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Extinguishing efficiency of powders against class A fires

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ABSTRACT

The Nordtest method NT FIRE 044 (*FIRE PROTECTION: Fire extinguishing media – powder*) describes a method for determining the characteristic extinguishing efficiency of powders against class C (gases) fires. The results of the test are used to give the powder both a class B (liquids or liquefiable solids) and C classification.

The present paper describes an equivalent test method for determining the characteristic extinguishing efficiency of powders against class A (solids which form glowing embers) fires. This method can be included as an amendment to the existing Nordtest method NT FIRE 044.

PREFACE

This report is a slightly modified version of the draft final report of the NORDTEST Project No. 1206-95 (January 24, 1996). The project was initiated because no operator or extinguisher independent standards for testing the characteristic extinguishing efficiency of powders against class A fires were available. The test method presented is equivalent to the test method of NT FIRE 044 for classifying powders against class B and C fires.

The authors wish to thank Prof. Matti Kokkala, who originally suggested the test method, and Mr. Tauno Andstén for providing us with the results of the preliminary test series.

Maarit Tuomisaari and Martti Yli-Penttilä

CONTENTS

1 INTRODUCTION

The Nordtest method NT FIRE 044 /1/ describes a method for determining the characteristic extinguishing efficiency of powders against class C (gases) fires. The results of the test are used to give the powder both a B (liquids or liquefiable solids) and C classification.

The method also includes a crib fire test for determining the extinguishing efficiency of powders against class A fires. The result of the test, however, is a combination of the characteristic extinguishing efficiency of the powder and the construction of the extinguisher. Therefore, the A classification is not equivalent to the B and C classifications. Annex D of NT FIRE 044 includes a note that the test method for A classification needs further development.

In the current national test methods and in the European standard for portable fire extinguishers EN 3-1 /2/ the extinguishers are classified against A fires based on their efficiency to extinguish crib fires. The classification depends on the size of the crib being extinguished. Like NT FIRE 044, these tests measure the extinguishing efficiency of the combination of the powder and the construction of the extinguisher – which is also reasonable – but an additional drawback of these crib fire tests is that the test result depends on the skills of the operator carrying out the test.

A preliminary test series carried out at VTT in 1993 indicated that the characteristic extinguishing efficiency of powders against class A fires can be determined using a flue type combustion chamber, the inner surface of which is being extinguished. In this method the specific influence of operators is eliminated as much as possible and the method gives the powders an A classification equivalent to the B and C classifications of NT FIRE 044.

The principal idea of the method is the same as in a solid fuel ramjet combustion chamber /3, 4/ applied e.g. in propulsion systems in aerospace engineering. For the present purpose, where suppression is the major issue, factors affecting the combustion are optimized in a different way.

The present paper describes how the test method of the preliminary study was optimized and finalized to be included as an amendment to the existing Nordtest method NT FIRE 044 for powder classification.

The report is organized as follows. The experimental set-up is described in Chapter 2 and the experimental results are summarized in Chapter 3. The results and the proposed test method are discussed in Chapter 4. The test method to be included as an amendment to NT FIRE 044 is given in Appendix 2.

2 EXPERIMENTAL ARRANGEMENT AND PROCEDURE

Figure 1 shows a schematic drawing of the experimental set-up while Figure 2 shows a photograph of the set-up. The set-up consists essentially of a vertically fixed flue, the inner surface of which is first ignited with a custom-made gas burner. After a sufficient free burning time, the flue is to be extinguished. A screw feeder in accordance with NT FIRE 044 is installed to inject the extinguishing powder into an adjustable air flow that distributes the powder into the flue from below. The following parameters need to be defined:

- flue material, size, thickness
- ignition source
- ignition and preburn times
- air flow rate during ignition and free burning.

The objective of the test method is to define the minimum powder feeding rate, i.e. the critical application rate $\dot{m}_e$ (g/s), at which the fire is extinguished in a reproducible manner and in a reasonable time. In NT FIRE 044 the reasonable time for extinguishing the C class gas fire is between 15 s and 60 s. If the time is shorter, the powder feeding rate is assumed to be above the critical application rate (a fraction of the powder is wasted and not used for suppression). If the time is longer, it is not considered reasonable any more. The reproducibility is defined so that at a maximum deviation of 10 % in the critical application rate, the fire must be extinguished within the acceptable time in at least three out of five tests.

In the present method the acceptable time limits for suppressing the class A fire had to be modified as described in Chapter 3.3. The definition of reproducibility is the same as in NT FIRE 044.

Combining the critical application rate with the burning rate of the fuel $\dot{m}_f$ (g/s), the REMP-value (Required Extinguishing Media Portion, $\dot{m}_e / \dot{m}_f$) can be determined. It is a quantitative measure of the extinguishing effectiveness of the powder.

2.1 FLUE

2.1.1 Combustion in a ramjet

The basic idea of the test method is the same as in a ramjet combustion chamber. In a cylindrical ramjet, different combustion zones (see Figure 3) can be identified /3, 4/:

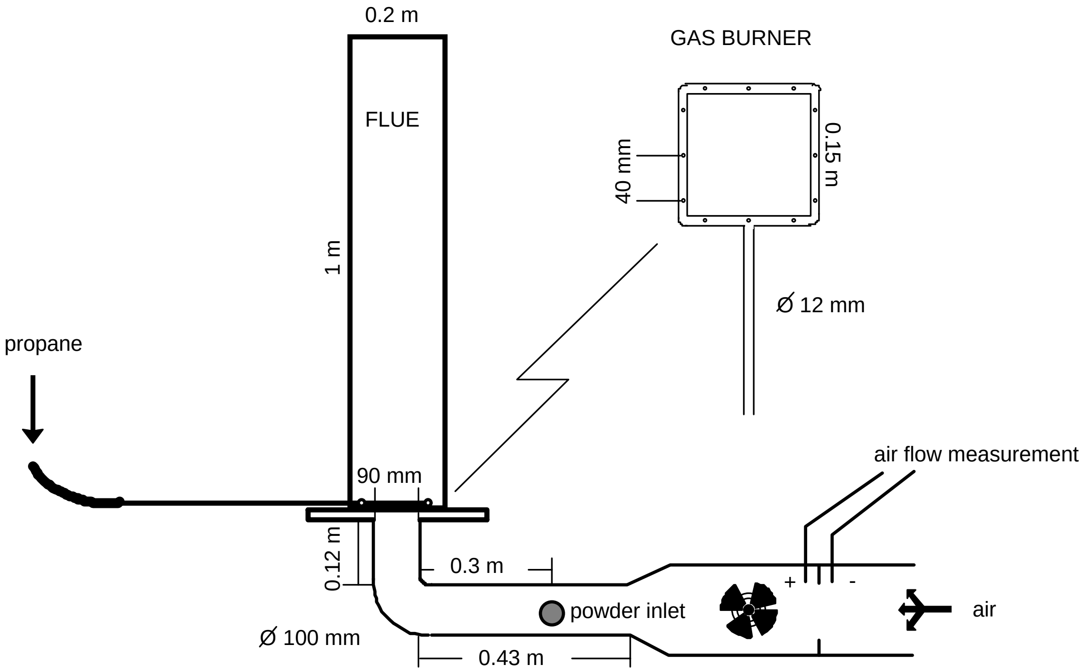


Figure 1. Schematic drawing of the experimental set-up.

Figure 2. Experimental set-up.
The storage tank and screw feeder motor to the right of the flue (not shown in Figure 1) make up the powder feeding system.

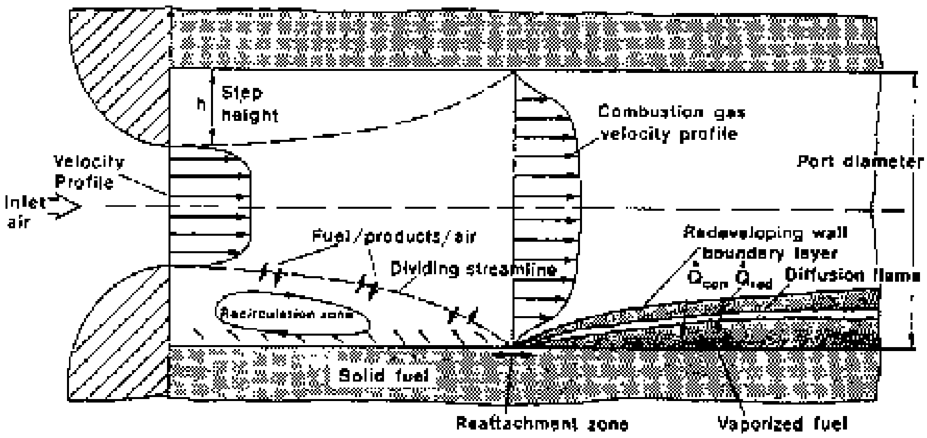


Figure 3. Schematic illustration of a ramjet flowfield /3/.

