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An intermediate scale comparison between the FMRC and the EUR Standard Plastic commodities

Brandforsk project 735-941

SP Rapport 1999:30
Fire Technology
Borås 1999

Abstract

An intermediate scale comparison between the FMRC and the EUR Standard Plastic commodities

This report describes the development of a EUR Standard Plastic commodity and intermediate scale comparison tests with the FMRC Standard Plastic commodity. The intention was to develop a commodity with similar fire and suppressibility characteristics. The primary intention is to use this commodity as a benchmark commodity for the commodity classification tests.

Both commodities consists of polystyrene plastic cups without lids, placed upside down in compartmented cartons.

Intermediate scale comparison tests were conducted where four pallet loads of commodity in a 2 by 1 by 2 configuration were ignited and water was applied at a predetermined heat release rate. By comparing the heat release rate histories of the tests it can be concluded that the fire development of the two commodities are similar. After the application of water the behaviour is such that it can be concluded that the FMRC commodity is more difficult to suppress compared to the EUR commodity in this scale.

No general explanation for this is known, the principle design of the commodities are similar and so is the overall size of one pallet load and the amount of combustibles. Three concurrent reasons are suspected; (1) the FMRC cardboard cartons are not as rigid as the EUR cartons, (2) the individual compartments of the FMRC cartons are larger and (3) the fact that the individual weight of the FMRC polystyrene cup is higher.

Key words: Plastics, intermediate scale fire tests, sprinkler systems.

SP Sveriges Provnings- och Forskningsinstitut
SP Rapport 1999:30
ISBN 91-7848-788-9
ISSN 0284-5172
Borås 1999

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Contents

Preface

These tests were financed by Brandforsk (project 735-941) and by SP and is a continuation of previous projects using the commodity classification technique.

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Sammanfattning

Factory Mutual's standardplastgods, det s k "Factory Mutual Standard Plastic Commodity" används sedan länge som referensgods i fullskaliga sprinklerförsök. Godset användes till exempel när ESFR konceptet utvecklades i mitten av 1980-talet. Som namnet anger innehåller godset en stor mängd plast, förpackad i wellpappkartong. Plasten finns i form av plastmuggar. Totalt lagras åtta stycken wellpappkartonger på varje lastpall. De enskilda wellpappkartongerna har en fackindelning om 125 fack där vardera en plastmugg (polystyren) lagras. Totalt lagras alltså 1000 stycken plastmuggar på varje lastpall.

Eftersom de enskilda wellpappkartongerna har sådana yttermått att de inte passar på Europapallar har SP-Brandteknik tagit fram en egentillverkad polystyrenmugg och en wellpappkartong som både passar lastpallar med måtten 1200 mm x 800 mm och 1200 mm x 1000 mm. Detta gods har givits namnet "EUR Standard Plastic Commodity". Avsikten har inte i första hand varit att godset skall användas vid sprinklerförsök. Istället har avsikten varit att godset skall användas för att ta fram referensvärden i den s k godsklassificeringsmetodiken. Godset skall alltså utgöra en slags länk mellan det amerikanska klassificeringssystemet och det europeiska klassificeringssystemet. Det är därför viktigt att den två godsen har relativt jämförbara brand- och släckengenskaper.

Denna rapport beskriver det arbete som lagts ned på att utveckla "EUR Standard Plastic Commodity" godset och de försök som genomförts i mellanskala för att jämföra brand- och släckengenskaperna. Arbetet har krävt stor noggrannhet, bland annat har mycket tid lagts på att hitta wellpappkartong och plaströvara med så lika brandegenskaper som den amerikanska förlagan som möjligt. Plastmuggen designades för att volymsmängden plast på en lastpall skall vara jämförbar och så att de enskilda muggarna har jämförbar godstjocklek.

Försöken genomfördes under Industrikalorimetern, med vars hjälp brandeffektutveckling som funktion av tid kan mätas, i en uppställning med totalt fyra stycken pallar gods i ett pallställage. Vatten påfördes, vid en given brandeffekt, med hjälp av en matris av vattenspraymunstycken. Båda godsen provades vid tre stycken vattentätheter.

Resultaten visar att brandtillväxten, fram till den tidpunkt när vatten började påföras är jämförbar för de två godsen. Vid vattenpåföringen dämpas branden i EUR godset mer markant än branden i FMRC godset. Detta visar att godsens brandegenskaper är jämförbara men inte dess släckengenskaper.

Troligen kan skillnaden i släckengenskaper härledas till tre stycken samverkande faktorer; (1) wellpappen i FMRC kartongerna är inte lika styv som wellpappen för EUR kartongerna, (2) de enskilda facken är något större i FMRC kartongerna och (3) de enskilda FMRC muggarna har högre vikt än de enskilda EUR muggarna.

Den praktiska slutsatsen av försöken är därmed att om EUR godset används som referensgods i godsklassificeringsmetodiken så kommer ett godtyckligt gods som provas att bedömas med en viss säkerhetsmarginal gentemot FMRC godset. Resultaten visar att även små, till synes betydelselösa skillnader, mellan två gods ger utslag i brandegenskaper och släckbarhet.

