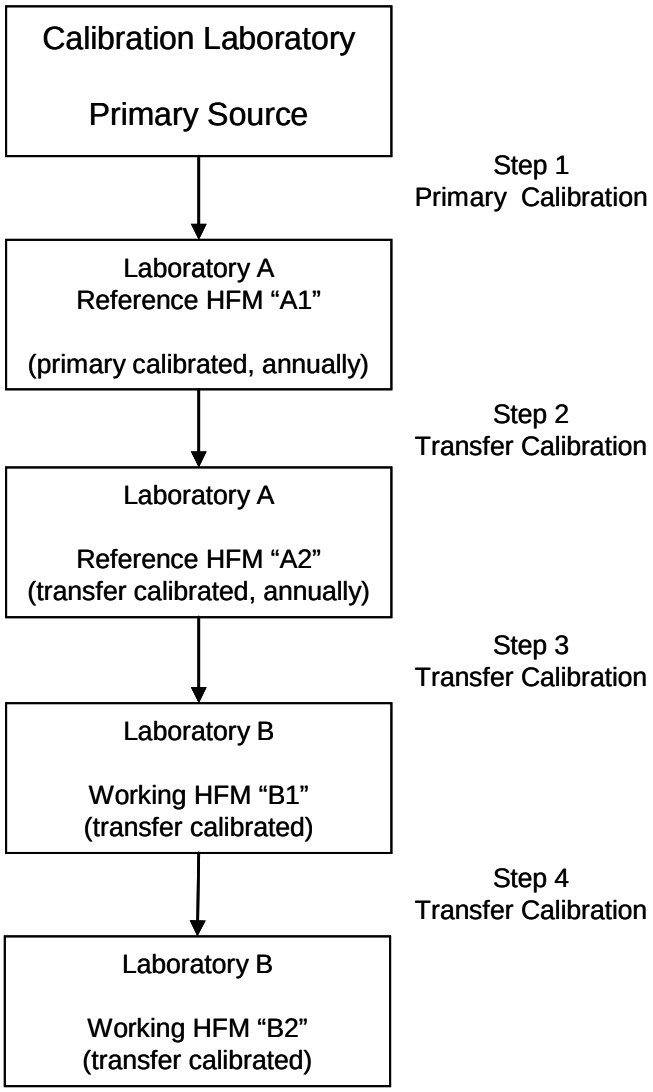


Figure 1. Schematic illustration of possible 4 step calibration scheme.

Factors that should be considered when carrying out transfer calibrations include;

- Type of radiation source
- Geometry and uniformity of radiation source
- Temperature of radiation source
- View angle of heat flux meter in relation to the source
- Angular sensitivity of the heat flux meter in relation to the source.

Heat flux meters used to calibrate the cone calorimeter are exposed to incident heat which is comprised of both radiation and convective components. The relative proportion of each component is dependent upon the orientation of the cone heater and the level of incident heat.

Setting up procedure

Using a suitable metal support stand (e.g. retort) with a boss and clamping arrangement, support the working heat flux meter to be calibrated centrally under the cone heater as shown in Figures 2.