- Immediately after the inlet, there is a recirculation zone where the flow lines circulate back towards the inlet. The regression rate is low due to low velocities but the recirculation causes intense mixing of fuel, air and hot combustion products. The stabilized flame being formed in the recirculation zone can propagate throughout the combustor. To achieve sustained combustion a minimum step-height is required. With increasing step-height the length of the recirculation zone increases.
- Outside of the recirculation zone downstream, the flow lines attach to the solid boundary. This point is a stagnation point, where boundary layers begin to develop. No true reattachment point can be defined because of mass addition from the solid fuel walls, but it is possible to create a zone where effective reattachment does occur. The convective heat transfer and hence the regression rate is usually higher than further downstream, where the boundary layer is thicker.
- Further downstream of the reattachment point, there is a turbulent diffusion flame within the redeveloped boundary layer. Fuel vapours from the surface and oxygen-rich gases from the core flow diffuse from opposite sides into the boundary layer. This diffusion-controlled flame is sustained by the hot combustion products of the recirculation zone, which are partly mixed with the incoming core flow. The amount of vaporized fuel is determined by the convective and radiative heat transfer from the diffusion flame to the fuel surface. The thick boundary layer restricts the heat transfer but, on the other hand, the flow is accelerated by the burned fuel gases and convection is enhanced by the increasing velocity. These two effects may compensate for each other, and the surface outside the recirculation zone downstream may remain nearly parallel to the centre line.

2.1.2 Dimensions of the flue

For practical reasons the combustion chamber in the present case was not cylindrical but rectangular which complicates the flow lines at least locally close to the corners. Also, for practical reasons, chipboard was chosen to be the class A material. The edges of the walls were fixed to each other with a wood glue and the joints were strengthened by nails at 15 cm spacing.

Several different flue forms and sizes were tested during the preliminary study, ranging from 0.15 m cubes up to 1 m long flues. Also, the material thickness was varied from 11 mm to 18 mm. The present flue size, shape and thickness were selected empirically so that the mass loss rate was high enough to reach a sufficient resolution, the whole inner surface burned smoothly enough, and the fire did not self-extinguish.

In the preliminary tests and also in some of the present tests, a cover with a ∅100 mm outlet tube was applied on top of the flue partly because the residence time of the powder in the flue was expected to be too short without the cover. Also a typical ramjet combustion chamber has a narrow throat in the downstream end to maximize the thrust. Tests proved, however, that the cover was unnecessary for the present purpose, and it also rendered it more difficult to make visual observations during the test.

The finally applied flue was constructed of nominally 18 mm thick chipboard made of mixed confiner wood. The chipboard had a typical wall panel construction, i.e. a three-layer-construction: two denser outer layers and a middle layer. The outer layers were ~2.5 mm thick and had a density of ~830 kg/m^3, the middle layer was ~13 mm thick with the density of ~470 kg/m^3. The density, however, is not a critical factor in the test (see Chapter 2.5).

The cross section of the flue was a square, the dimensions of the inner surface being 0.2 m × 0.2 m × 1 m high. With the nominal material densities, the flue would weigh some 9 kg. The actual weight, however, was about 11 kg, so the density and thickness values have to be taken as approximations. Prior to assembling the flue, the chipboard plates were conditioned to a moisture content of about 6 ... 8 %. Only after the tests was it realized that more attention should have been paid to the issue of humidity. This has been taken care of in the proposed test method in Appendix 2.

In the tests, the burning rate of the chipboard was approximately 16.5 g/s. The heat of combustion at the given moisture content is approximately 12.5 MJ/kg /5/, and hence the approximate maximum heat release rate is 200 kW.

2.2 IGNITION SOURCE

In the preliminary tests the flues were ignited with a self-made torch-type gas burner that was manually inserted into the flue, held inside the flue during ignition, and then removed. The ignition procedure was not very reproducible and it could also be dangerous to the operator. Hence the method of ignition was modified.

A fixed propane gas burner was constructed for igniting the inner surfaces of the flue. The burner was made of ∅12 mm o.d. stainless steel tube in the form of a rounded square with 0.15 m sides (see Figures 1 and 5). On top of each side there were three ∅3 mm holes at 40 mm distance from each other. With smaller holes (∅2 mm) the flames tended to become detached from the burner, and the ignition procedure was not reproducible. The gas burner was fixed at the bottom of the flue throughout the experiment.

The propane flow rate was set to 0.8 g/s. At a lower rate the flue did not ignite at its entire length. The flow rate was determined with a rotameter.

2.3 AIR FLOW

The necessary air for sustaining the combustion process and also for distributing the powder, was fed into the flue via a ∅100 mm pipe, through a ∅90 mm hole in the centre of the lower end of the flue (see Figure 5). The bottom of the flue was otherwise closed by an incombustible Promatec plate (0.39 m × 0.39 m × 25 mm thick). For blowing the air, a pressure blower of type ABBA HA 219 manufactured by Svenska Fläktfabriken AB, Sweden, was used.

Different flow rates were tested to maximize the combustion efficiency and to sustain a steady regression rate. Combustion of wood requires roughly 5 kg of air per 1 kg of wood /6/. In the present tests, the burning rate was originally underestimated down to 11 g/s which corresponds to an air requirement of 50 g/s or about 40 l/s. To allow for slightly higher burning rates, 50 l/s was chosen for the air flow rate. The actual burning rate turned out to be about 16.5 g/s which corresponds to an air requirement of 65 l/s. In practice, however, the 50 l/s gave reasonable results, and it is also recommended in the proposed test method. In the preliminary tests the applied air flow rates (max 13.9 l/s) were much too low and the observed mass loss was caused by pyrolyzation of the surface, but the volatiles reacted with air mostly above the flue.

The flow rate was determined by measuring the pressure difference over an orifice plate in the blower. The differential pressure transducer was of type DTM 100 (0 - 100 mbar) manufactured by Huba Control, Switzerland, and shown in Figure 6.

The combustion efficiency was not specifically determined but in Ref.2 it was found to depend on the oxygen content, the length of the flue and its composition. With different plastics as the fuel, the efficiency varied between 70 and 90 % and it tended to level off at lengths larger than 0.6 m. In the present case the fuel material was fixed and the oxygen content could be varied only through the flow rate and not by changing the concentration. The length 1 m was assumed to be long enough for a cellulosic material to reach the maximum possible combustion efficiency.

In Ref.1 the regression rate was found to decrease with increasing diameter of the chamber. The size of the present chamber is clearly larger than is generally used for propulsion purposes, but to achieve sufficient resolution in extinguishing times and powder amounts, the burning surface had to be relatively large.

2.4 POWDER FEEDING

A powder feeder in accordance with NT FIRE 044 was applied. The screw feeder was of type K-TRON T20 manufactured by K-TRON SODER AG, Switzerland. The powder was fed into the air stream some 45 cm before the bottom of the flue (see Figure 5) at a preselected fixed rate. The rotation speed of the feeder had to be calibrated separately for each powder. The applied rates were always below 3 g/s.

2.5 TEST PROCEDURE

Prior to a test the flue material was stored in ambient conditions for variable times. After assembling the flue, its initial weight was recorded. The actual test was divided into three phases: ignition, free burning and suppression.

Ignition: After assembling the test set-up (except for the flue that was not placed in its position), the air flow rate was adjusted to 50 l/s and the propane gas flow rate to 0.8 g/s, and the gas was ignited (see Figure 7). The flue was then placed into its position. When in place, the flue was allowed properly ignited for 90 s, after which the gas burner was turned off (see Figure 8).

Free burning: The flue was allowed to burn freely for 60 s.

Suppression: The powder was fed into the flue at a preselected rate and the time of extinguishment was recorded by visual observation. After extinguishment, powder feeding was continued so that the total feeding time was 90 or 120 s, after which the flue was allowed to cool down. Lastly the flue was weighed to determine the average regression rate.

In a few tests the weight loss was recorded continuously, which – in a standard procedure – is quite necessary. For weighing the flue, both the gas burner and the air inlet tube were supported separately so that they were not in direct contact with the flue. The flue on the Promatec plate was fitted on a stand that was placed on a load cell. The output of the balance was recorded with a Solartron 35951 I.M.P. data acquisition system connected to an IBM 286 PC. The time resolution was 5 s.

