

Determination of the response time of thermocouples to be used for the measurement of air or gas phase temperature in reaction to fire testing

(revision of EGOLF SM1:1995)

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Foreword

This document has been prepared by EGOLF and the method adopted by all EGOLF member laboratories for use in the determination of the response time of thermocouples to be used for the measurement of air or gas phase temperature in reaction to fire testing.

It is recommended to other organisations and laboratories that it should be universally accepted for this purpose.

It is particularly recommended to CEN Technical Committee TC127, plus other CEN Technical Committees with an interest in fire testing of materials and products, that it should be adopted for use in support of all European standard reaction to fire tests where the determination of the response time of thermocouples to be used for the measurement of air or gas phase temperature is important.

1 Scope

This test method establishes a procedure for measuring the response time of bare wire or sheathed thermocouples intended for measurement of air or gas phase temperature during reaction to fire tests. The test is conducted in still air conditions.

During fire tests the temperature in the region of the test specimen may vary with time. This may occur through controlled change of the environment as part of the test procedure, or, as a result of heat released from the test specimen during the test. In both cases, the accuracy and speed with which gas phase temperature can be measured and/or controlled, if necessary, depends upon the response time of the thermocouple in use.

In a fire test standard method, thermocouples to be used are normally defined in terms of a specific thermocouple construction, with appropriate tolerances. Sometimes alternative thermocouples may be allowed, with the provision that those used have a response time equal to or less than that of the type specified.

If a standard thermocouple construction has been specified in a fire test standard method, then thermocouples of that construction should be used. The numerical response time for these thermocouples, if required for information purposes, shall be determined using this test method.

If an actual value or a range of values of response time is specified in the fire test standard method then proof that a thermocouple meets this value or range of values shall be obtained by use of this test method.

If a thermocouple of non-standard construction or unknown response time is considered for use then proof of its acceptability shall be obtained using this test method. In this case, comparative testing of the thermocouple considered for use against a control thermocouple meeting the required standard construction or specified response time shall be made.

The test method is only applicable to bare wire thermocouples of wire diameter equal to or greater than 0.5 mm and to sheathed thermocouples of total diameter equal to or greater than 0.5 mm.

The test method is not applicable to bare wire thermocouples of wire diameter less than 0.5 mm, to sheathed thermocouples of total diameter less than 0.5 mm, or to copper disc or other types of surface temperature thermocouples or measurement devices.

2 Definitions

2.1 response time: the time taken for a thermocouple in still air to respond to a step change in temperature from an initial value to a final value measured by the time taken to achieve 63.2% of the difference between initial and final values. This is approximately the time for the thermocouple to achieve a temperature within $1/e$ of its initial value, where e is the base of natural logarithms.

Note : The response time of a thermocouple is also sometimes referred to as its time constant or transient response characteristic.

3 Symbols and designations

Symbol	Designation
e	the base of natural logarithms ($e = 2.718$)
T_{critical}	critical temperature used for the calculation of the response time, in °C
$T_{\text{background}}$	unshielded background temperature, in °C
$t_{\text{crit.}}$	time at which the test thermocouple reaches the critical temperature during cooling, in minutes and seconds
t_{700}	time at which the test thermocouple reaches 700°C during cooling, in minutes and seconds

4 Principle of the test method

A test thermocouple is inserted into a preheated furnace or other acceptable heating device, set at a temperature of 750°C. The test thermocouple is allowed to equilibrate to that temperature. The test thermocouple is then quickly removed from the furnace and placed in still air at a temperature of 20°C, where it cools. The temperature indicated by the test thermocouple is recorded as it cools.

The time taken to fall from a temperature of 700°C to a defined critical temperature is taken as the measured response time of the test thermocouple.

5 Test equipment

5.1 Furnace or heating device

A horizontal electric muffle furnace or a fluidised bed heating device shall be used. The size of the heating device used shall be such that sufficient length of the test thermocouple is heated. In practice, the length of the heating device shall be at least twice the required immersion length for the test thermocouple as given in 6.2 and figure 1, (which illustrates the use of an electric muffle furnace).