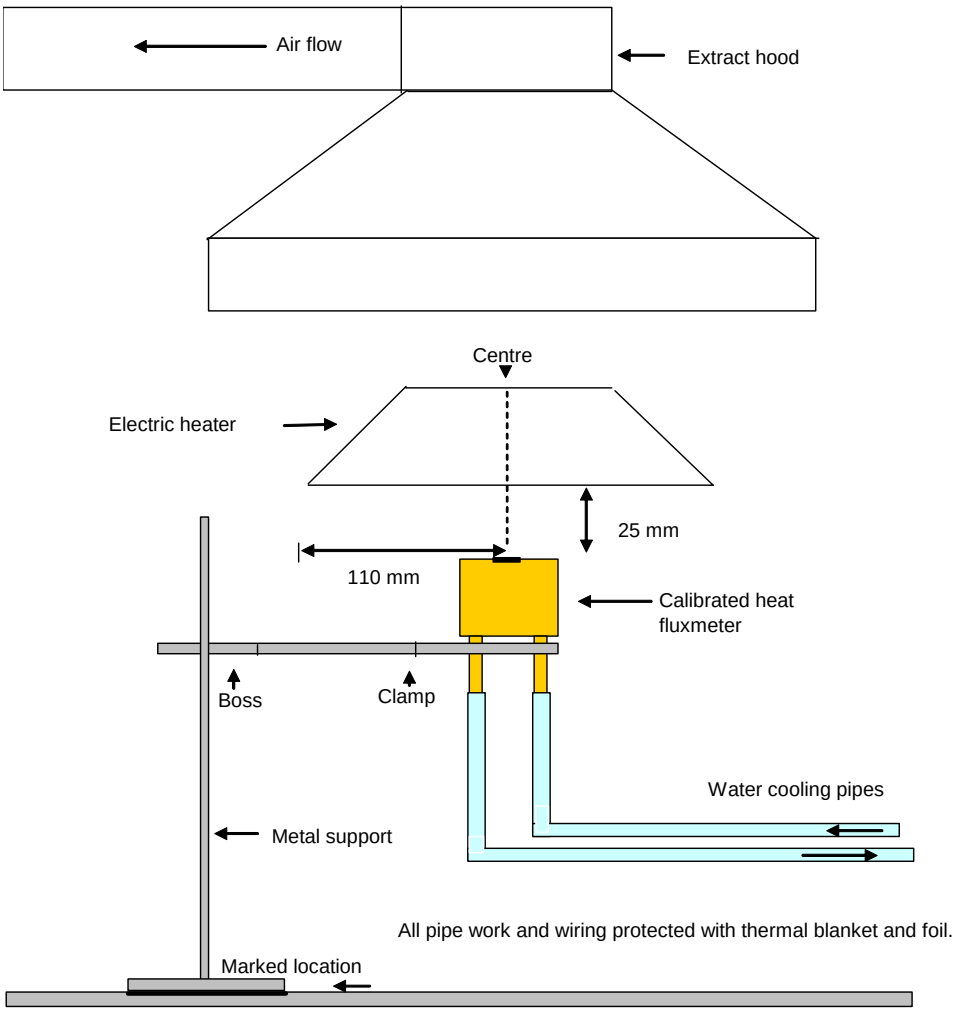


Figure 2. Schematic diagram of calibration arrangement.

Ensure that the heat flux meter is clamped around the water cooling pipes under its cooling jacket as shown. The face of the heat flux meter should be located at the same distance from the cone heater as the surface of a specimen to be tested.

Attach a suitable length of plastic tubing securely to the water cooling pipes of the heat flux meter. Water can then be supplied to the water jacket of the heat flux meter by tap or a

water tank and pump arrangement. The outlet pipe from the heat flux meter can be fed into a drain or returned back to the tank in the latter case.

Connect the output leads from the heat flux meter and thermocouples to a calibrated data logging device or PC, capable of measuring to a resolution of 0.001 mV, using the correct type of cable.

Protect exposed tubing, wires and other vulnerable surfaces including boss and clamp with thermal blanket and aluminium foil.

When in place, outline the base of the support stand and move the entire arrangement to one side.

Repeat the above procedure using the primary calibrated heat flux meter. Ensure that the support stand is identical to the previous one and that it is sitting exactly on the same marked area described earlier.

Procedure for Step 2 calibration

With the primary calibrated heat flux meter in place, locate a sheathed thermocouple approximately 20 mm into the entrance of water cooling outlet pipe. Also locate a bare wire thermocouple close to the apparatus, set up to monitor the ambient air temperature.

Attach the plastic tubing to a water supply and ensure that the water flow from the outlet pipe is continuous and free from air bubbles.

Operate the cone hood extractor and turn on power to cone heater. Adjust the power to the cone heater until the desired initial thermal exposure is achieved with the primary calibrated heat flux meter. Monitor the output of the primary calibrated heat flux meter on the data logger display until the output voltage readings have stabilised. Once in this stabilised condition, record the heat flux meter reading over a period of 5 minutes, using a scan interval of less than or equal to 5 seconds.