The time of extinguishment was taken to be the time at which no flames could be seen from a distance of about half a metre (as close as possible to the top of the flue), even though in a few cases small flames remained burning for a while at the bottom of the flue. Some experiments were also carried out with an electrical circuit for determining the exact time of extinguishment: in the presence of the flame the ions would induce a current between the electrodes. The injected powder, however, complicated the situation so that no sharp drop in the current could be observed at the time of extinguishment.

Figure 4 shows the weight loss during test #78, where no extinguishing was attempted. The gas burner is on during the first 90 s. It takes about 30 s to ignite the surfaces properly, after which the regression rate is more or less constant. The burning rate during the 60 s free burning time is about 16.6 g/s.

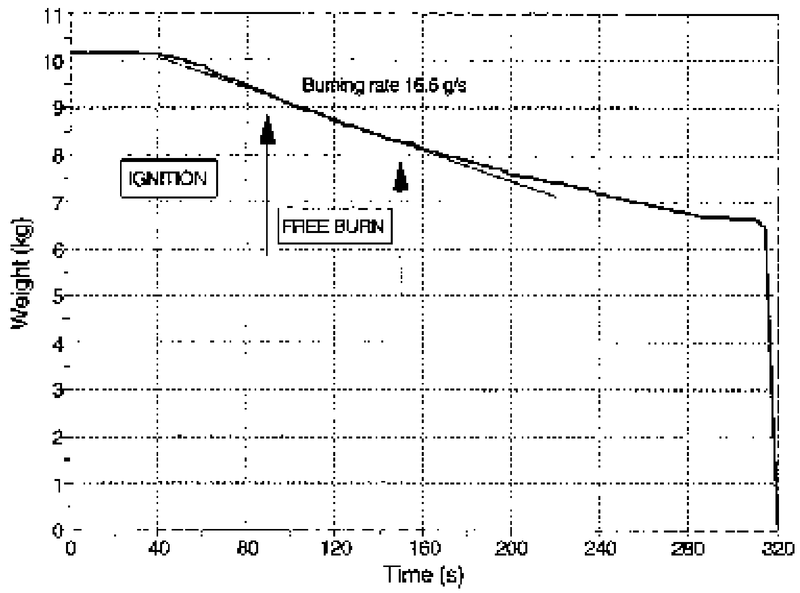


Figure 4. Mass loss during a test without suppression.

The charring rate β is approximately inversely proportional to the density of wood ρ

$$\beta \propto \left(\frac{1}{\rho}\right)$$

and hence the heat release rate $\dot{Q}$ (and the burning rate)

$$\dot{Q} = \beta \rho H_c$$

is almost independent of the density /5/. H_c is the heat of combustion and it is about the same for all conventional wood species or products but depends on the moisture content of the wood: at 0 % and 20 % the heat of combustion is about 15 MJ/kg and 10.5 MJ/kg, respectively. Hence the density of the chipboard is not critical, only the moisture content has to be defined.

The burning rate curve of a charring material like chipboard has a peak immediately after ignition /5/. The development of an insulating char layer decreases heat transfer to the virgin materials and, consequently, burning becomes slower. In the present system no fast burning is seen in the very beginning because it takes a few tens of seconds for the fire to spread over all the surfaces. However, as can be seen in Figure 4, the burning rate shows a slowly decreasing trend after all the surfaces have been ignited.

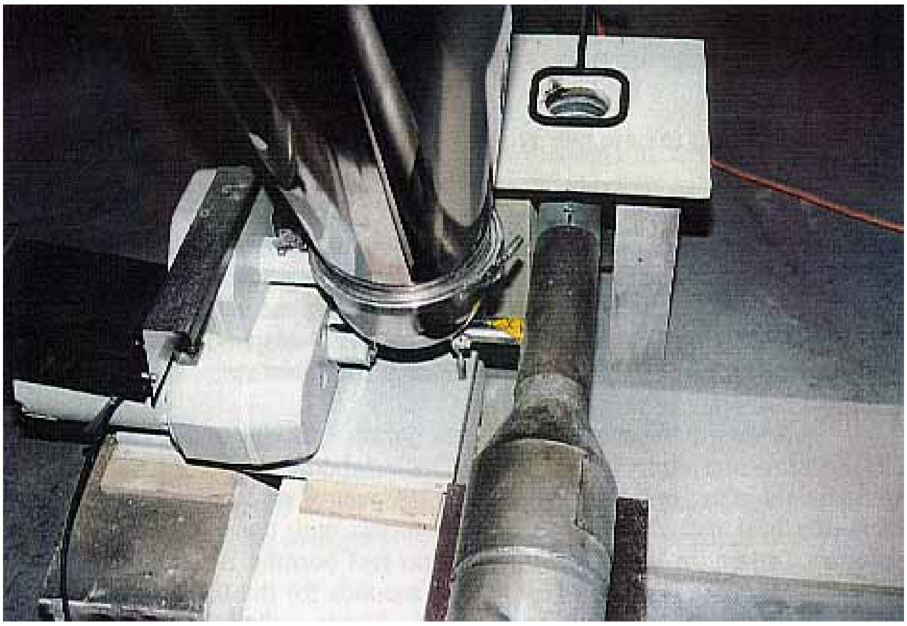


Figure 5. The powder feeder (left) is connected to the air stream line. The air blower is seen at the lower edge of the picture, and the gas burner on the Promatec plate centred around the air inlet hole at the upper edge.

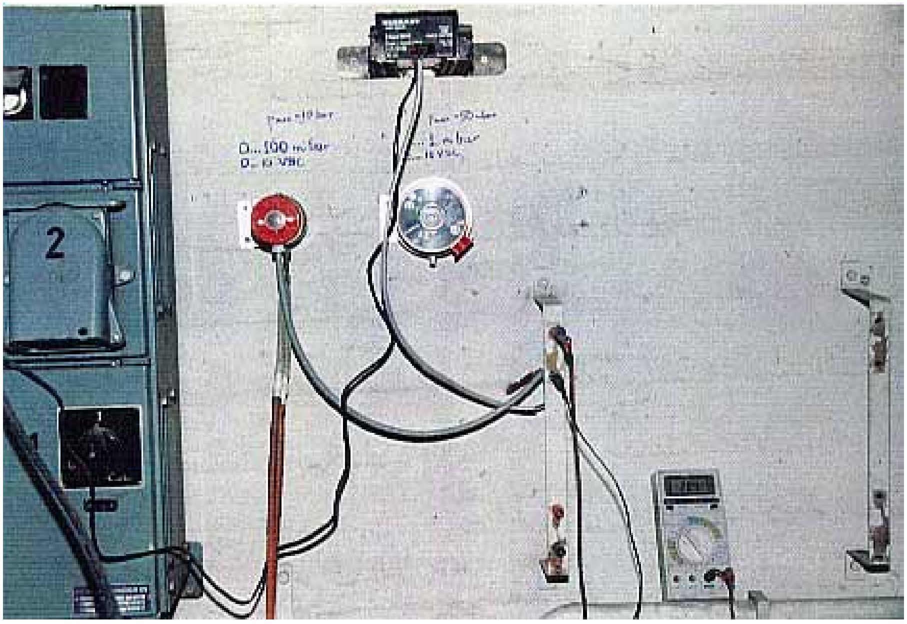


Figure 6. The pressure transducer set-up (red manometer) for determining the air flow rate.

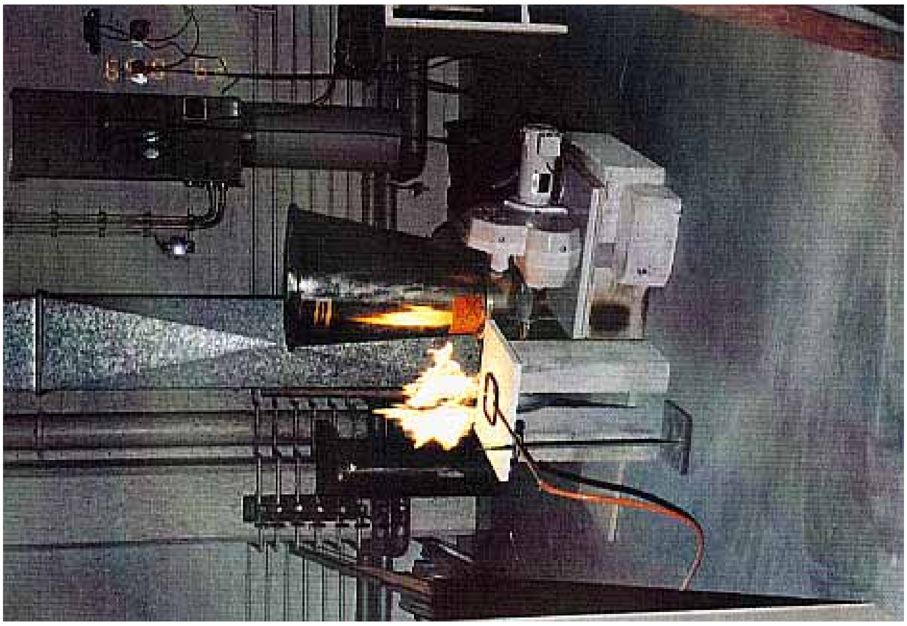


Figure 7. Ignition: the gas burner has been ignited.

