IMPROVEMENTS OF TEST METHOD FOR WATER MIST SYSTEMS - CEN/TS 14972:2008, ANNEX A.3.

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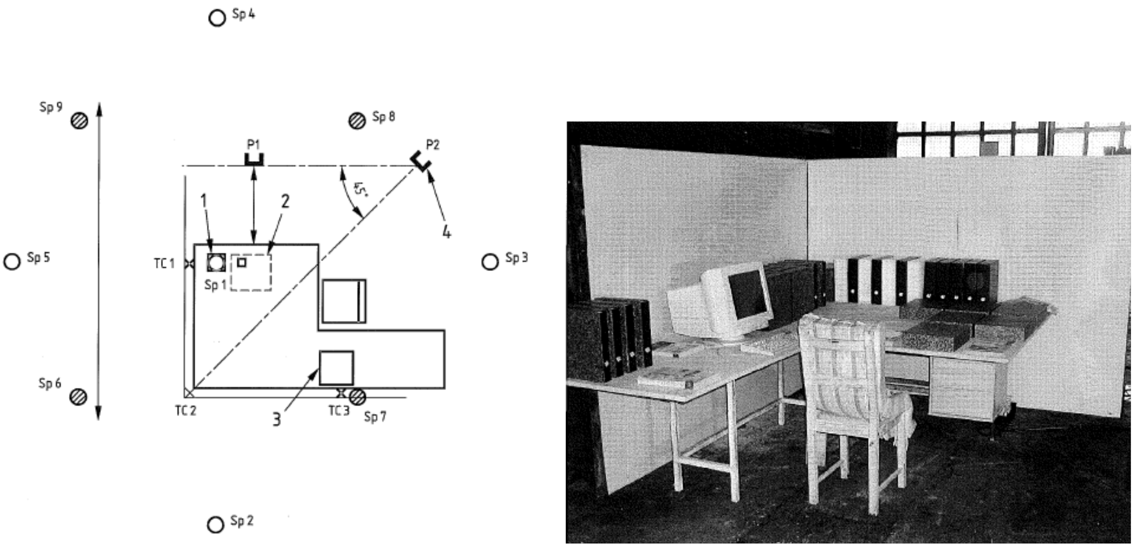
ABSTRACT

Today's water mist systems are primarily designed on the basis of application testing. For land based applications a test called "Office test", or more correctly the CEN/TS 14972:2008, Annex A.3, is used. This test standard has shown not to be a particular good test standard, as there have been problems with repeatability and reproducibility of the test. This paper is an analysis of the uncertainties with respect to repeatability and reproducibility of the test method. Furthermore suggestions for an improved test method are given.

BACKGROUND

The test method is used to evaluate fixed extinguishing systems using water mist for the land based market. Annex A.3 in CEN/TS 14972:2008 describes the test in detail[1]. It is a fire test in an open office configuration, where an office desk is placed in a corner against two separating walls. The separating walls are positioned with an angle of 90 degrees and are about 2 m in height. The test set-up includes use of different items of furniture with use of different materials. A sketch and picture is shown below in figure 1. To perform a test according to the standard, 4 experiments are done. The first two experiments are performed with traditional sprinklers classified as ordinary hazard 1 defined in EN 12845:2004[2]. Then using exact the same setup, 2 experiments are conducted with the water mist system to be tested.
To pass the test the water mist systems must demonstrate that the damages due to the fire are less or equal to what are achieved when using a traditional sprinkler system. So this test is basically a comparison of equal systems and therefore the term equivalence test is also used.

Figure 1 Sketch and picture of the actual test-set up



SCOPE

The scope of the project was to analyse the actual test standard in Annex A.3 of CEN/TS 14972:2008 and to propose improvements to it in order to reduce the number of uncertainties.