Grunden är nu lagd för en metodik där gods på Europapallar kan utvärderas i en uppställning som bara kräver hälften så mycket gods, fyra istället för åtta pallar, som den ursprungliga metodiken.

Sökord: Sprinkler, plast, mellanskaleförsök.

1 Introduction

1.1 Background

The Factory Mutual Research Corporation (FMRC) Standard Plastic commodity has been widely used in large scale sprinkler testing to produce data which formed basis of several protection standards [1]. The sizes of the cartons used for the commodity makes them, however, impossible to use on European pallets. For that reason, a EUR Standard Plastic commodity has been developed by the Swedish National Testing and Research Institute (SP). The intention is to use this commodity as a benchmark commodity for the commodity classification tests, a technique developed by FMRC but previously evaluated by SP [2] and adopted as a Nordtest test method [3].

The EUR Standard Plastic commodity cardboard cartons are sized 600 mm by 400 mm by 500 mm (L x W x H). This allows the cartons to be arranged on both 1200 mm by 800 mm as well as on 1200 mm by 1000 mm European pallets.

Another reason for the development of a EUR Standard Plastic commodity is the need for a test commodity for the Shopping & Storage tests as described in IMO Res. A.800(19) [4]. The test method specifies the use of the FMRC Standard Plastic commodity as the fire source. However, similar commodities are permitted to be used if they are designed in a similar way and are proven to have the same burning characteristics and suppressibility.

A great deal of work has been spent to design a similar plastic cup, find similar polystyrene resin and similar corrugated cardboard. These efforts are described within the report. The individual weight of the polystyrene cup used with the EUR Standard Plastic commodity is less compared to the cup for the FMRC commodity. However, the primary aim during the development has been to get a similar commodity on a pallet load basis.

1.2 Objective of the test series

The objective of this project was twofold. The primary objective was to compare the fire and suppressibility characteristics of the two commodities. Previously, a comparison was made in a small scale. The small scale tests series is described in SP Report 1999:29 and indicated that the fire and suppressibility characteristics of the EUR Standard Plastic commodity are worse compared to the FMRC Standard Plastic commodity. The objective of this series of tests was to investigate if these conclusions were valid also in an intermediate scale.

The secondary objective was to investigate the possibilities of reducing the original 2 by 2 by 2 (eight pallets) test arrangement to a 2 by 1 by 2 arrangement (four pallets).

2 A description of the commodities

2.1 General description

The FMRC Standard Plastic commodity consists of empty polystyrene cups without lids, placed upside down, in compartmented cartons, 125 cups per carton. The cartons are cubic, measures 530 mm by 530 mm by 530 mm and are made from single-wall, corrugated cardboard. When compartmented, the cartons are divided into five layers by corrugated sheets, with each layer divided into 25 compartments by overlocking corrugated cardboard partitions, forming a total of 125 compartments where the plastic cups are placed.

The individual cups have a measured average weight of 33,8 g. The total weight of the plastic is therefore 4,2 kg per carton, the overall weight of one carton including the cups is approximately 6,9 kg. For the tests described within this report, cardboard cartons made by Avon Corrugated Corporation, USA were used.

Eight cartons were placed on each pallet. The overall dimension of one pallet load was therefore 1070 mm by 1070 mm by 1070 mm plus the height of the pallet. The total weight of one pallet load of the commodity was approximately 55,2 kg of which approximately 61 % by weight was plastic, excluding the pallet.

The cartons were stapled together to delay or prevent them from falling apart during the tests.

The EUR Standard Plastic commodity consists of empty polystyrene cups without lids, placed upside down, in compartmented cartons, 120 cups per carton. The cartons measures 600 mm by 400 mm by 500 mm (L x W x H) and are made from single-wall, corrugated cardboard. When compartmented, the cartons are divided into five layers by corrugated sheets, with each layer divided into 24 compartments by overlocking corrugated cardboard partitions, forming a total of 120 compartments where the plastic cups are placed.

The individual cups have a measured average weight of 28,2 g. The total weight of the plastic is therefore 3,4 kg per carton, the overall weight of one carton including the cups is approximately 5,4 kg. For the tests described within this report, the cardboard cartons were made by Maxbox Emballage AB, Sweden in quality E 300 C.

Ten cartons were placed on each pallet. The overall dimension of one pallet load was therefore 1200 mm by 1000 mm by 1000 mm (L x W x H) plus the height of the pallet. The total weight of one pallet load of the commodity was approximately 54 kg of which approximately 63 % by weight was plastic, excluding the pallet. The resin for the polystyrene was made by Hüls, in quality Vestyron 114.

The cartons were stapled together to delay or prevent them from falling apart during the tests.

The table below summarises some general technical data of the two commodities.

Table 1 A general technical comparison between the FMRC and the EUR Standard Plastic commodities.

