



# Interlaboratory Comparison between SP and NIS, Egypt on the cone calorimeter

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## **Abstract**

An interlaboratory comparison has been made between SP and NIS Egypt. The method used is the cone calorimeter described in ISO 5660. The comparison included calibration with ethanol and 4 materials, i.e. PMMA, Particle board, gypsum board and PUR foam. The results show an acceptable agreement between the labs for HRR levels while the time to ignition and effective heat of combustion deviates for the gypsum board.

Key words: cone calorimeter, interlaboratory comparison, fire

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## **Preface**

The work conducted in this project is part of a project supported by SIDA through the Swedish Research Council (Vetenskapsrådet) within the MENA programme which is gratefully acknowledged. The title of the project is “Research on the development of innovative environmentally friendly polymers with high fire properties using nanotechnology”. The project is a collaboration between SP Fire Technology, Sweden and NIS, Egypt.

Scientist and personnel of both institutes is acknowledged for their help and assistance during the project.

# 1 Introduction

The specific objectives of this overall collaborative research project is to develop methods and tools which can be used in the product development of new environmentally friendly nanocomposites with improved fire behaviour. The expected significance of the research project is an increased understanding of the physical phenomena involved in the fire retardant process of these new composites by means of small scale test methods. In order to develop the correct methods it was decided that a interlaboratory comparison was needed for the key method i.e. the cone calorimeter (ISO 5660). The interlaboratory comparison is the content of this report.

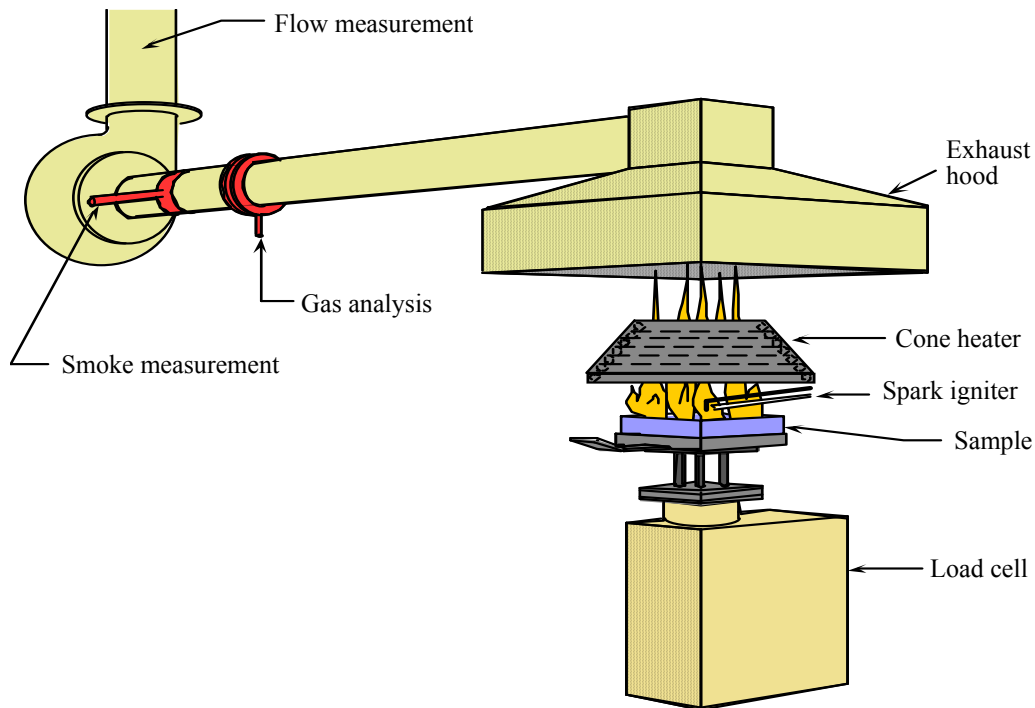
## 2 The Cone Calorimeter

The Cone Calorimeter, originally developed by Vytenis Babrauskas, is widely used as a tool for fire safety engineering, by industry for product development and as a product classification tool (IMO). It has been proven to predict large-scale test results in the Room/Corner Test, fire growth in upholstered furniture, flame spread on cables and in a number of other situations<sup>1-11</sup>. The Cone Calorimeter is one of the most important tests developed by ISO TC92 SC1 (Fire Safety – Fire Initiation and Growth) over its entire period of activity.

In the Cone Calorimeter, ISO 5660-1, specimens of 0.1 m by 0.1 m are exposed to controlled levels of radiant heating. The specimen surface is therefore heated up and an external spark ignites the pyrolysis gases from the specimen. The gases are collected by a hood and extracted by an exhaust fan. The heat release rate (HRR) is determined by measurements of the oxygen consumption derived from the oxygen concentration and the flow rate in the exhaust duct. The specimen is placed on a load cell during testing. The test apparatus is shown in Figure 1 and the test specifications are given in Table 1.