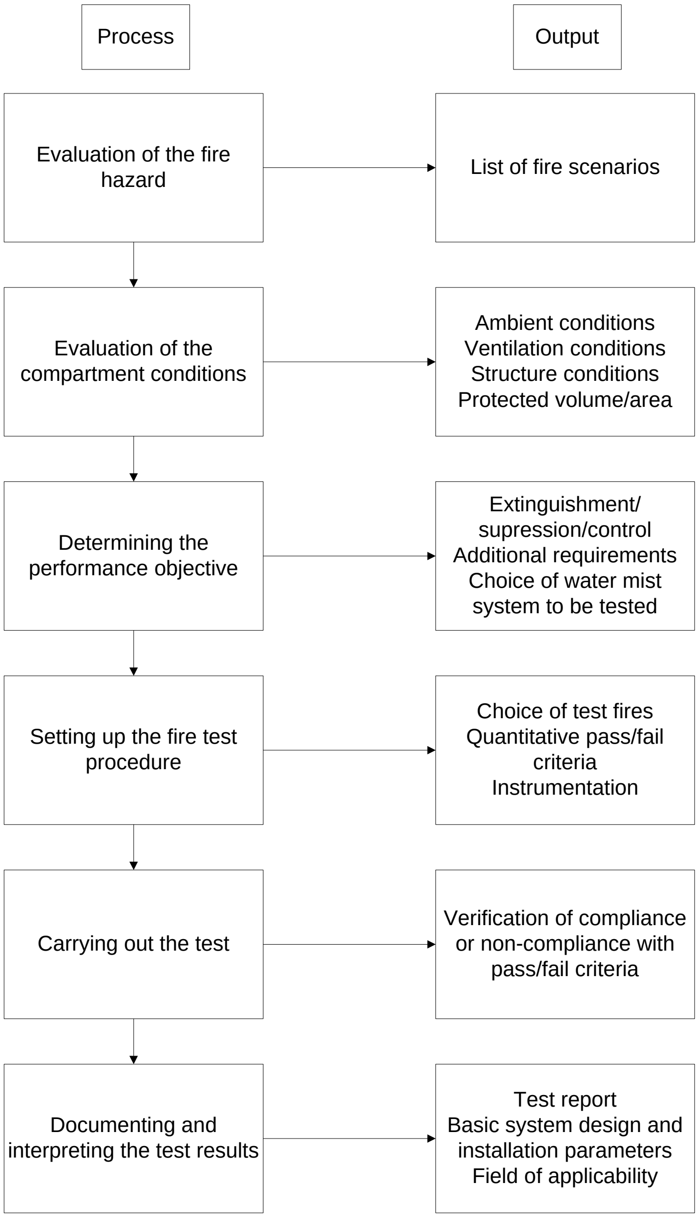
METHODS

A systematic methodology has been applied using two major criteria for all parameters that could result in bad reproducibility. Parameters included those related to material choice, fire behaviour of the materials and items of furniture, position of the items, mechanical properties of fixings, measurement sensors and position, etc. The first criterion was how the parameters could influence the test results and how big this influence was. A ranking system with 5 grades was used to determine how much the test result would be influenced. This was based on interviewing fire experts and if possible by conducting experiments. The second criterion was the tolerance of the different parameters. Here it was investigated how well the parameters were defined e.g. density, thickness, distance, heat release, position, etc. From this methodology a number of improvements are suggested which on their turn will be evaluated with the same methodology. Finally the test method was used in a number of preliminary tests to investigate the repeatability.