Commodity	FMRC Std Plastic	EUR Std Plastic	Difference [%]
Measures (pallet not included)			
Size of individual cartons [mm]	530 x 530 x 530	600 x 400 x 500	-
No. of cartons on each pallet	8 pcs	10 pcs	-
Arrangement of cartons	2 x 2 x 2	2 x (2 + 3)	-
Size of pallet load, exc. pallet [mm]	1070 x 1070 x 1070	1000 x 1200 x 1000	-
Pallet area [m^2]	1,14	1,20	+5,0 %
Total surface area of pallet load [m^2]	6,86	6,80	-0,9 %
Total volume of pallet load [m^3]	1,22	1,20	-1,6 %
Weights (pallet not included)			
Total weight of one pallet load [kg]	55,2	54,0	-2,2 %
Average weight of individual cup [g]	33,8	28,2	-16,6 %
Number of cups	1000	1200	-
Total weight of plastic per pallet load [kg]	33,8	33,8	± 0 %
Plastic density per pallet load (kg/m^3)	27,6	28,2	-2,2 %

2.2 The cardboard cartons

Factory Mutual specifies that the corrugated boxes, partitions and pads used for the Standard Plastic Commodity shall be of C flute configuration, PPP-B-640d Class II Government grade, plain printed and meet a number of transportation requirements. No fire characteristics of the corrugated cardboard is specified.

In order to find corrugated cardboard with similar fire characteristics a series of Cone Calorimeter tests according to ISO 5660-1 were conducted. The tests were done at 25 kW/m^2 irradiance, with the sample positioned horizontally using a retainer frame.

Three different C-flute corrugated cardboard cartons manufactured by a Swedish manufacturer, Maxbox Emballage AB, were compared to a carton manufactured by Rand-Whitney, MA, USA and a carton manufactured by Avon Corrugated Corporation, MA, USA. These cartons were provided by FMRC and are used for the FMRC Standard Plastic Commodity. Two samples from two different cartons were tested with the carton manufactured by Rand-Whitney. The tables below summarises the results from the tests, all values are an average calculated based on three tests.

Table 2 ISO 5660-1 test results for corrugated cartons used for the FMRC Standard Plastic Commodity.

	Rand-Whitney, sample 1	Rand-Whitney, sample 2	Avon Corrugated Corp.
Ignition [min:s]	0:15	0:19	0:22
Peak heat release rate [kW/m^2]	177	192	148
Average heat release, 3 min [kW/m^2]	40	41	37
Total heat produced [MJ/m^2]	7,1	7,4	6,6
Sample mass before test [g]	4,5	4,7	5,2
Effective heat of combustion [MJ/kg]	17,2	16,2	13,5
Measured thickness [mm]	4,0	3,8 - 3,9	3,5 - 3,9

Note: The nominal thickness of a C-flute carton is by definition 3,75±0,5 mm.

Table 3 ISO 5660-1 test results for three different corrugated C-flute cartons manufactured by Maxbox Emballage AB.

	Maxbox SIS 140C	Maxbox SIS 120C	Maxbox E 300 C
Ignition [min:s]	0:21	0:18	0:19
Peak heat release rate [kW/m^2]	237	180	165
Average heat release, 3 min [kW/m^2]	40	35	38
Total heat produced [MJ/m^2]	7,2	6,3	6,8
Sample mass before test [g]	4,5	4,3	4,9
Effective heat of combustion [MJ/kg]	17,5	14,9	15,6
Measured thickness [mm]	4,0	3,85	3,9

Note: The nominal thickness of a C-flute carton is by definition 3,75±0,5 mm.

Based on the Cone Calorimeter tests the Maxbox E 300 C quality was chosen for the EUR Standard Plastic cartons used in these tests.

Two drawings showing details of the FMRC and the EUR cardboard cartons are shown is enclosures 1 and 2, respectively. The compartments are wider and deeper in the FMRC cartons, which corresponds to the larger plastic cups and the overall measures of the cartons. The heights of the compartments are comparable.

2.3 The plastic cups

The approach was to custom make a plastic cup, similar in design to the FMRC cup, but slightly less in weight with the intention of providing the same amount plastic per pallet load.

The average weight of a FMRC plastic cup was measured to be 33,8 g. The average weight of the EUR plastic cup is 28,2 g. This cups is therefore slightly smaller, but the cup was designed for approximately the same wall and bottom thickness as the FMRC cup.

FMRC provides a technical specification of the polystyrene resin used for the cups and a similar resin was bought from a supplier in Sweden.

To compare the fire characteristics of the resins, cups were grinded to millimetre sized pieces. 100 g were tested using the Cone Calorimeter according to ISO 5660-1. The tests were done at 25 kW/m^2 irradiance, with the material positioned horizontally using a retainer frame. A total of two tests were conducted using either material. It can be concluded that the fire characteristics of the resins were very similar. The results are summarised in the table below, all values are an average calculated based on two tests.

Table 4 ISO 5660-1 test results for 100 g of the polystyrene resin.