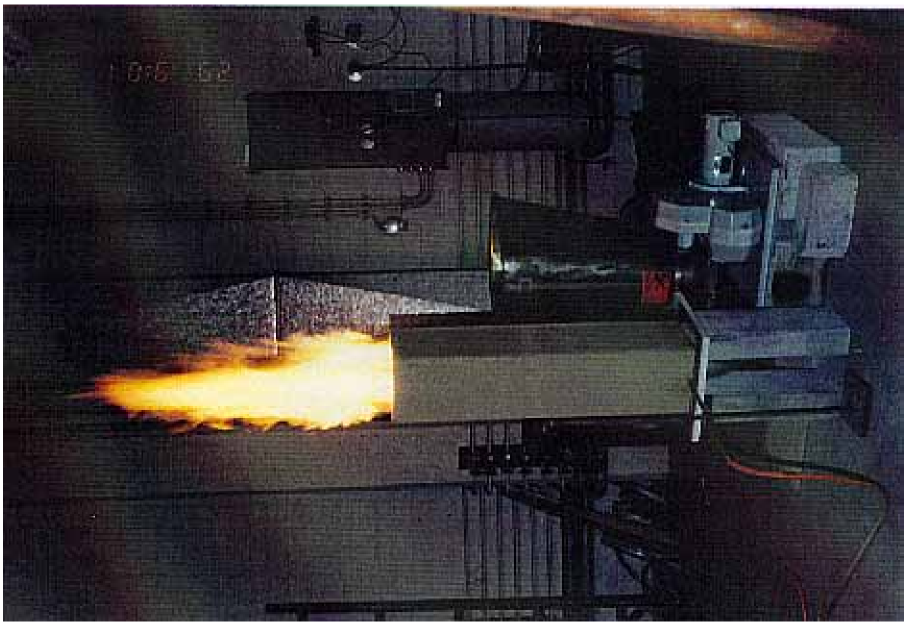


Figure 8. Free burning: the gas flow has been turned off and the flue is burning freely.

3 EXPERIMENTAL RESULTS

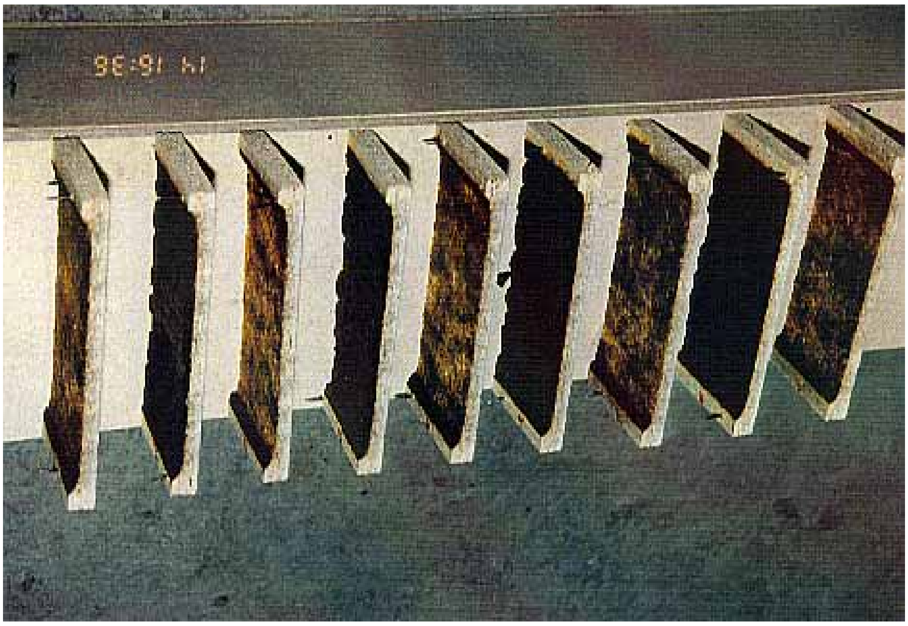
3.1 COMBUSTION OF THE FLUE

Two flues were disassembled after the test and the damages were analysed. Figures 9 a and b show photographs of the inner surfaces after a test. Figures 10 a and b show the inner surface profiles. The profiles can be interpreted by the different zones described in Chapter 2.1.1. At the very bottom of the flue, less material has been consumed (recirculation zone). At about 15 - 25 mm height there is a maximum in the fuel consumption (stagnation point or area). Further downstream the combustion has been more or less homogeneous (zone with the boundary layers) with a tendency to a lower regression rate at the top of the flue. This tendency may be due to a direct contact with ambient, cool air, whereas in a ramjet combustion chamber, after the fuel grain, there is a hot mixing chamber and the temperature gradient along the fuel cylinder is considerably smaller than in the present case.

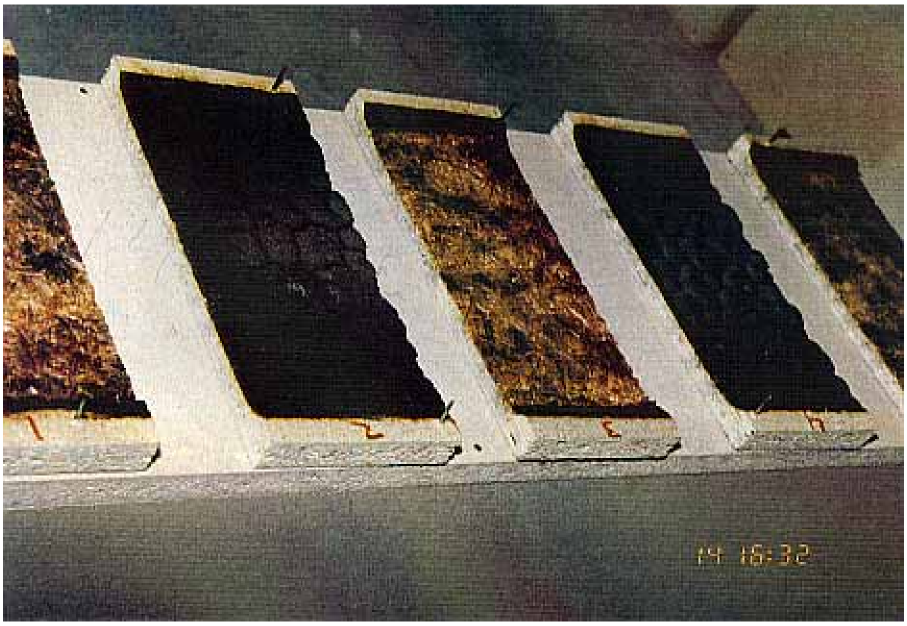
In both of the studied cases the 2.5 mm thick outer layer of the chipboard plate is consumed and, on the average, also 2.6 mm and 3.7 mm of the middle layer is lost. In the horizontal direction the material consumption has been very homogeneous except very close to the corners. From the point of view of material thickness, the burning time could have been longer than that applied, but in practice the joints between the wall plates eventually started to leak and hence the burning time had to be restricted.

Figures 11 a and b show the weight loss recorded during two tests. In test #79 the critical application rate is used and the fire is extinguished within an acceptable time (see Chapter 3.3). In test #80 the application rate is very low, and the fire is extinguished only after several minutes. The burning rate during free burning varies between 16.6 (Figure 4) and 16.9 g/s. The overall behaviour of the curves is very similar.

The effect of moisture content on the burning rate was not studied. The moisture content was determined by evaporating all the water in an oven at 105 ^{o}C and measuring the weight loss for a few representative samples. The moisture content was between 6 - 8 %.