ANALYSIS OF CEN/TS 14972:2008, ANNEX A.3

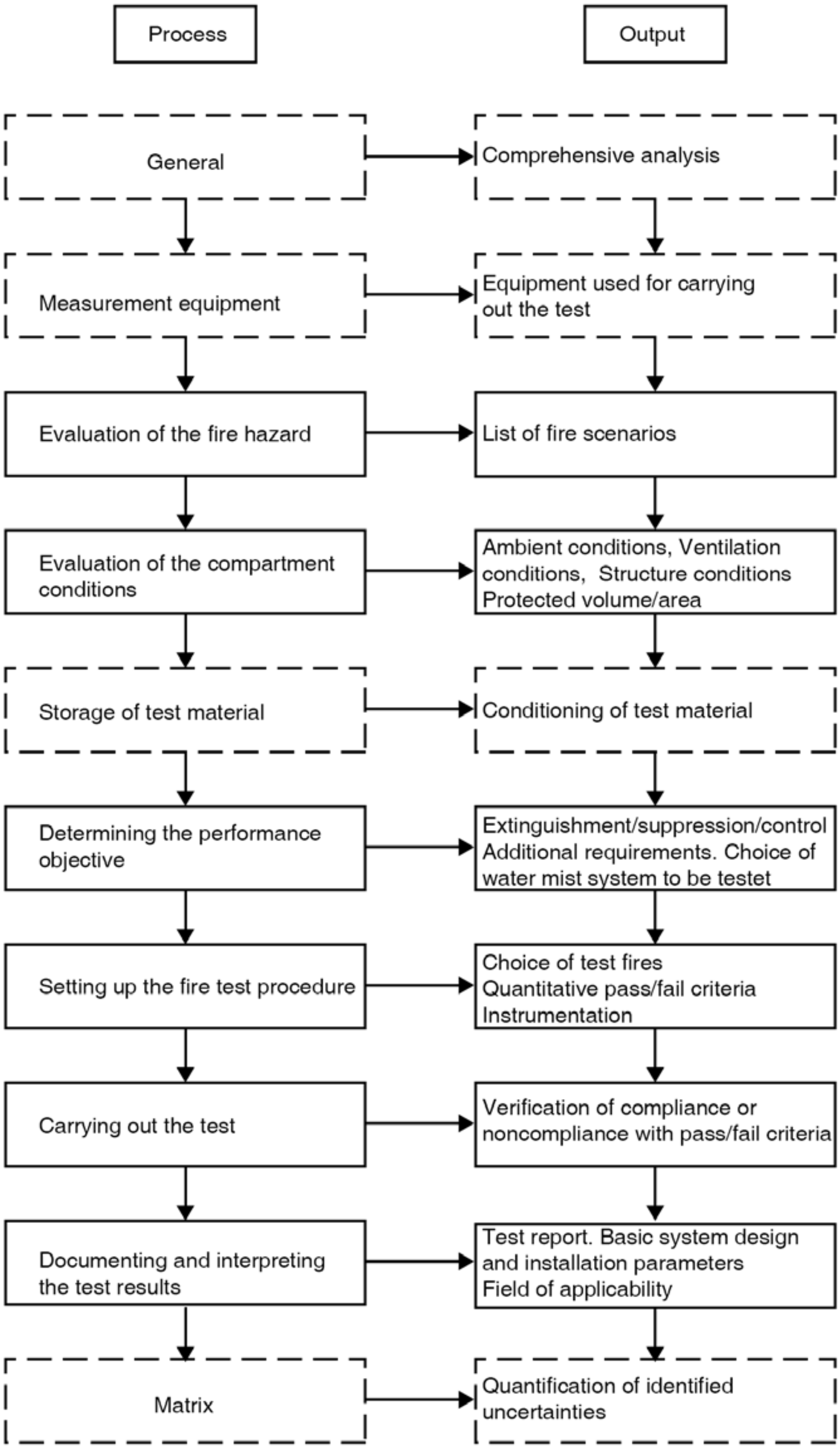
In order to analyse the existing standard a verified model described in Annex B, "Guidelines for Developing representative Fire Testing Procedures for water mist system" of CEN / TS 14972:2008 is used, see Figure 2.

Figure 2. “Guidelines for developing representative fire test procedures for watermist systems” in CEN/TS 14972:2008



This and similar models are described and used in a number of test documents by FIA and by Wighus[3, 4]. The model is essentially created as a guideline for the development of new testing methods, but in this case is used as the template for an analysis of an existing test from an uncertainty perspective. To get a more detailed view of the uncertainties a number of additions to the model have been introduced, see Figure 3. These additions are general setup, measurement equipment, storage of test material and a matrix to qualify the uncertainties.

Figure 3. Modified guideline for developing representative fire test procedures for water mist systems. The boxes with dashed lines are additions to the guideline.