	FMRC resin	EUR resin
Ignition [min:s]	02:31	02:19
Peak heat release rate [kW/m^2]	734	741
Average heat release, 3 min [kW/m^2]	353	352
Average heat release, 5 min [kW/m^2]	379	376
Total heat produced [MJ/m^2]	301	291
Sample mass before test [g]	100	100
Effective heat of combustion [MJ/kg]	30,2	29,2

3 Intermediate scale fire tests

3.1 The Industry Calorimeter

The tests were conducted under the Industry Calorimeter, a large hood connected to an evacuation system capable of collecting all the combustion gases produced by the fire. The hood is 6 m in diameter with its lower rim 8 m above the floor. To increase the gas collecting capacity of the hood, a cylindrical fibre glass ”skirt”, hanging from the lower rim of the hood, was used. The height of the fibre glass cylinder was 2,5 m. In the duct to the evacuation system, measurements of gas temperature, velocity and generation of gaseous species such as CO_2 and CO and depletion of O_2 are being made. Based on these measurements both the convective and total heat release rate can be calculated.

3.2 The water applicator

The water applicator consists of six parallel, double-jacketed, steel pipes fitted with six spray nozzles along each pipe, forming a matrix of nozzles 450 mm apart. The nozzles produce a full-cone, wide angle spray, resulting in an even water distribution over a maximum area of 7,29 m^2. For these tests, only four of the pipes were used (the two outer pipes were disconnected). This arrangement provided a matrix of six by four water spray nozzles which corresponded to a total coverage area of 4,86 m^2. This resulted in some degree of overlap, outside of the pallets.

The distance from the top of the commodity to the tips of the nozzles of the water applicator was approximately 250 mm.

The suppression water is fed from both ends into the pipe. In order to reduce the fill-up time as much as possible, an air relief device is installed at the midpoint of the pipes. This allows the air in the pipes to bleed, but shuts off as soon as the pipes are filled with water. In order to reduce the fill-up time even more, a special charge line is also connected. This is controlled with a time relay and is shut off at the same moment as the pipes are filled with water. This ”charge time” has to be adjusted for each flow rate. The feeding line is equipped with a flow meter and a pressure transducer in order to adjust the flow rate corresponding to the desired water density.

In order to protect the water applicator from flames, the applicator is cooled by water in the annular area of the double jacketed pipes. The cooling water is fed from one end and discharged through the other.

3.3 Test procedure

The commodity was placed on pallets and placed in a row rack storage segment. In each tests, four pallets were placed in a 2 by 1 by 2 configuration. It should be noted that this is different from the original Commodity Classification set-up where eight pallets in a 2 by 2 by 2 configuration is used. The commodities were ignited at the flue, near the bottom of the commodity at the lower tier, using standardised ignition sources. Enclosure 3 provides a schematic drawing of the set-up.

The water was manually activated when the fire had reached a convective heat release rate of 2 MW (this is approximately half the heat release rate when water is applied when eight pallets are used). At that point the fire involved the whole upper tier of commodity. Three different water discharge densities were used, according to the test programme showed in the table below.

Table 4 Test programme with associated water discharge densities, water flow rates, pressures and spray nozzles.

Test id.	Nominal water discharge density [mm/min]	Water flow rate [L/min]	Approximate water pressure [bar]	Nozzles used, manufactured by Lechler GmbH
EUR1	5,0	24	2,0	460.408
EUR2	7,5	36	3,0	460.448
EUR3	10,0	49	2,0	460.528
FMRC1	5,0	24	2,0	460.408
FMRC2	7,5	36	3,0	460.448
FMRC3	10,0	49	2,0	460.528
EUR/FMRC1	7,5	36	3,0	460.448

One test was conducted where the EUR Standard Plastic commodity cartons were packed with the FMRC plastic cups.

3.4 Observations and results

The test results from the intermediate scale tests are summarised in tables 5 and 6. Heat release rate histories are given in figures 1 through 4.

Table 5 Test results for the tests with the FMRC Standard Plastic commodity.

Test no.	FMRC1	FMRC2	FMRC3
Date of test	1999-02-08	1999-02-09	1999-02-09
Nominal delivered density [mm/min]	5,0 mm/min	7,5 mm/min	10,0 mm/min
Start of water application [min:s]	01:44	01:30	01:37
Max. one minute average total HRR [kW]	7877 kW	7000 kW	3398 kW
Max. one minute average convective HRR [kW]	4918 kW	4109 kW	1662 kW
Convective energy, 02:00 - 24:00 minutes [MJ]	1681 MJ	1402 MJ	637 MJ
Amount of consumed goods	100 %	98 %	78 %

Table 6 Test results for the tests with the EUR Standard Plastic commodity and the tests where the EUR Standard Plastic commodity cartons were packed with the FMRC plastic cups.