The furnace or heating device used in the test shall be capable of being operated and controlled at a temperature of (750 ± 25) °C. The temperature control shall be indicated by a calibrated reference thermocouple, of equal or lesser response time than the test thermocouple, and

controlled such that the drift rate of the thermocouple temperature during heating and at equilibrium does not exceed 5°C/minute.

5.2 Temperature measurement and recording device

The temperature measurement and recording device used for both the test thermocouple and the reference thermocouple shall:

- be provided with their own cold junction reference or an appropriate compensation device
- be capable of measuring the output with an accuracy of not less than 0.25% of its full scale deflection over a temperature range of 0°C to 1000°C
- be capable of responding to a full scale deflection in a time equal to or less than one second
- be capable of assimilating the incoming data and producing a permanent record of the temperature of the thermocouple at intervals of 1 second or less
- permit clear interpretation of the temperature data from the cooling test thermocouple.

5.3 Thermocouple support bracket

A thermocouple support bracket (attached to a wall or other permanent support) shall be provided, from which the test thermocouple may be suspended during the cooling phase of the test.

When suspended vertically from this support bracket the test thermocouple junction shall be downwards and at least 300 mm from any surface.

The support bracket shall be positioned close enough to the furnace or heating device to permit rapid transfer of the test thermocouple to the support bracket and yet once suspended from its support bracket shall not be subject to any significant radiant influence or temperature fluctuation arising from the furnace or heating device.

The position of the support bracket relative to the furnace or heating device shall be determined as specified in 7.1.

There shall be attached, to the test thermocouple and any extension lead used, a hook or other fastening device to permit the hanging of the test thermocouple from the support bracket.

5.4 Test environment

The test room or that portion of the test room in which the test is to be carried out shall be draught free and of constant temperature, such that a final unshielded background temperature (see 7.1.2) of between 17.5°C and 22.5°C is provided.

Influences which would cause rapid local changes of temperature during the test shall be eliminated.

6 Test thermocouples

6.1 Characteristics of test thermocouples

Where the test thermocouple is to be tested to give an indicative response time, characteristic of a thermocouple type, it shall be representative of that type.

6.2 Immersed length the test thermocouple

The immersed length of the test thermocouple shall be suitable for that type of thermocouple and its intended use. Normally, a minimum of 250 mm of the test thermocouple shall be immersed within the furnace or heating device.

6.3 Number of tests

At least two tests shall be carried out for each test thermocouple. If the criteria for consistency of results, given in clause 8, are not met two further tests shall be undertaken for each test thermocouple.

7 Test procedure

7.1 Establishment and measurement of background conditions

7.1.1 Background temperature and influence of proximity of the furnace or heating device

Raise the temperature of the furnace or heating device to a stabilised temperature of (750 ± 25) °C, as indicated by the reference thermocouple. Maintain it at this stabilised temperature.

Suspend the test thermocouple from the support bracket as defined in 5.3.

Record the ambient temperature given by the test thermocouple until the temperature has stabilised to ± 1 °C for a sufficiently long period, e.g. 5 minutes. The average recorded figure shall be used as the unshielded background temperature.

The causes of any fluctuations in background temperature must be identified and eliminated before proceeding further with the test.

Shield the test thermocouple from any radiant influence caused by the proximity of the furnace or heating device with a sheet of aluminium foil placed approximately 300 mm from the test thermocouple and between the two. Record the resulting temperature given by the test thermocouple until the temperature has stabilised to ± 1 °C for a sufficiently long period, e.g. 5 minutes. The average recorded figure shall be used as the shielded background temperature.

The difference between the unshielded and shielded values of background temperature shall not exceed 5°C. If the difference is greater than 5°C increase the distance between the furnace or heating device and the test thermocouple on its support bracket and repeat the procedure until a difference of less than 5°C is achieved. Fix the relative positions of the furnace or heating device and the support bracket.

7.1.2 Final unshielded background temperature

Once the position of the furnace or heating device and the support bracket have been established according to 7.1.1, remove the shielding and measure and record the final unshielded background temperature.