An uncertainty analysis of the test document is performed to get an idea of which parameters are relevant to the experimental results. The goal is to separate out the parameters that have the greatest impact on the experimental repeatability and reproducibility. Furthermore to access how precise these parameters are described in the test document.

The detailed analysis of the parameters can be found in the B.Sc. by Håkansson & Langenbach [5]. Below are the 18 parameters listed in table 1.

Table 1 Overview of parameter

Nr	**Character of the parameter**	**Type of parameter**
1	Measurement equipment	Thermocouples
2	Combustible material	Solid wood – support systems, walls, drawer chair
3	Combustible material	Particle board – Office desk
4	Combustible material	Computer components
5	Combustible material	Paper material
6	Combustible material	Mattress material
7	Combustible material	Total fire Load [MJ]- variation
8	Design test set-up	Position support system, chair, table
9	Design test set-up	Mounting and design walls
10	Design test set-up	Position, design and mounting office desk
11	Design test set-up	Position, design and mounting chair
12	Design test set-up	Position, design and mounting drawer
13	Design test set-up	Position, design and mounting – material on office desk
14	Ignition source and procedure	Ignition source
15	Test room	Temperature test room
16	Test room	Ventilation
17	Storage of test materials	Conditioning
18	Evaluation of test results	Assessment of the damage criteria

As an example of one of the uncertainties is the use of solid wood in the test as the flame spread on wood will for example be depending on the grain orientation and density differences in the wood itself [6, 7].As another example the criteria for condition of the test material is very broad and do not follow the standard normally used, which can have a significant effect on fire spread as demonstrated by Axelsson et al. [8]. Also the time between the material is taken from the condition room to the time the test is carried out influences the result as shown by Khan & de Ris [9].

Uncertainty matrix

A matrix is used to illustrate the uncertainties in the existing test and what impact they have on the final outcome. The uncertainties identified categories judged on tolerance and effect. The tolerance measures the relative size of the range within which the parameter is allowed to fluctuate based on the test document. The effect is a relative measure of the impact that each parameter with a given tolerance has on the final outcome.

X-axis indicates the tolerance, i.e. the range within which the parameter in the current test document is allowed to vary. For example, the typical mass of an object is allowed to vary by 5%. This means for example that the desktop will have a total mass in the range of 53.2 to 58.8 (56) kg. Factors not specified in the present test document get a maximum tolerance. Rating scale is between 1-5.

Y-axis indicates the impact of the specified tolerance for the individual parameters is considered to have on the repeatability of either fire development or the outcome of the experiment. Rating scale is between 1-5.

Table 2. Tolerance and Effect matrix

Effect (Tolerance impact on the result)

Effect \ Tolerance	1	2	3	4	5
5				6, 18	5, 7, 8, 9, 13, 14,17
4				1, 3, 10, 12	16
3				2	4, 11, 15
2					
1					

Tolerance

It can be seen that most of the parameters are placed in the upper right corner which means that they have a high tolerance and also significant effect on the test result.

The main conclusions of this methodology used on the existing test method were:

- The uncertainty in the test procedure in its current form makes the test method unacceptable in order to obtain repeatable results.
- More work need to be done with respect to repeatability and especially reproducibility of the test in order for the test to become a European Standard (EN standard).

DEVELOPMENT OF NEW TEST METHOD

From the results of the parameter analysis done on the actual test a number of improvements are suggested to reduce the number of degrees of freedom and uncertainties in the test set-up:

- Introduction of a “model” approach in the test method without losing the scope of the original set-up
- Introduction of a symmetric test set-up to obtain a more stable and more symmetrical flame spread (the fire itself is placed asymmetrical in the setup)
- Create conditions to challenge the extinguishing system by increasing the amount of the total fire load which is ignited during the test. This is done adding an obstruction consisting of shelves and by introducing a set-up which allows more vertical and horizontal flame spread.
- Use of only a few well defined reference materials in the test
- Detailed description of the test set-up and involving materials
- Introduction of a number of functional performance requirements on the test set-up. For example the fact that the support for the table should not collapse. Moreover the shelves and/or walls should remain in place for at least 10 min. This should be in proved by means of free standing reference test.
- To determine qualitative by means of an engineering analysis the uncertainties and when possible determine them even quantitatively
- Tolerances according to ISO Standard 6182-1:2004 [10] should be used. This means that tolerance on length should be within 2% of the given value and temperatures within 5% of the given value.
- Improving the damage analysis by introducing a grid as overlay on the test setup

The improvements have been validated and developed both theoretically and by means of practical tests and can be found in detail in the thesis of Håkansson and Langenbach [5].