Test no.	EUR1	EUR2	EUR3	EUR/FMRC1
Date of test	1999-02-05	1999-02-05	1999-02-08	1999-02-11
Nominal delivered density [mm/min]	5,0 mm/min	7,5 mm/min	10,0 mm/min	7,5 mm/min
Start of water application [min:s]	01:42	01:40	01:41	01:36
Max. one minute average total HRR [kW]	5136 kW	4065 kW	3681 kW	6159 kW
Max. one minute average convective HRR [kW]	2986 kW	2280 kW	2084 kW	3573 kW
Convective energy, 02:00 - 24:00 minutes [MJ]	2283 MJ	1467 MJ	589 MJ	2158 MJ
Amount of consumed goods	100 %	90 %	72 %	100 %

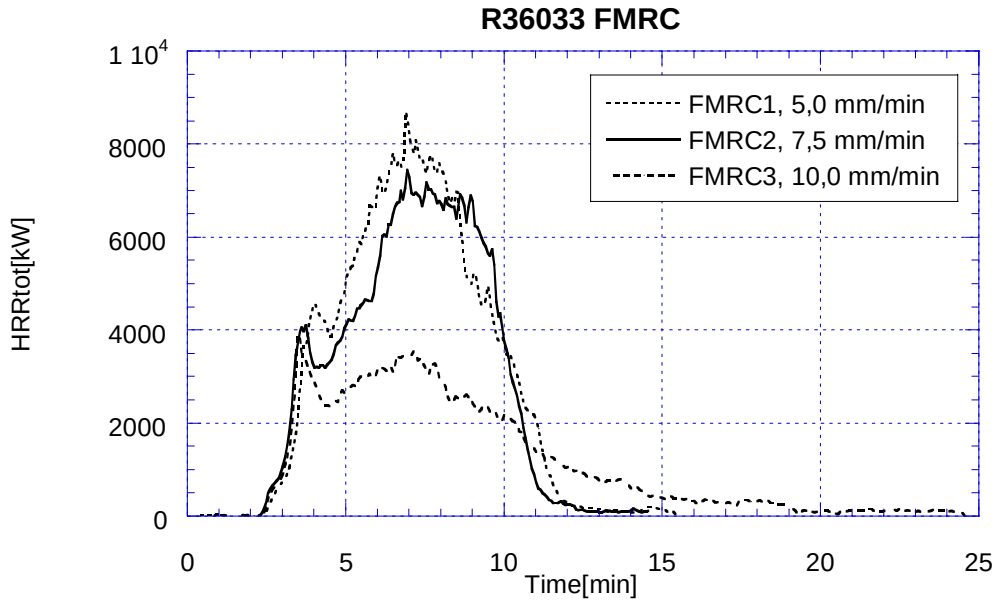

Figure 1 *Total heat release rate histories for the FMRC Standard Plastic commodity tests. Ignition at 02:00, manual extinguishment, if any, at 24:00*

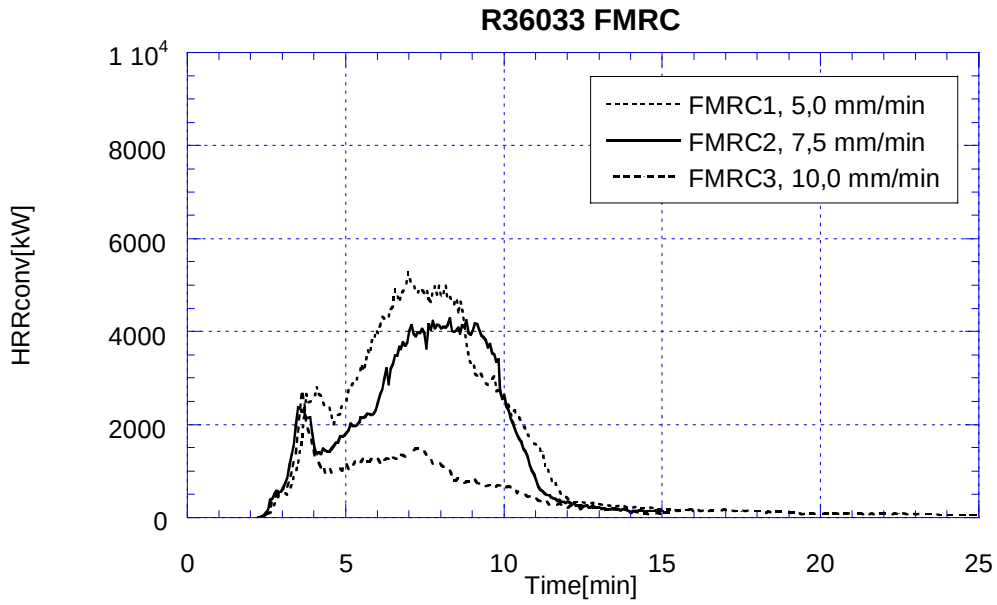

Figure 2 *Convective heat release rate histories for the FMRC Standard Plastic commodity tests. Ignition at 02:00, manual extinguishment, if any, at 24:00.*