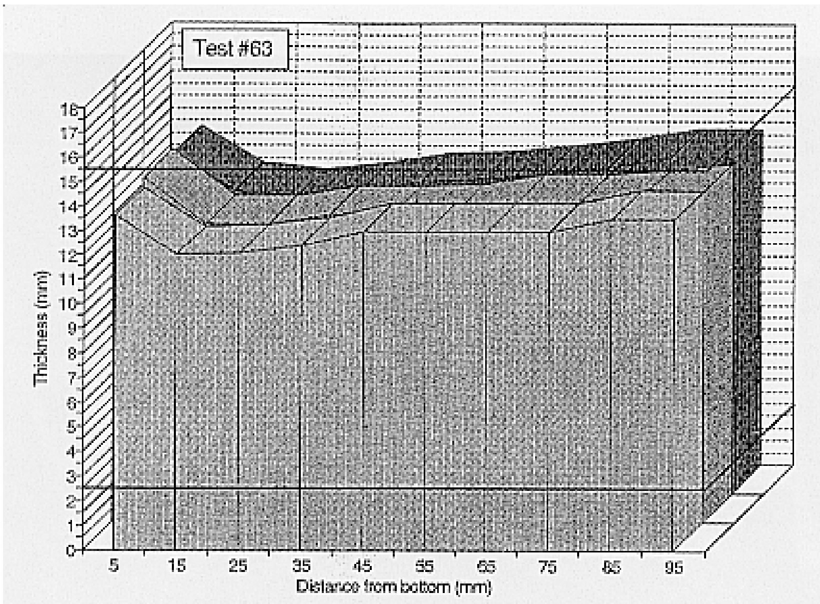


a) Pieces at their correct heights of the flue.

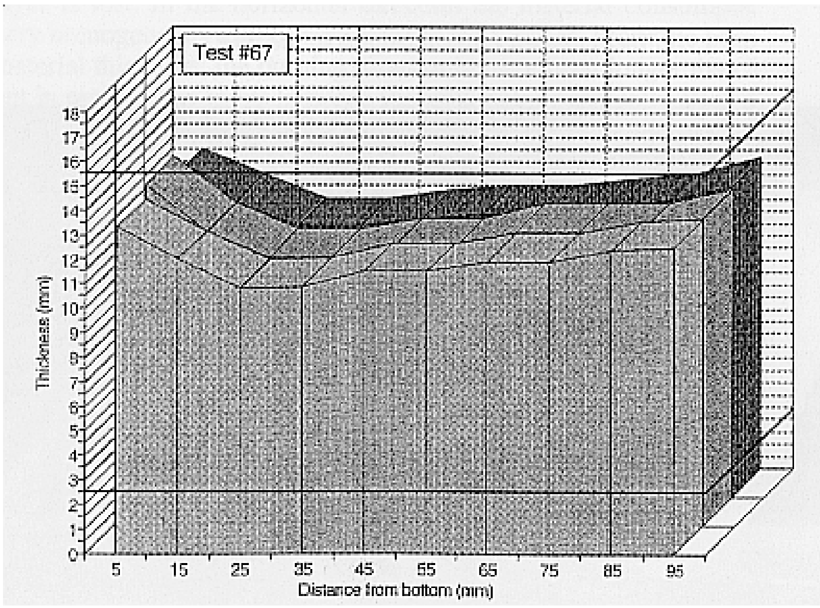


b) A close-up of the burned inner surface.

Figure 9. Cut pieces of a tested flue.
The char is scraped off from every second piece.

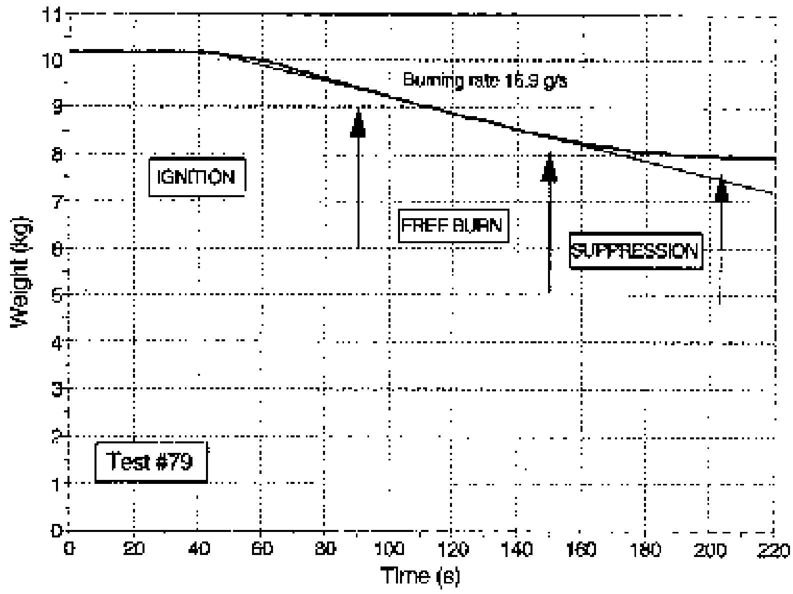


a) Test #63.

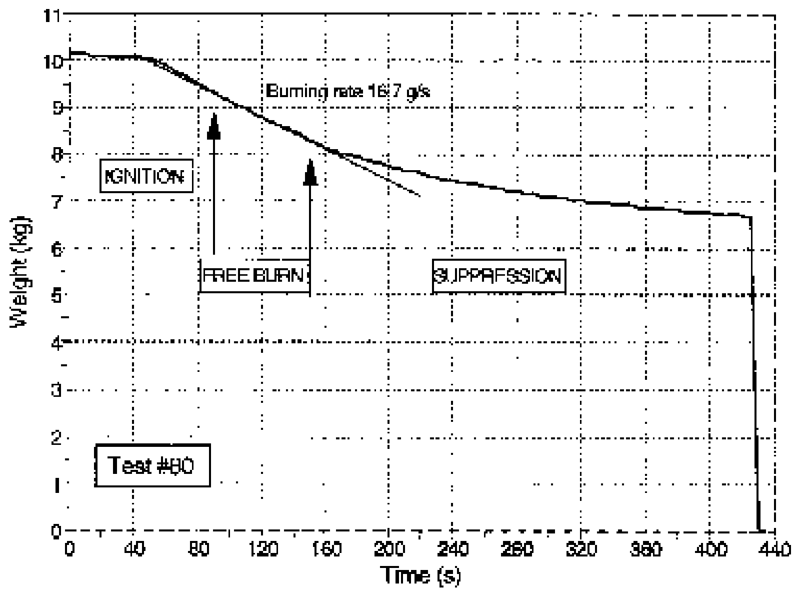


b) Test #67.

Figure 10. Inner surface profiles of two tested wall plates (originally 18 mm thick). The middle profile in each picture is determined for the centreline of the wall and the two outer profiles 5 cm away from the centreline in both directions. (The thick lines show the approximate locations of the boundaries between the different layers.)



a) Test #79: extinguishment within a reasonable time.



b) Test #80: Extinguishment within a few minutes.

Figure 11. Weight loss during tests.

3.2 CALIBRATION OF THE POWDER FEEDER

The following six commercial powders were tested: Favorit Tertia, Glutex, Kidde ABC, Monnex, Permex U40 ABE and Totalit Standard. The Monnex powder has only a B classification and it was selected for comparison, all the other powders are approved for both class A and B fires.

The powders have different particle sizes, densities and flow characteristics, and the screw rotation rate of the powder feeder corresponds to different mass flow rates depending on the powder. The calibration constants for the studied powders are given in Table 1. The powders are not identified with their proper names but they are given identification numbers in a random order.

Table 1. The calibration constants A for the screw driver feeding different powders ($\dot{m}$ [g/s] = $A \times v$ [rpm], r^2=1.00, 4 - 8 measurement points).

Powder	Monnex	1	2	3	4	5
$A\ [10^{-3}\ (\frac{g}{s}) / rpm\ ]$	3.0	3.335	4.087	4.222	4.485	3.921

3.3 MINIMUM POWDER FEEDING RATE

The test was repeated with each powder several times at different powder feeding rates. Some tests were also repeated with the same rate in order to study the reproducibility of the tests. For one powder two separate sets of tests were carried out at different times. Based on NT FIRE 044, extinguishing times of about 60 s were aimed at. In the following, only the most important results are presented, all test results are presented in tabular form in Appendix 1.

Figure 12 summarises the extinguishing times (within certain limits) as a function of powder feeding rates. The results indicate that a reasonable acceptable extinguishing time is between 40 s and 60 s instead of 15 s and 60 s which is adopted for the gas extinction in NT FIRE 044. Below 40 s the variations in the application rate may be much larger than the reproducibility limit of 10 % and the critical application rate is presumably exceeded.

Table 2 summarises the critical application rates and the REMP-values for the different powders when using the given extinguishment time limits. The burning rate during free burning was properly recorded only in the very last tests where it varied between 16.6 g/s and 16.9 g/s. For calculating the REMP-value for the other tests, a constant burning rate of 16.5 g/s was assumed. The burning rate was slightly lower than that measured because presumably the moisture content was higher in the earlier tests.