DESCRIPTION PROPOSED NEW TEST METHOD

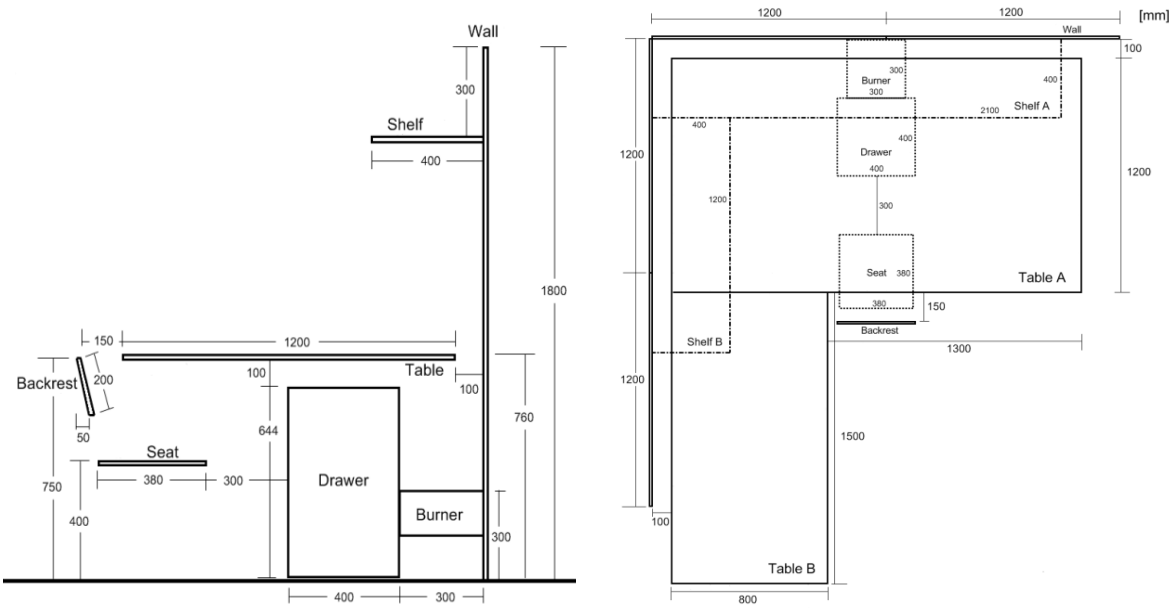
General description

A proposal for an improved test method was the main result of the work. This proposal should be seen as a first attempt in the improvement of the test standard. In the proposal a more pragmatic approach is used for the office test using a new theoretical framework. This encompasses that only two different combustible materials are used in the setup of the test. These materials are placed symmetrical and are well defined. A picture can be seen in figure 4.

Figure 4 Picture of the revised set-up

The thorough specification and the symmetry of the test setup, see figure 5 improve both repeatability and reproducibility of the test procedure. It also facilitates the process of evaluating the test results. All measurements in figure 5 are in millimetres with the dimensions, length x width x height/thickness.

Figure 5: Test setup seen from above (left) and on the side (right). Combustible items on the table plates and chair are not included.