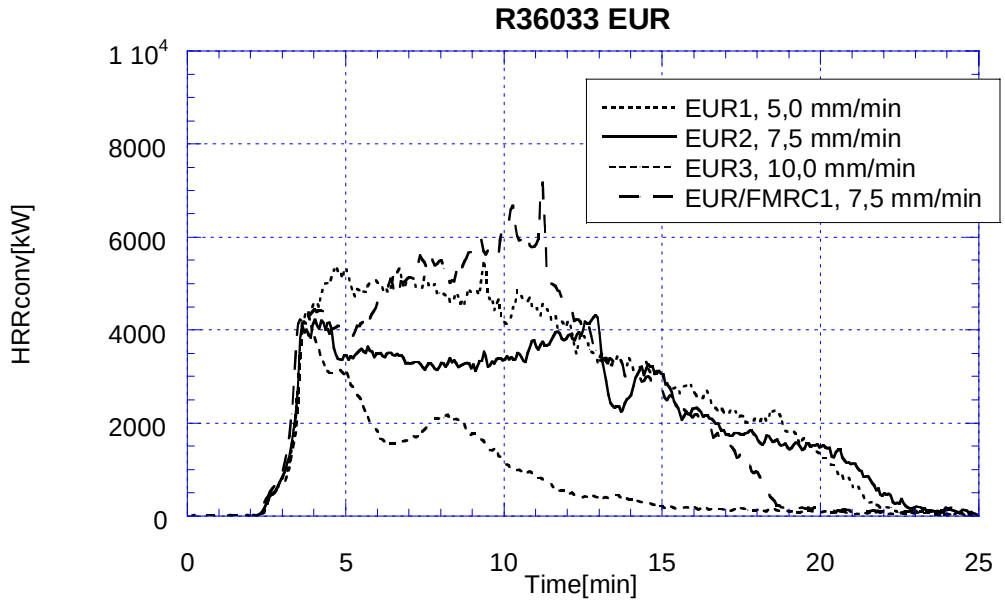

Figure 3 *Total heat release rate histories for the EUR Standard Plastic commodity tests and for the test with EUR Standard Plastic commodity cartons with FMRC plastic cups. Ignition at 02:00, manual extinguishment, if any, at 24:00.*

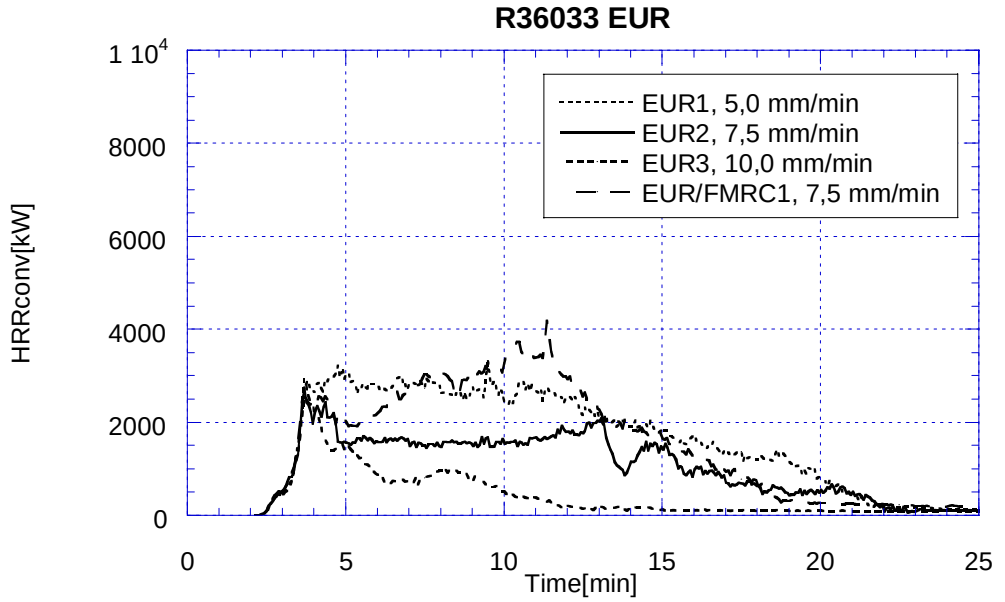

Figure 4 *Convective heat release rate histories for the EUR Standard Plastic commodity tests and for the test with EUR Standard Plastic commodity cartons with FMRC plastic cups. Ignition at 02:00, manual extinguishment, if any, at 24:00.*

4 Discussion and conclusions

The previous small scale tests described in SP Report 1999:29 indicated that the fire and suppressibility characteristics of the EUR Standard Plastic commodity are worse compared to the FMRC Standard Plastic commodity. The objective of the intermediate scale tests described in this report was to verify the small scale conclusions in a larger scale.

There are many reasons for expecting approximately the same fire and suppressibility characteristics of the two commodities. The principle design of the commodities are similar and so is the overall size of one pallet load. The amount of combustibles are similar and the chosen materials are as similar as practically possible.

From the intermediate scale tests, it is however clear that the FMRC Standard Plastic commodity has got fire and suppressibility characteristics that are worse compared to the EUR Standard Plastic commodity. This is contradictory to the experience from the small scale tests. The reason for this could not be explained. The initial fire development, until the application of water were, however, reasonably similar for the two commodities. The repeatability of the fire development of the EUR Standard Plastic commodity was, however, better.

There seems to be three concurrent reasons for the difference in fire and suppressibility characteristics:

1. Based on the visual observations during the tests it was felt that the EUR commodity cardboard cartons ”protected” the plastic cups better compared to the FMRC commodity cartons. One test was therefore conducted where the FMRC plastic cups were packed in the EUR commodity cartons. Although the choice of the corrugated cardboard carton was based on Cone Calorimeter comparison tests it is obvious from this test that the cardboard cartons is one key to the explanation of the differences between the two commodities. The fact that there are ten EUR commodity cartons, with some overlap, on each of the pallets, as compared to eight FMRC cartons contribute to better stability. This may also be one part of the explanation.