7.2 Introduction of test thermocouple

Introduce the test thermocouple into a preheated furnace or heating device of size and temperature capability as specified in 5.1, through a small opening, as shown in figure 1. The immersed length of the test thermocouple into the heating device shall correspond to that specified in 6.2.

7.3 Stabilisation of temperature of test thermocouple

Monitor the temperature of the test thermocouple, by comparison to that of the reference thermocouple, to establish that the correct equilibrium test temperature has been reached and that there is a temperature drift, over a period of 5 minutes, of not more than 5°C/minute.

7.4 Measurement of thermocouple response time

Activate the temperature measurement and recording device. Confirm the temperature recorded by the test thermocouple and the reference thermocouple. Confirm the continued absence of temperature drift by monitoring both for a period of between 5 to 15 seconds.

Rapidly, in less than 2 seconds, remove the test thermocouple from the furnace or heating device and suspend it from the support bracket.

Continue to monitor the temperature of the test thermocouple, until the indicated temperature has fallen significantly below that critical temperature used in the calculation of response time, as defined in clause 8, preferably to less than 100°C.

Terminate the recording of temperature information.

8 Interpretation of data and expression of results

From the recorded data, the elapsed time is determined, during which the temperature indicated by the test thermocouple, after removal from the furnace or heating device, falls from a value of 700°C to a defined critical temperature.

This critical temperature ($T_{critical}$) is defined as being the final unshielded background temperature plus 36.8% of the total temperature change to be experienced by the test thermocouple in cooling from the chosen higher temperature (700°C) to the final unshielded background temperature and is expressed according to the following equation.

$$T_{critical} = T_{background} + [0.368 \times (700 - T_{background})]$$

For example when the final unshielded background temperature is 20°C, then the critical temperature used in the calculation of the response time shall be :

$$T_{critical} = [20] + [0.368 \times (700 - 20)] = 270.24^{\circ}\text{C}.$$

The elapsed time, in seconds, indicated by ($t_{crit.} - t_{700}$) shall be reported as the response time of the test thermocouple, see figure 2.

If the difference in the result between the initial two tests specified in 6.3 is less than 10% then the mean value of these results shall be reported as the response time of the test thermocouple.

If the difference between the two test results is greater than 10% then these results shall be discarded and two further tests shall be carried out and the result reported as above.

If the difference between the new results is still greater than 10% a statement shall be made that a response time for the test thermocouple could not be established by this method. If the

variation cannot be explained in a systematic manner, consideration should be given to the rejection of the thermocouple.