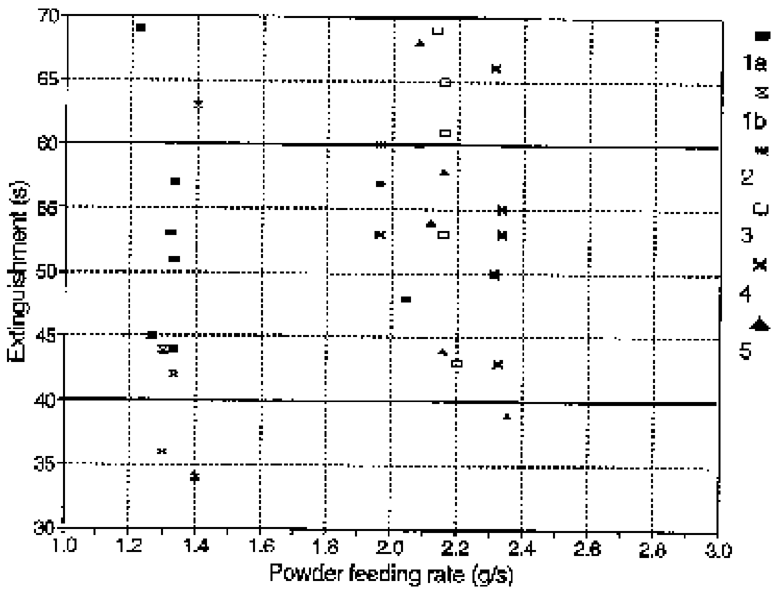


Figure 12. Application rates for the different powders.

Table 2. Critical application rates (extinguishment between 40 s and 60 s) and REMP-values.

Powder	Critical application rate (g/s)	(g/s/m^2)	REMP-value	No. of acceptable tests
1 a	1.33 ± 0.01	1.66	0.08	4
b	1.30 ± 0.03	1.63	0.08	3
2	1.98 ± 0.04	2.48	0.12	5
3	2.17 ± 0.03	2.71	0.13	2
4	2.32 ± 0.01	2.90	0.14	4
5	2.13 ± 0.04	2.66	0.13	4

It should be noted that the given values are not strictly comparable due to the uncertainties in the burning rate of the fuel. The average burning rate of acceptable tests could vary as much as 20 %. If the same variation applies to the true burning rate during free burning, it would show up in the second decimal of the REMP-value by ± 0.02 at most. The variations in the burning rate may be partly caused by different moisture contents that were not determined systematically; their effect on the critical application rate is not known.

The critical application rates are only 10 - 50 % of the rates used for suppressing a small room fire manually with portable extinguishers /7/. The difference is to a large extent caused by uneven application of the powder in the large-scale tests. On the other hand, the low critical application rates obtained here, indicate that the efficiency of suppression can be improved by proper application techniques.

A few tests were run with the Monnex powder, and the fire could be extinguished at mass flow rates higher that 1.2 g/s but the flue always reignited after the powder feeding stopped. This case was not studied any further because one essential criterion for passing the tests and giving the powder an A classification is that the flue must not reignite.

4 DISCUSSION

An extensive number of tests were carried out to form a basis for a test method for determining the extinguishing efficiency of powders against class A fires. The proposed test method given in Appendix 2 is equivalent to that of NT FIRE 044 for classifying powders against class B and class C fires, and it is almost totally independent of the operator.

The fuel in the tests is in the form of a square chipboard flue, the inner surface of which is to be extinguished within an acceptable time. The density or the wood material of the chipboard is not a critical factor, but its moisture content should be under better control than in the present tests. This issue has been considered in the proposed method.

Most of the equipment required by the existing NT FIRE 044 can be used also in the proposed amendment: the fuel of course, and the gas burner are different and an extra air blower is also required for the class A fire tests. The same powder feeder, weighing system and measuring facility can be used – it is not required, though. For example, recording the powder feeding rate during a test was not found necessary as in the existing NT FIRE 044: careful calibration of the powder feeder is sufficient. Also, for recording the weight loss of the flue, 5 s was found to be a sufficient time resolution instead of 1 s.

The acceptable time limits for extinguishment had to be modified from the current 15 - 60 s, because the variations in the powder feeding rate could be too large. The limits were set to 40 - 60 s, as they were found to give reproducible results and differences between different powders could be exposed.

Another way to compare the efficiency of the powders would be to apply a fixed powder application rate, say 2 g/s, and to measure the time to extinguishment. This way – although informative – would not reveal the critical application rate and the REMP-value.

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TEST RESULTS

In the following, all test results are given in tabular form. The results also include the data obtained in the preliminary tests even though the data are not complete. The columns in the table should be interpreted as follows:

Test #	Running number of the tests. The preliminary tests are identified as *pr#*.
Date	Test date (not available for the preliminary tests)
Flue side, height	The dimensions of the rectangular flue (square cross section)
Cover	Cover applied or not applied
Burner	Type of gas burner
Air flow	Air flow rate through the flue during the test (In the preliminary tests the flow rate could be different during ignition and free burning.)
Gas flow	Propane flow rate in the gas burner
Ign.time	Ignition time, i.e. time with the gas burner on
Free burn	Time after turning off the gas burner and before starting the suppression
Powder	Identification number of the extinguishing powder
Feed rate	The feeding rate of the powder as given by the automatic feeder (rpm) and converted to g/s
Ext.time	Extinguishing time after starting the suppression
Feed time	Total powder feeding time
Air flow	Free air flow time after interrupting the powder feeding
Initial weight	Initial weight of the flue
Final weight	The weight of the flue after the test
Ave burn rate	The burning rate calculated by dividing the difference between the initial and final weights by the sum of the ignition, free burning and suppression times
REMP ave	REMP-value calculated by the average burning rate
REMP true	REMP-value calculated by the stabilized free burning rate of 16.6 g/s

Test #	Date	Flue side, height (m)	Cover (+/-)	Burner	Air flow (l/s)	Gas flow (g/s)	Ign. time (s)	Free burn (s)	Powder	Feed rate (rpm)	Feed rate (g/s)	Ext. time (s)	Feed time (min)	Air flow (min)	Initial weight (kg)	Final weight (kg)	Ave burn rate (g/s)	REMP ave	REMP true	Comments
pr1	93	0.15,0.15	+	torch	5		60	120												
pr3	93	0.2,0.2	+	torch	0.5		180													self-extinguished
pr4	93	0.15,0.15	+	torch	5		240	240							2.37	2.01	0.7			
pr5	93	0.15,0.15	+	torch	5		180	240							2.38	2.03	0.8			
pr8	93	0.15,0.5	+	torch	5.6		120	120							3.51	2.95	2.3			
pr9	93	0.15,0.5	+	torch	0.2		120	180							3.50	2.93	1.9			
pr10	93	0.15,0.5	+	torch	0.2		120	180							3.47	2.53	3.2			
					6.4			120												
pr11	93	0.15,0.5	+	torch	0.2		120	180							3.10	2.26	2.8			
					7.2			120												
pr12	93	0.15,0.5	+	torch	0.2		120	120							3.54	2.41	4.7			
					7.5			180												
pr13	93	0.15,1.0	+	torch	8.3		90													
					13.9			120												
pr14	93	0.15,1.0	+	torch	8.3		120								6.74	4.46	9.5			
					13.9			120												
pr15	93	0.15,1.0	+	torch	8.3		120								5.65	3.71	6.5			
					15.8			180												
pr16	93	0.15,0.5	+	torch	0.4		90		1a			3								
					6.4			120												
pr17	93	0.15,1.0	+	torch	6.4		120		1a			10					8.8			
					13.9			120												
pr18	93	0.15,1.0	+	torch	6.4		120		1a			8					9.0			
					13.9			120												
1	13.9.95	0.2,1.0	+	sqr, 2mm	16.7	0.8	120	90							11.43	9.27	10.3			
2	"	0.2,1.0	+	sqr, 2mm	13.9	0.7	60	120							11.29	9.62	9.3			
3	15.9.95	0.2,1.0	-	sqr, 2mm	38	0.7	120	120							9.22	7.10	8.8			flue of test #1
4	18.9.95	0.2,1.0	+	sqr, 2mm	38	0.8	60	120							7.42	5.20	12.3			12 mm plate
5	"	0.2,1.0	+	sqr, 2mm	38	0.7	60	60							11.01					self-extinguished
6	"	0.2,1.0	+	sqr, 2mm	38	0.8	50	130								7.82				flue of test #5
7	28.9.95	0.2,1.0	+	sqr, 2mm	38	0.8	60	180	Monnex	900	2.7	9			9.61					reignition
8	29.9.95	0.2,1.0	+	sqr, 3mm	50	0.8			Monnex	500	1.5	-	1.5							
9	"	0.2,1.0	+	sqr, 3mm	50	0.8	60	60												self-extinguished
	"	0.2,1.0	+	sqr, 3mm	50	0.8	60	140	Monnex	500	1.5	12								
10	2.10.95	0.2,1.0	+	sqr, 3mm	50	0.8	90	120	Monnex	500	1.5	15			11.27	7.83	15.3	0.10		reignition
11	"	0.2,1.0	+	sqr, 3mm	50	0.8	90	60	Monnex	400	1.2	60			11.18	7.67	16.7	0.07		reignition
12	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	Monnex	900	2.7	11	1	1	11.20	8.28	18.1	0.15		reignition
13	5.10.95	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	Monnex	800	2.4	8	2		11.21	8.59	16.6	0.14		reignition
14	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	Monnex	800	2.4	9	5	3.7	10.86	6.00	30.6	0.08		reignition
15	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	Monnex	600	1.8	13	5	1.6	11.33					reignition
16	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	1a	600	2.0	19	5	5	11.19	9.25	11.5	0.17	0.12	
17	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	1a	400	1.3	44	4	6	11.15	8.92	11.5	0.12	0.08	
18	12.10.95	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	1a	307	1.0	210	4	1	11.34	8.36	8.3	0.12	0.06	
19	13.10.95	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	1a	366	1.2	69	2	1	11.58	9.41	9.9	0.12	0.07	
20	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	1a	733	2.4				11.32				0.15	reignition
21	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	1a	733	2.4	17	0.5	0.0	11.41	9.40	12.1	0.20	0.15	
22	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	1a	400	1.3	51	2	1	11.39	9.19	10.9	0.12	0.08	
23	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	1a	380	1.3	86	2	1	11.16	8.75	10.2	0.12	0.08	
24	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	1a	400	1.3	57	2	1	11.22	9.08	10.3	0.13	0.08	
25	16.10.95	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	1a	395	1.3	53	2	1	11.32	9.11	10.9	0.12	0.08	
26	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	5	375	1.3	-	2		11.50					not extinguished
27	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	5	450	1.8	86	2	1	11.35	9.00	10.0	0.18	0.11	
28	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	5	500	2.0	117	2	1	11.30	8.68	9.8	0.20	0.12	