2. Another key to the difference might be the different size of the individual compartments of the cartons. The compartments of the FMRC cartons are slightly wider and deeper. This could potentially allow better access of air to the fire. The heights of the compartments are comparable.

3. The third possible explanation is the fact the individual weight of the polystyrene cup used with the EUR Standard Plastic commodity is less compared to the cup used for the FMRC commodity.

If the EUR Std Plastic commodity is used as a benchmark commodity for commodity classification tests, the characteristics of a tested commodity will be judged with some degree of conservatism relative to the characteristics of the FMRC Std Plastic commodity.

The secondary objective was to do an initial investigation of the possibilities of reducing the original 2 by 2 by 2 (eight pallets) test arrangement to a 2 by 1 by 2 arrangement (four pallets). The experience from these tests indicate that this might be possible. An investigation if different commodities gets the same ranking in the two different scales is, however, necessary.

5 References

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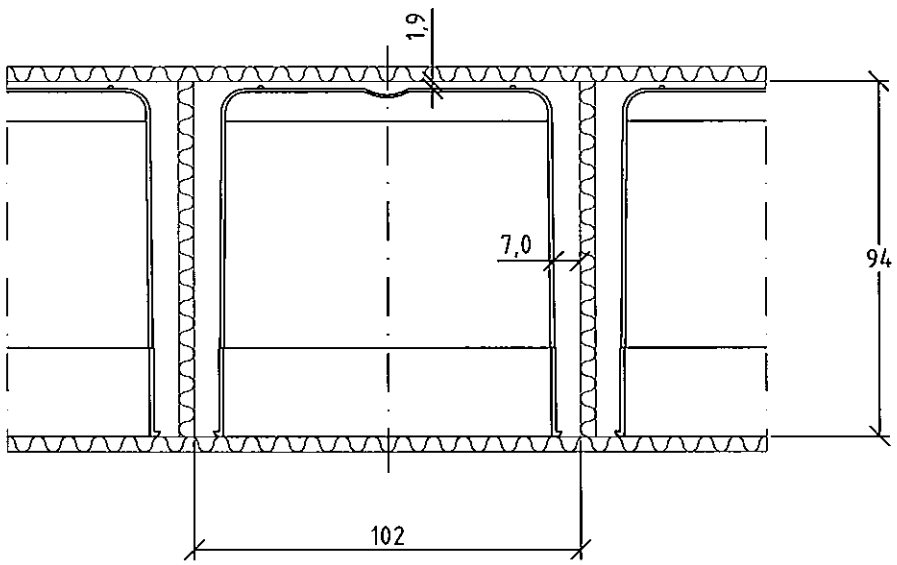
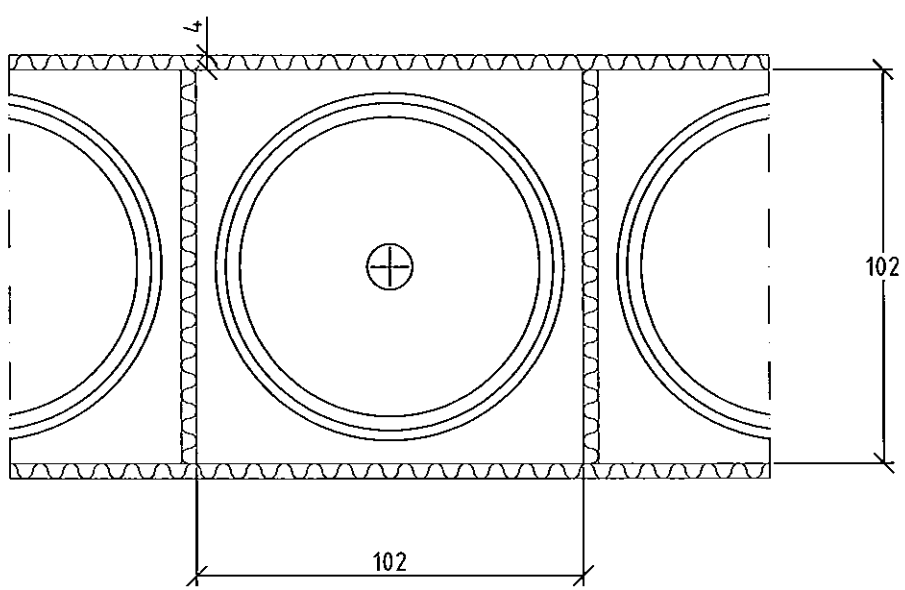
Detail of FMRC cardboard cartons

With the FMRC plastic cup

Bilaga nr: 1	
Rapport nr: 1999:30	
Datum: 1999-11-22	Rev. Datum:
Skala: 1:2	Sign: MA