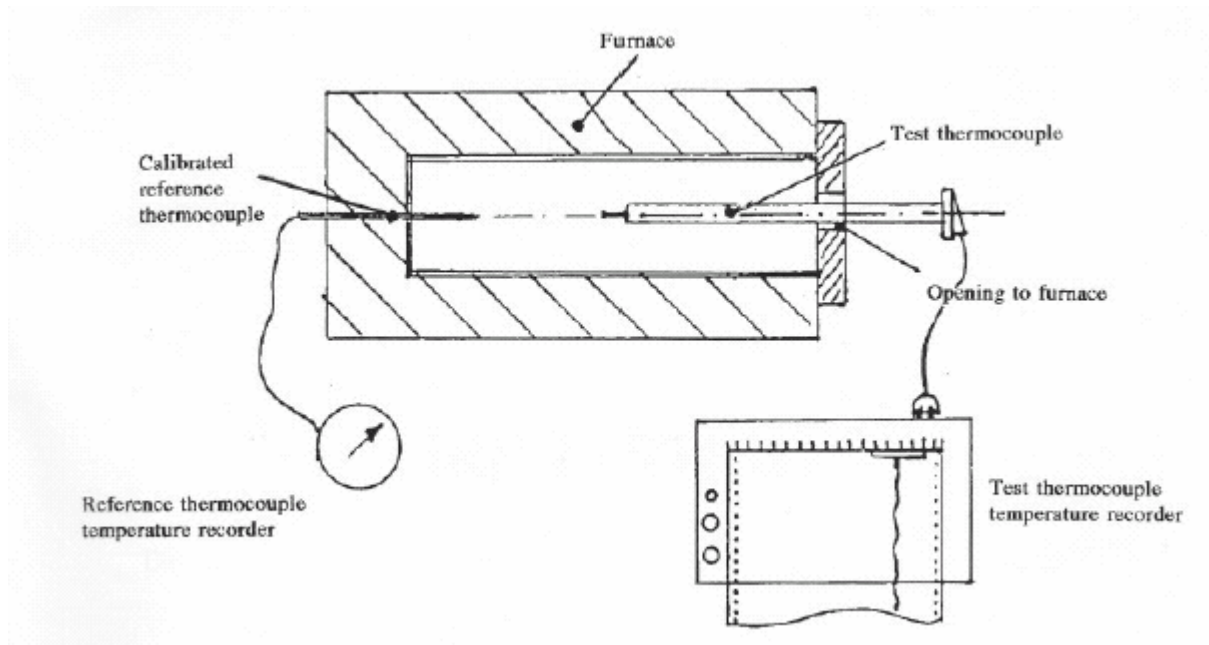


Figure 1 Description of apparatus

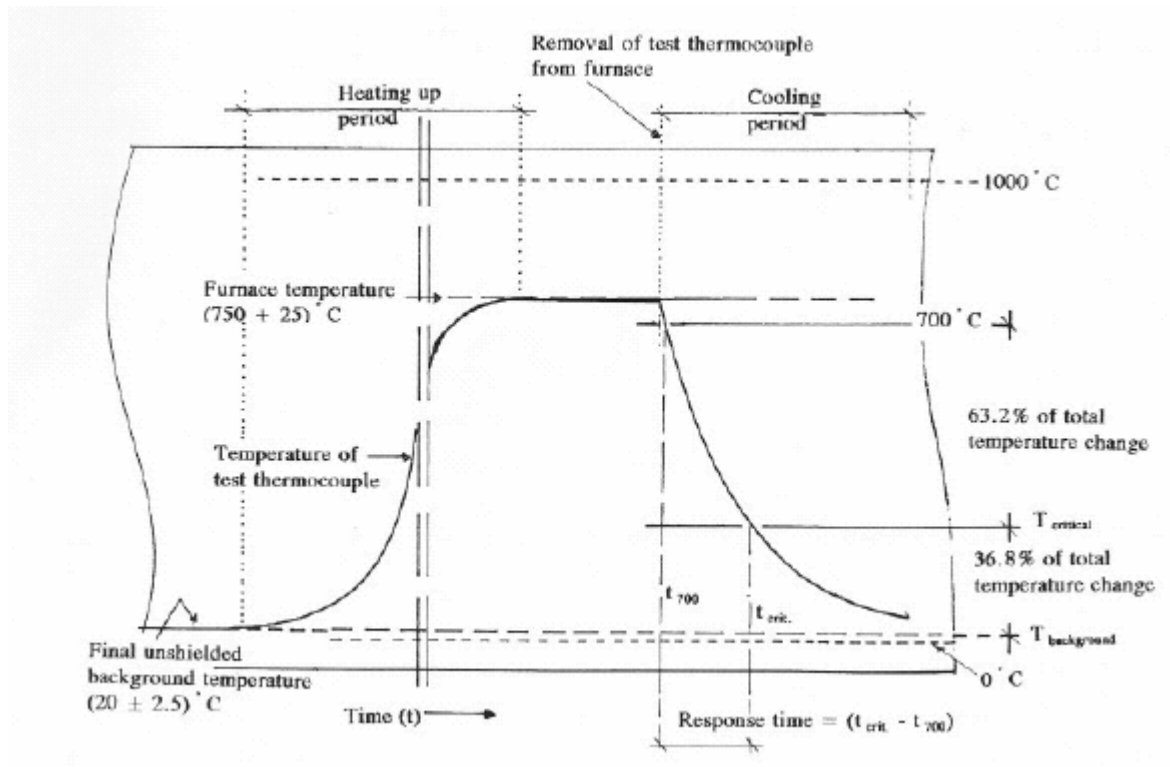


Figure 2 Description of analysis of data