Office fuel package

The fuel package is intended to be a model of a realistic worst case fire load in an office. The geometry of the fuel package implies both horizontal and vertical spray shielding and substantial potential for fire growth beyond the initial sprinkler operation. The choice of well defined corrugated cardboard and chipboard as reference materials reduces the uncertainties to internal properties such as handling of the material, water content and density. It also secures access to the specific materials independent of producer. The cardboard is to be cut and mounted into cassettes to facilitate the handling of the material and to reduce uncertainties due to movements within the material.
The type of corrugated cardboard that shall be used is defined as:

- 150C, 165 Eurokraft - 127 Semi-chemical fluting- 165 Eurokraft [11]

The type of chipboard that shall be used is defined according to the EN-standard with an added demand on density of the material:

- EN 312:2003 Type P1 with density 620-650 kg/m3 [12]

The fuel package consists of the following elements:

- A desk with metal frame including table plates made of chipboard
- One chair with metal frame
- One drawer unit made of chipboard
- Cassettes of corrugated cardboard representing files, books and office papers
- Two walls made of chipboard
- Two shelves made of chipboard

The definition of each individual component shall be as listed in table 3. The numbers in the brackets display the number of each item that is included in one test setup.

Table 3: Office fire load

Combustible material	Item	Mass/density [kg/m3]	Dimensions per item [mm]
Chipboard	Table plates (2)	620-650	Table A 2100x1200x22 Table B 1500x800x22
	Wall panels (4)	620-650	1800x1200x10
	Drawer unit (1)	620-650	644x400x400/22
	Bookshelves (2)	620-650	Shelf A 2100x400x22 Shelf B 1200x400x22
	Chair-seat (1)	620-650	380x380x10
	Chair- backrest (1)	620-650	400x200x10
Corrugated cardboard	Items on desk (42 cassettes)	See definition	Approx. A4 shape (300×200x100)
	Items on chair-seat (2 cassettes)	See definition	Approx. A4 shape (300×200x100)

The combustible items shall be conditioned for two weeks in a conditioning room with a relative humidity of 50±5% and a temperature 23±2 °C. The test shall be initiated within 30 minutes after the combustible items have been extracted from the conditioning room.

Desk

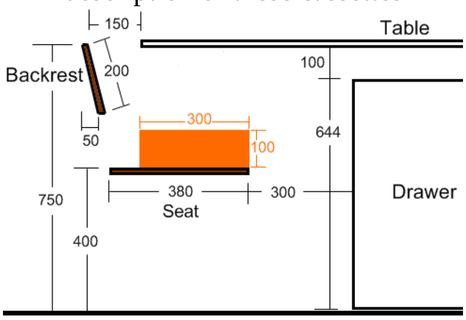
The desk shall consist of two metal frames, on which two plain uncoated 22 mm thick chipboard plates are mounted. The diameter of the metal components shall not exceed 40 mm to enhance the reproducibility in flame spread underneath the table plates. Table A measures 2100x1200x22 mm, and table B measures 1500x800x22 mm. The upper side of the desk shall be 760 mm above floor level.

There shall be a 100 mm spacing between the walls and the chipboard plates, see figure A.1 and A.2, to improve vertical flame spread. The desk is not allowed to fall or severely deform within 10 minutes from ignition of burner.

Chair

The chair shall consist of a metal frame where two pieces of chipboard are mounted, one as a horizontal seat, 380x380x10 mm, and one as a backrest 400x200x10 mm. The chair shall be centred with respect to table A and the front edge of the chair shall be positioned 300 mm from the wooden drawer. Flush with the front edge of the chair seat there shall be mounted two cassettes of corrugated cardboard, see figure 6.

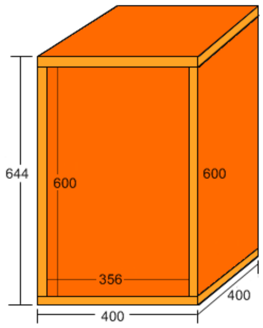
Figure 6 Chair from the side. The orange represents the cassettes of corrugated cardboard. See description of these cassettes



Wooden drawer unit

The drawer unit shall be made of 22 mm chipboard and shall have the measures of 644x400x400 mm, see figure 7. The unit shall be placed centred with respect to table A and in conjunction with the burner. Four steel supports shall be mounted to the bottom of the drawer to give the required distance of 100 mm, with respect to table 3.