Then replace the primary calibrated heat flux meter and stand with the working heat flux meter and repeat the above procedure.

Repeat the above procedure with the primary calibrated heat flux meter, in order to check that the cone heater (thermal exposure) is stable.

Then adjust the power to the cone heater to a new level and repeat the above procedure. Care should be taken when selecting the thermal exposure conditions to ensure that the full range of the heat flux meter is covered by the calibrations, but that the maximum heat flux is not exceeded.

It is recommended that a minimum of 5 data points be collected for a transfer calibration.

Procedure for Steps 3 & 4

For Step 3 & 4 calibrations, the primary calibrated heat flux meter is replaced with the reference heat flux meter (transfer calibrated) and the remainder of the procedure as outlined above should then be followed.

Data presentation and results

Determine the average voltage output for each heat flux meter at each of the different thermal exposure conditions. Convert the measured voltage output from the primary calibrated heat flux meter to a heat flux, using the appropriate calibration equation. Tabulate the data as shown below in table 1.

	Calibrated heat flux meter		Heat flux meter to be calibrated		
Heater temperature (^{O}C)	**Average voltage (mv)**	**Average heat flux (kW/m^2)**	**Average voltage (mv)**	**Water coolant temperature (^{O}C)**	**Ambient air temperature (^{O}C)**
300	1.73	10.12	1.38	24.1	25.1
644	5.21	30.15	4.17	24.7	25.3
790	7.8	45.21	6.24	24.8	25.6
835	10.43	60.5	8.34	24.7	25.7
925	12.86	75.23	10.28	24.7	25.7
			Average =	**24.6**	**25.48**

Table 1. Example of tabulated data.

Plot the primary calibrated heat fluxes against the voltage output of the working heat flux meter, as shown in Figure 3. The calibration equation for the working heat flux meter is determined from the slope and intercept of the straight line relationship as shown in Figure 3.