Test #	Date	Flue side, height (m)	Cover (+/-)	Burner	Air flow (l/s)	Gas flow (g/s)	Ign. time (s)	Free burn (s)	Powder	Feed rate (rpm)	Feed rate (g/s)	Ext. time (s)	Feed time (min)	Air flow (min)	Initial weight (kg)	Final weight (kg)	Ave burn rate (g/s)	REMP ave	REMP true	Comments
29	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	5	600	2.4	39	2	1	11.28	9.24	10.8	0.22	0.14	
30	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	5	550	2.2	58	2	1	11.41	9.30	10.2	0.21	0.13	
31	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	5	550	2.2	44	2	1	11.11	9.01	10.8	0.20	0.13	
32	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	5	540	2.1	54	2	1	11.06	8.92	10.5	0.20	0.13	
33	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	5	530	2.1	60	2	1	10.82	8.63	10.4	0.20	0.13	
34	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	5	530	2.1	68	2	1	10.73	8.45	10.4	0.20	0.13	
35	18.10.9	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	474	1.9	20	2	1	10.83	8.93	11.2	0.17	0.12	
36	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	474	1.9	37	2	1	10.98	8.99	10.7	0.18	0.12	
37	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	390	1.6	39	2	1	11.05	9.01	10.8	0.15	0.10	
38	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	350	1.4	52	2	1	11.41	9.44	9.8	0.15	0.09	
39	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	340	1.4	56	2	1	11.10	9.04	10.0	0.14	0.08	
40	10.11.9	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	330	1.3	-	2	0	10.89					interrupted
41	27.11.9	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	340	1.4	66	2	0	10.91	8.55	10.9	0.13	0.08	
42	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	340	1.4	93	2	0	11.20	8.75	10.0	0.14	0.08	
43	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	350	1.4	73	2	0	10.94	8.68	10.1	0.14	0.09	
44	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	360	1.5	87	2	0	11.16	8.82	9.9	0.15	0.09	
45	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	370	1.5	63	2	0	11.15	8.95	10.3	0.15	0.09	
46	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	370	1.5	120	2	0	11.13	8.45	9.9	0.15	0.09	
47	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	370	1.5	-	2	0	11.06					interrupted
48	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	380	1.6	-	2	0	10.27					interrupted
49	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	420	1.7	138	2	0	10.35					interrupted
50	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	460	1.9	106	2	0	11.11	8.40	10.6	0.18	0.11	
51	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	500	2.0	48	1.5	0	11.15	8.89	11.4	0.18	0.12	
52	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	480	2.0	57	1.5	0	10.62	8.22	11.6	0.17	0.12	
53	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	480	2.0	60	1.5	0	10.35	7.90	11.6	0.17	0.12	
54	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	480	2.0	90	1.5	0	10.27	7.60	11.2	0.18	0.12	
55	28.11.9	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	480	2.0	57	1.5	0	10.94	8.59	11.3	0.17	0.12	
56	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	3	480	2.0	84	1.5	0	10.61	7.94	11.4	0.18	0.12	
57	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	3	500	2.1	72	1.5	0	10.53	7.97	11.5	0.18	0.13	
58	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	3	520	2.2	43	1.5	0	10.75	8.50	11.7	0.19	0.13	
59	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	3	510	2.2	53	1.5	0	10.47	8.30	10.7	0.20	0.13	
60	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	3	505	2.1	69	1.5	0	10.86	8.40	11.2	0.19	0.13	
61	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	3	505	2.1	84	1.5	0	10.63	7.86	11.9	0.18	0.13	
62	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	3	510	2.2	65	1.5	0	10.37	7.79	12.0	0.18	0.13	
63	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	3	510	2.2	61	1.5	0	10.47	8.03	11.6	0.19	0.13	
64	29.11.9	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	4	510	2.3	76	1.5	0	10.40	7.85	11.3	0.20	0.14	
65	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	4	520	2.3	55	1.5	0	10.24	7.66	12.6	0.19	0.14	
66	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	4	520	2.3	53	1.5	0	10.38	7.93	12.1	0.19	0.14	
67	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	4	515	2.3	66	1.5	0	10.33	7.73	12.1	0.19	0.14	
68	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	4	518	2.3	43	1.5	0	10.52	8.20	12.0	0.19	0.14	
69	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	4	515	2.3	50	1.5	0	10.63	8.28	11.8	0.20	0.14	
70	30.11.9	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	1b	400	1.3	110	1.5	0	10.09	7.37	10.4	0.13	0.08	
71	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	1b	460	1.5	27	1.5	0	10.8	8.59	12.3	0.12	0.09	
72	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	1b	420	1.4	63	1.5	0	10.10	7.48	12.3	0.11	0.08	
73	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	1b	420	1.4	34	1.5	0	10.63	8.37	12.3	0.11	0.08	
74	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	1b	400	1.3	42	1.5	0	10.92	8.65	11.8	0.11	0.08	
75	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	1b	390	1.3	44	1.5	0	10.79	8.36	12.5	0.10	0.08	
76	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	1b	390	1.3	36	1.5	0	10.84	8.62	12.0	0.11	0.08	
77	"	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	1b	380	1.3	45	1.5	0	10.71	8.42	11.7	0.11	0.08	
78	12.1.96	0.2,1.0	-	sqr, 3mm	50	0.8	90	>18												free burn, 16.6 g/s
79	12.1.96	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	480	2.0	53	4	0			11.1	0.18	0.12	16.9 g/s
80	12.1.96	0.2,1.0	-	sqr, 3mm	50	0.8	90	60	2	350	1.4	>300								16.7 g/s

PROPOSED AMENDMENT TO NT FIRE 044

FIRE PROTECTION:
FIRE EXTINGUISHING MEDIA – POWDER

In the following, relevant amendments to the existing Nordtest method are given. The exact formulation of the text depends on whether the method is accepted as an amendment or as a replacement for the existing method for A classification. The whole text of NT FIRE 044 has to be revised correspondingly.

FOREWORD

The methods of determination of efficiency against class A, class B, and class C fires are completely new and they are based on results and experience from research projects referenced in Annex C. The methods allow quantitative information about the efficiency, and the influence of the operator is minimized.

6. METHOD OF TEST

6.2 Class A fire test

6.2.1 Principle

The performance against a class A fire is tested by using a flue-type construction, the inner surface of which is to be extinguished by the powder fed into the flue from below. The achieved critical application rate of powder is used as a measure of its extinguishing efficiency.