Figure 7: The wooden drawer unit with measurements of all individual chipboard plates

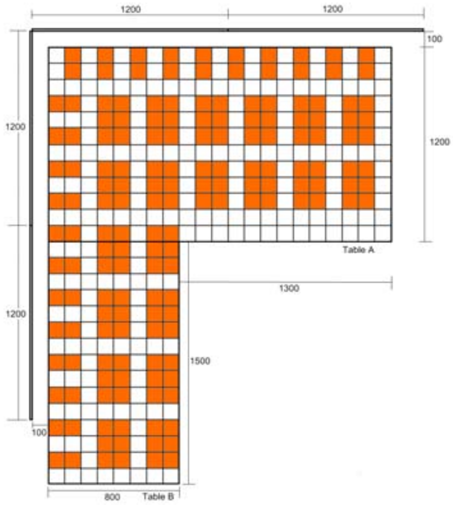


Items on the table

The combustible items on the table shall consist of corrugated cardboard mounted into cassettes with the dimensions 300x200x100 mm. The cassettes shall be fixed with wire, see figure 8, and be symmetrically placed in accordance with figure 8. The symmetry improves repeatability in the flame spread. The grid on the tables creates 100x100 mm squares.

Figure 8: Cassettes of corrugated cardboard fixed with wire.

Figure 9 Layout of the combustible items on the table. In total 42 cassettes are on the table.



Wooden shelves

Two shelves made of chipboard shall be mounted on the walls. Shelf A measures 2100x400x22 mm and Shelf B measures 1200x400x22 mm. The units shall be placed horizontally 1500 mm above the floor and should be connected to each other. The shelves are not allowed to fall down within 10 minutes from ignition of the burner.

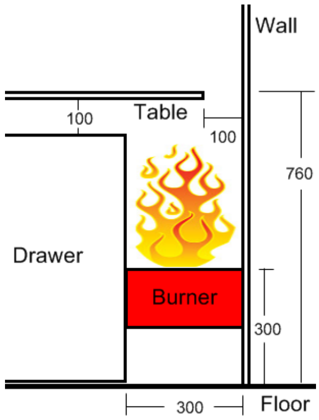
Walls

The walls shall stand on the floor and be made of four chipboard plates measuring 1800x1200x10 mm. Each wall shall extend 2400 mm from the corner, and as given in chapter A.3.2.3 there shall be 100 mm spacing between the walls and the table plates. The wall panels shall be attached to solid non-combustible plates with equivalent measures as the wall panels. The non-combustible plates shall be of Euroclass A1 according to EN ISO 1182 [13].The walls are not allowed to bend or twist within 10 minutes from ignition of burner.

The ignition source

The ignition source shall be accomplished by a porous propane gas burner measuring 300x300 mm in accordance with ISO 9705 [14].The heat release rate of the burner shall be 50 kW. The burner shall be placed centred with respect to table A. The top of the burner shall be placed 300 mm off the floor flush with the drawer on one side and the wall on the opposite side, see figure 10. The burner shall be ignited and operated for 180 seconds and then shut off.

Figure 10 The position of the gas burner with respect to the drawer unit and the wall.



ANALYSIS OF NEW TEST METHOD AND COMPARISON WITH ACTUAL TEST METHOD

The parameters are the same except for an extra parameter which is due to the fact that an obstruction for water droplets was introduced in the adapted test method. This is given as number 19. Applying the same procedure from table 1 for the new proposed method, produces the results in table 4.

Table 4: Qualitative matrix for the difference parameters in the new proposed test method.

Effect (Tolerance impact on the result)	1	2	3	4	5
5					
4		19	18		
3	14	3, 5, 7,10, 13, 16	9, 12		
2	15, 17	1, 11			
1	2, 4, 6, 8				
	Tolerance				

As can be seen in the table the majority of parameters has moved to the down left corner of the matrix meaning that less tolerances and less impact of tolerances on the test results are achieved. This means that at least the repeatability is improved by means of a more theoretical approach.

With the new test method a first set of tests were also done. These results showed an acceptable level of repeatability. More information can be found in the thesis of Håkansson and Langenbach [5].