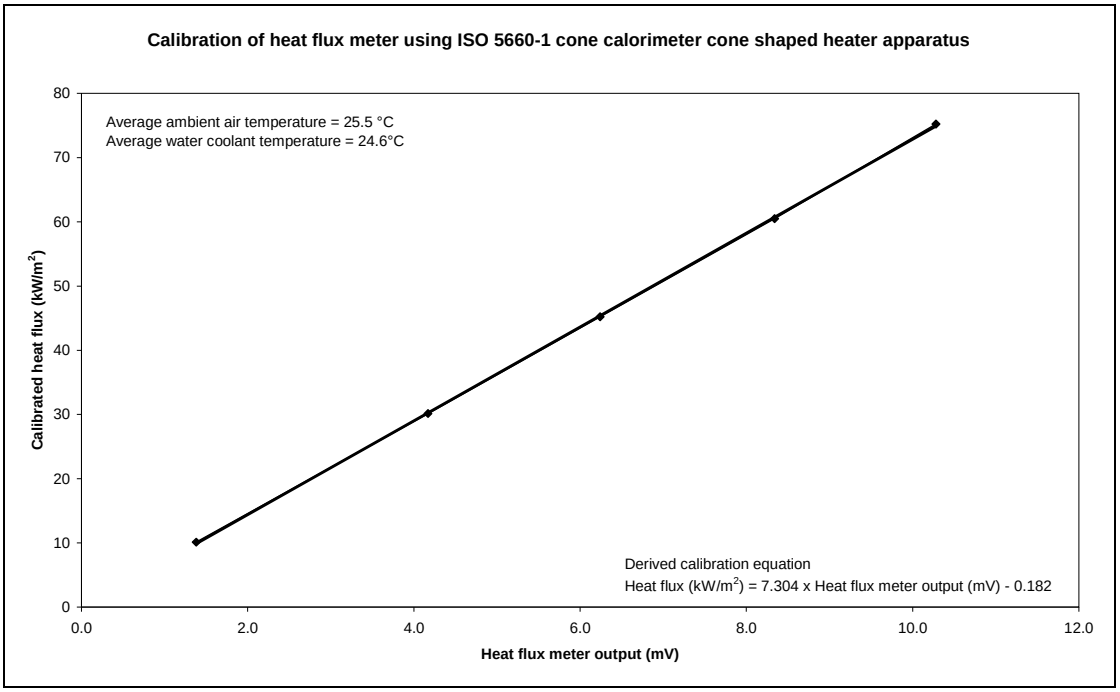


Figure 3. Example of plotted data for heat flux meter calibration.

Note: It is recommended that a historical log of the calibrations for each heat flux meter is retained by the laboratory. This is useful information that can be used to identify any problems associated with the heat flux meter that can occur from time to time. As a general rule, the calibration of an individual heat flux meter should be fairly stable provided that it is kept free from occurrences that could result in damage, shock and/or impact.

ANNEX 4 - DATASHEETS (OPTIONAL)

SECURITY MARKING

HEAT RELEASE RATE **STANAG 4602**

AFAP-5 (ISO 5660-1 modified) Edition No. **Item Ref.**

Report No.	**Report Date**
Report Title	
Test Laboratory Address	**Supplier Address**
Material	

Test specimen

(I) Thickness mm or μm:

(II) Specimen construction and preparation:

(III) Coatings:

(IV) Face tested:

Repeat Tests:

(details of any repeat tests required in accordance with AFAP-5)

Observations:

Deviations from test method:

This document contains commercial Information – See conditions of release. These results relate only to the behaviour of the specimens of the material under the particular conditions of test (See appropriate Standard)

SECURITY MARKING

HEAT RELEASE RATE **SECURITY MARKING** **STANAG 4602**

AFAP-5 (ISO 5660 modified) **Item ref.**

PARAMETER			TEST 1	TEST 2	TEST 3	MEAN
Irradiance (25 kW/m^2 or 50 kW/m^2)		(kW/m^2)				
Time To Ignition	t_{ig}	(seconds)				
Peak Heat Release Rate	$\dot{q}_{A,max}$	(kW·m^{-2})				
Total Heat Release	$Q_{A,tot}$	(MJ·m^{-2})				
Max Ave Rate Of Heat Emission	MAHRE	(kW·m^{-2})				
Max Sliding Ave Heat Release Rate	*HRR30max*					
Max Sliding Ave Smoke production Rate	*SPR30max*					
Test duration		(seconds)				
Time to peak heat release rate		(seconds)				
Ave. heat release rate for 180 s after ign	$\dot{q}_{A,180}$	(kW·m^{-2})				
Ave. heat release rate for 300 s after ign.	$\dot{q}_{A,300}$	(kW·m^{-2})				
Specimen mass loss	m_A	(g·m^{-2})				
Average mass loss rate between ignition and end of test	$\dot{m}_A$	(g·m^{-2}·s^{-1})				
Average mass loss rate between 10-90% of mass loss	$\dot{m}_{A,10-90}$	(g·m^{-2}·s^{-1})				
Smoke production non flaming phase	$S_{A,1}$	(m^2·m^{-2})				
Smoke production flaming phase	$S_{A,2}$	(m^2·m^{-2})				
Total smoke production	$S_{A,1}+S_{A,2}$	(m^2·m^{-2})				
Peak smoke production rate	$P_{sA,max}$	(s^{-1} [= (m^2·s^{-1})/m^2])				
Time to peak smoke production rate		(seconds)				
Ave. P_{sA} for 180 s after ign.	$P_{sA,180}$	(s^{-1} [= (m^2·s^{-1})/m^2])				
Ave. P_{sA} for 300 s after ign.	$P_{sA,300}$	(s^{-1} [= (m^2·s^{-1})/m^2])				
CO_2 yield between ignition and end of test		(kg·kg^{-1})				
CO yield between ignition and end of test		(kg·kg^{-1})				

SECURITY MARKING