Side view

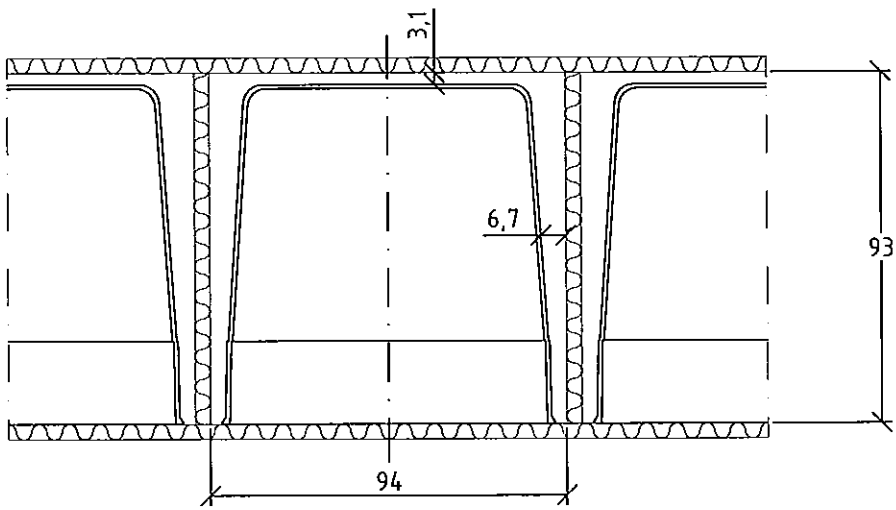


Top view

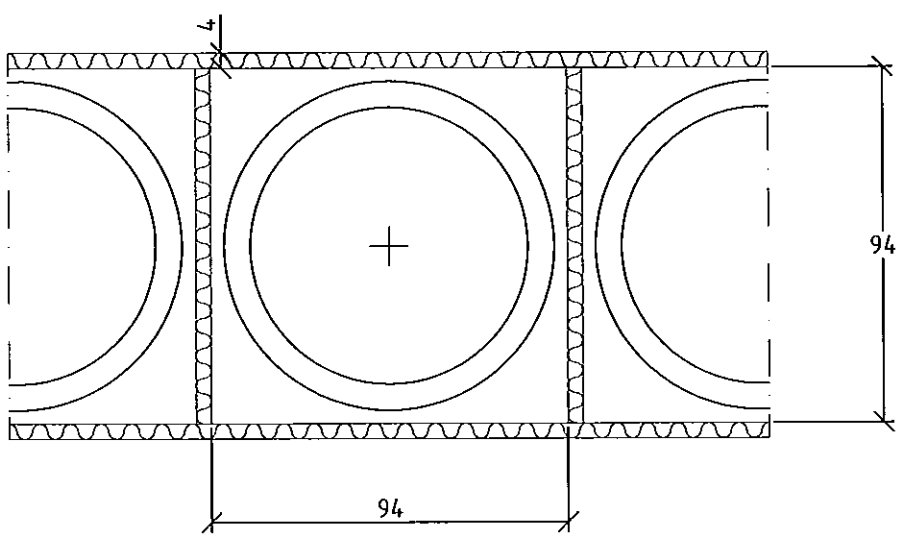
Detail of EUR cardboard cartons

With the EUR plastic cup

Bilaga nr: 2	
Rapport nr: 1999:30	
Datum: 1999-11-22	Rev. Datum:
Skala: 1:2	Sign: MA



Side view

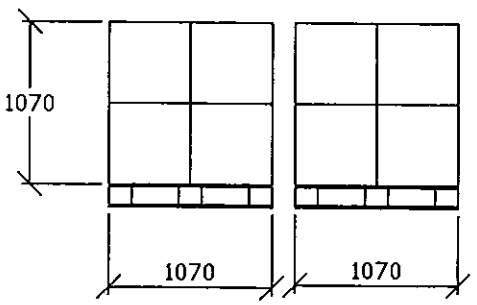


Top view

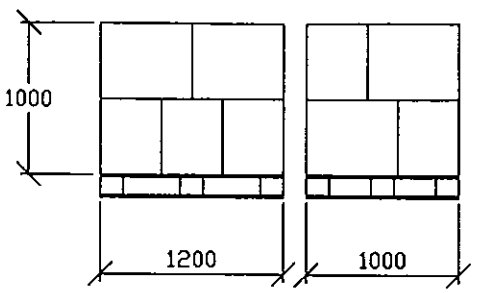
Test arrangement

With dimensions of the commodities

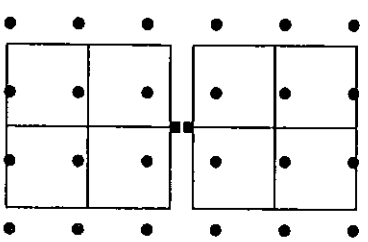
Bilaga nr: 3	
Rapport nr: 1999:30	
Datum: 1999-11-22	Rev. Datum:
Skala: 1:50	Sign: MA

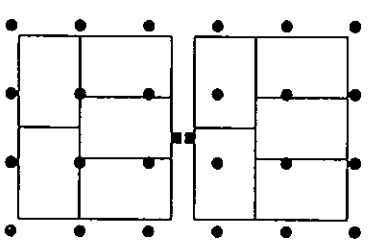


FMRC Std Plastic commodity



EUR Std Plastic commodity





Top view with positions of nozzles relative to commodity