PLASTIC IN FIRE TESTS

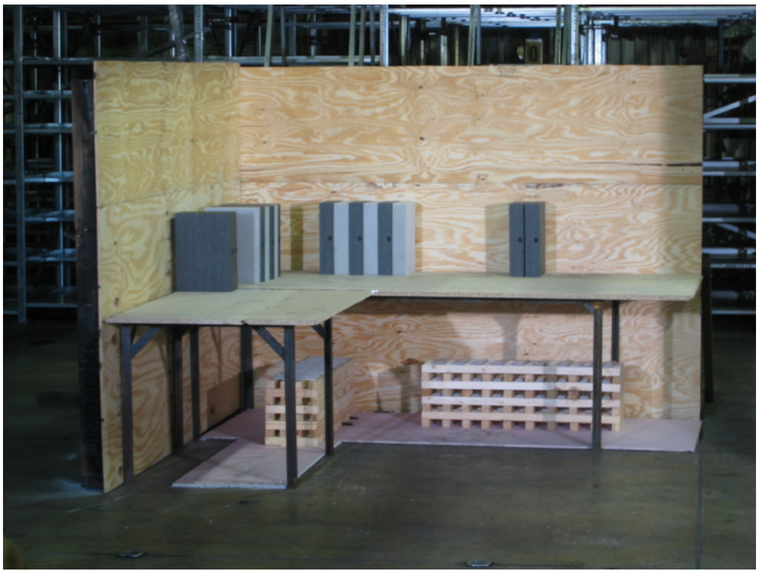
In the new test method no plastic materials have been included. The reason for this is that they increase the uncertainty in the test. In most offices however there are plastic materials and therefore this issue is discussed here.

Plastic material can be divided into two main groups based on burning behaviour: thermoplastic and thermosetting plastic. Thermoplastic melts before it burns and a thermosetting plastic decomposes and burns before it melts. The later type is easier to reproduce in fire tests as it will stay in the same position during the test, where as thermoplastic will melt and can run in arbitrary directions. Thermoplastic is a greater challenge for a water mist systems and it is also the more abundant type in an office. Examples of thermosetting plastic are melamine resin used on office desktop and on office shelves and typical thermoplastic is polyurethane foam (PUR) used as seating material in chairs. Also polyethylene (PE) used in plastic bags is a thermoplastic material. One problem with plastic materials is that many of them produce toxic gasses when burned. Especially plastic containing nitrogen, which will produce isocyanates and this can be at high levels [15, 16]. It is suggested that a suitable plastic material to use for a standard test is PMMA. PMMA is a thermoplastic, which is well defined and does not produce toxic products when burned. Sheets of PMMA could be packed in corrugated cardboard to represent a binder with paper.

COMPARISON WITH OTHER PROPOSALS

At the IWMA meeting in October 2010 in the UK, BRE presented their setup for an office test for water mist system. There are many similarities with the proposal by Håkansson and Langenbach[5]. The computer monitor has been removed and the items are placed in a systematic way. The biggest difference is that the BRE proposal has more material under the table and also included plastic material. Compared to typical offices in the Scandinavian countries too much material is placed under the table, creating a too challenging fire scenario.

Figure 11 BRE office setup presented at IMWA conference in 2010, UK.



DISCUSSION AND CONCLUSIONS

The uncertainties in the present test are of such a level that the test is not acceptable in order to produce repeatable and reproducible data. It is necessary that work and further development is performed with respect to the repeatability and reproducibility before the test method can be accepted or even considered as an EN standard. The test set-up in this test report should be seen as a first step towards the right direction in order to improve the test method. With the revised test document a model approach has been adapted. This means for instance that only two combustible materials are involved in the test set-up and that symmetry was introduced in the configuration. These improvements mean a considerable reduction of the uncertainties with respect to the actual document. This has been validated both theoretically and by means of practical tests in small and full scale. However it should be noted that even more experimental work is needed to fully establish a stable and reliable test method can be approved and used for regulations and possible certification. An issue, which has been discussed, but not included in the present proposal, is the use of plastic material in the test. The use of plastic material would result in a more challenging test setup.

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