6.2.2 Apparatus

6.2.2.1 Flue

The 1 m high, rectangular (inner side width 0.2 m) flue is made of 18 mm thick chipboard. Both ends of the flue are open. In the test, the flue is standing on an incombustible plate (e.g. Promatec, Navilite) with an air inlet hole in the middle. The hole diameter must be slightly bigger than the air inlet tube so that the flue and the tube can be supported separately.

Prior to the test the flue is conditioned in 23 ± 2 ^{o}C and 50 ± 5 % humidity to achieve 8 % equilibrium moisture content of the chipboard.

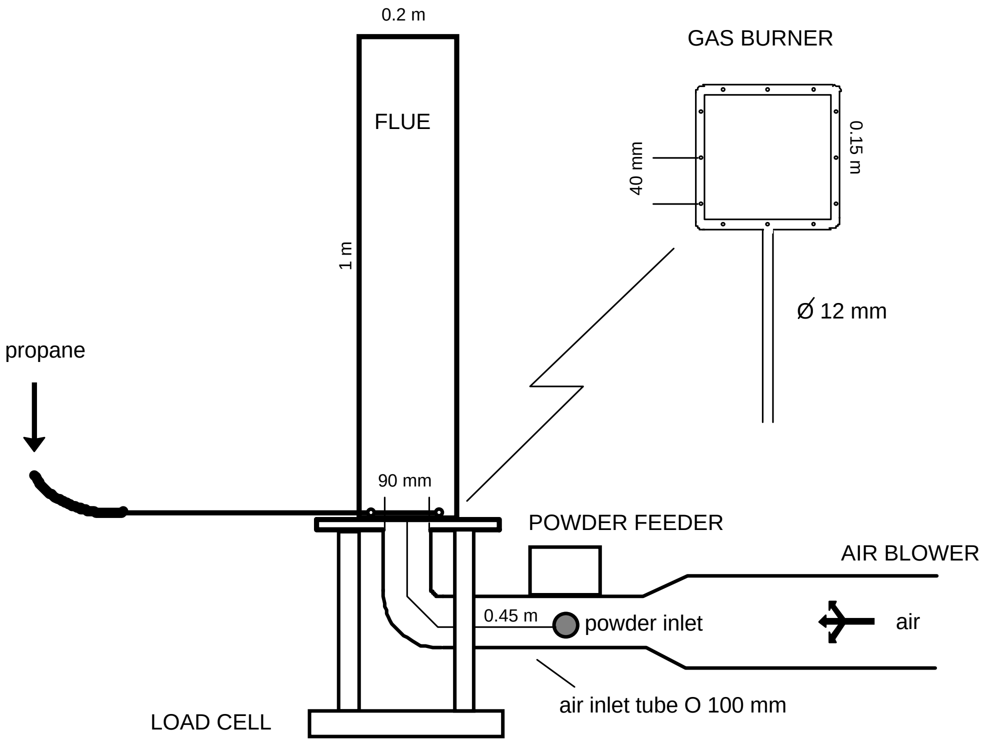

Figure 1. Test set-up for class A fire test.

6.2.2.2 Gas burner

The gas burner is made of ∅12 mm o.d. stainless steel tube in the form of a rounded square with 0.15 m sides (see Figure 1). On top of each side there are three ∅3 mm holes at 40 mm distance from each other.

6.2.2.3 Air flow

The air for sustaining a combustion process and for distributing the powder, is fed into the flue via ∅100 mm o.d. pipe with a narrowing of ∅90 mm i.d. at the centre of the lower end of the flue (see Figure 1). For blowing the air, a pressure blower is used.

The air flow should be measured with a mass flowmeter or a combination of rotameters, a pressure gauge and a thermocouple. The mass flow should be measured with an accuracy of ± 2 %.

6.2.2.4 Powder feeder

Powder feeding equipment with facility to adjust the feeding rate steplessly. Suitable equipment is described in Annex A. The powder feeder has to be calibrated (rotation rate vs. mass flow rate) separately for each powder.

The powder is fed into the air stream about 0.45 m before the flue entrance.

6.2.2.5 Weighing system

Weighing system to measure the weight loss of the flue. The flue on the ≥ 25 mm thick incombustible plate has to be supported by a stand not in contact to any other parts of the set-up, and the weight loss is to be measured by a weighing system with the following criteria:

- The load sensing system should be designed in such a manner that the recoil forces from the flames or the jet of extinguishing medium do not affect the measurement.
- The weight reduction of the flue should be recorded to an accuracy of ± 25 g.

6.2.2.6 Measuring facility

Measuring facility capable of reading the weight loss at least once per 5 s. This implies the use of a penplotter or preferably a computer-based measuring device.

6.2.2.7 Gas supply

Propane gas supply, capable of supplying a constant gas flow of approximately 0.8 g/s (corresponding to 40 kW).

The gas flow should be measured with a mass flowmeter or a combination of rotameters, a pressure gauge and a thermocouple. The mass flow must be measured with an accuracy of ± 2 %.

The gas supply must be connected to the burner with a hose in such a way that the weighing measurements are not affected.

6.2.3 Test procedure

The powder hopper is filled with approximately 2 kg of powder. The gas burner is ignited and the rate of propane flow is adjusted to 0.8 g/s. The air flow is started and adjusted to 70 l/s. The flue is fitted into its proper position.

The ignition time is 90 s, after which the gas burner is turned off. After a free burning time of 60 s the feeding equipment is started and the flame is observed for 1 min to see whether extinction occurs.

Several tests have to be performed. From test to test, the feeding rate of powder (guiding initial value 2.5 g/s) is increased or decreased until the critical application rate is achieved where the flame is extinguished within 40 - 60 s. When this application rate has been found, at least five acceptable tests (see 6.2.5) should be performed at this critical application rate, and extinction be achieved in at least three of these tests.

When extinction occurs, the feeding equipment is shut off after a 90 s total feeding time, and there must be no reignition.

6.2.4 Expression of results

The weight loss measurements of the flue are plotted and the burning rate during free burn determined (see Figure 2).

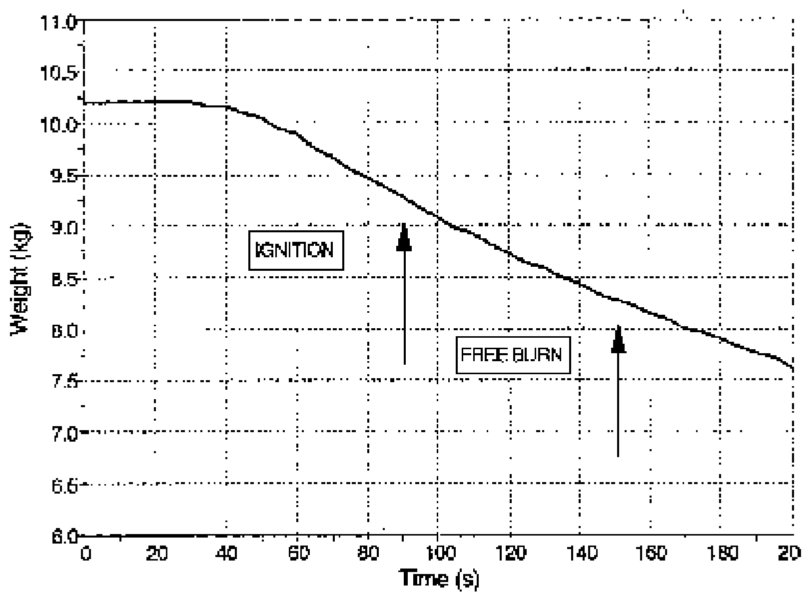

Figure 2. Example of a weight loss curve (burning rate of the flue) obtained during one test.

When three successful tests have been achieved (see 6.2.5) the required extinguishing media portion (REMP) is calculated by dividing the feeding rate of powder with the burning rate of the flue. The final result is the average REMP-value from the three tests (see 4.5).

6.2.5 Accuracy

If the duration of the test is less than 40 s, the test is rejected as this might indicate that the feeding rate has been above the critical application rate, and it is difficult to make an accurate determination of the feeding rate.

The calibration of the powder feeding equipment should be checked after each successful test, and the difference between the feeding rates may not be more than 10 %. If the deviation is greater, further tests have to be carried out.

PROPOSED REQUIREMENTS

D.1 Class A

Extinguishing powders claimed by the manufacturer to be suitable for class A fires must be classified with respect to their efficiency according to Table D.1. (*The table numbering has to be changed in Annex D.)*

The tests and evaluation of results are to be performed using the method specified in 6.2.

Table D.1. Classification of efficiency against A fires.

Classification	REMP-value
High efficiency	<0.10
Normal efficiency	0.10 - 0.15
Low efficiency	>0.15

Note: The classification limits are preliminary and may need to be adjusted when more experience has been gained.