The Cone Calorimeter standard is revised and a three-part edition is under publication. Part 1 is the traditional test for measurement of HRR, Part 2 is intended for smoke measurements and Part 3 is the guidance standard<sup>12,13,14</sup>. In addition a very simple reduced version of the Cone Calorimeter for measurement only of mass loss rate from the burning specimen is published<sup>15</sup>.

The Cone Calorimeter is a fire test apparatus that is used for many different applications including building materials, cable insulation, fabrics, etc. This makes it possible to compare the fire hazard associated with the tested materials for a wide range of applications. The Cone Calorimeter gives output data such as time to ignition, Effective Heat of Combustion (MJ/kg), Heat Release Rate (kW/m<sup>2</sup>), Mass loss rate, smoke production, Carbon monoxide production, etc. These data are important when evaluating a material's fire behaviour and when calculating the fire threat to humans and the probability for fire spread. They are considered more semi-empirical but much better than data coming from a small flame test.



**Figure 1.** ISO 5660-1 and ISO 5660-2 the Cone Calorimeter.

**Table 1.** ISO 5660 – 1 and ISO 5660-2 test specifications.

|                   |  |
|-------------------|--|
| Specimens         | 3 specimens 100mm x 100mm  |
| Specimen position | Horizontal in specimen holder  |
| Heat source       | Conical shaped electrical heater giving a heat flux in the range of 0-100 kW/m <sup>2</sup> . If no specifications are given tests at 25, 35 and 50 kW/m <sup>2</sup> are recommended.   |
| Test duration     | 32 min unless the burning practically has stopped for 10 min. If there is no ignition test is stopped after 30 min.  |
| Conclusions       | HRR data: Time to sustained flaming, curve of HRR versus time, 180s and 300s average of the HRR, peak HRR and possibly other HRR data.<br>Smoke data: Graph of smoke production rate per unit area of exposed specimen as well as discrete values for non-flaming and flaming phases. As supplementary information it is also possible to report the yield of smoke per unit mass loss of the specimen, the specific extinction area, $\sigma$ (units m <sup>2</sup> /kg). |

The Cone Calorimeter can be used to test materials at different incident thermal fluxes. This makes it possible to test the material at the flux that is most likely to occur or the maximum possible flux in the materials current application.

It is easy to apply more measurements to the Cone Calorimeter such as additional gas analyses to measure component such as HCl, HCN etc.

With the data from the cone calorimeter it is possible to have a wide range of applications which are summarised below

1. Direct application of the results for prescriptive regulations. More and more the cone is starting to be used for prescriptive regulations. Examples are e.g. trains where the test method is included in the new EN standard for train products.

2. Indirect application towards other prescriptive methods. There exist a number of correlations or models where you can use cone data to link the data of the cone calorimeter to other test methods. Some of these correlations were focused to full scale tests like the room fire ISO 9705 test in the beginning but there are now correlations available both for the Euroclasses for wall and ceiling linings (EN 13823 SBI method) and for small scale flame applications such as the UL94 or the quality control methods such as the oxygen index. A good overview is given in the article of the Fire and Materials conference 2005<sup>16</sup>. Apart from building materials there exist also models and correlations for building content such as furniture.
3. Input to advanced mathematical models. The use of e.g. CFD models is increasing more and more to investigate the fire safety of buildings, transport means etc. These models use basic physics. In the beginning these models were used mostly for smoke transport but recently also advanced pyrolysis models are included so that flame spread on surfaces can be predicted. Some of these pyrolysis models use direct or indirect data from the cone calorimeter.

The SP cone calorimeter used in the comparison was delivered to SP by FTT in 1996. This cone has since the comparison was conducted been replaced by a new one delivered by FTT.

The cone calorimeter situated at NIS was delivered to NIS by Rheometric Scientific, UK in 1998. This cone has been upgraded with new software since the comparison.

### 3 Method

Through the framework of the Swedish-Egyptian bilateral research project, ‘‘Research on the development of innovative, environmentally friendly polymers with high fire properties’’, both parties arranged a series of bilateral comparisons of some materials using a Cone calorimeter, ISO-5660-1 in both countries.

The test procedure is carried out according to ISO-5660-1 Test method. The heat flux applied is 50 kW/m<sup>2</sup> and the distance between the sample holder and the cone heater is 25 mm. The thickness of the samples is 10 mm. The sampler holder with frame is used and the interval of data collection is two seconds. The test program includes:

- Calibration by ethanol
- Test on Particle Board, Gypsum Board, PMMA, Polyurethane samples

The samples were provided by SP.

The results are presented graphically for the HRR against time and in tables comparing the following main information:

- Time to ignition in seconds ( $t_{ign}$ )
- Maximum heat release rate, ( $q_{max}$ ) kW/m<sup>2</sup>.
- Average HRR over 180 s ( $q_{180}$ ) kW/m<sup>2</sup>.
- Total heat release (THR), MJ/m<sup>2</sup>.
- Effective heat of combustion, MJ/kg. ( $\Delta H_c$ )
- Total mass loss, g. (TML)

## 4 SP results

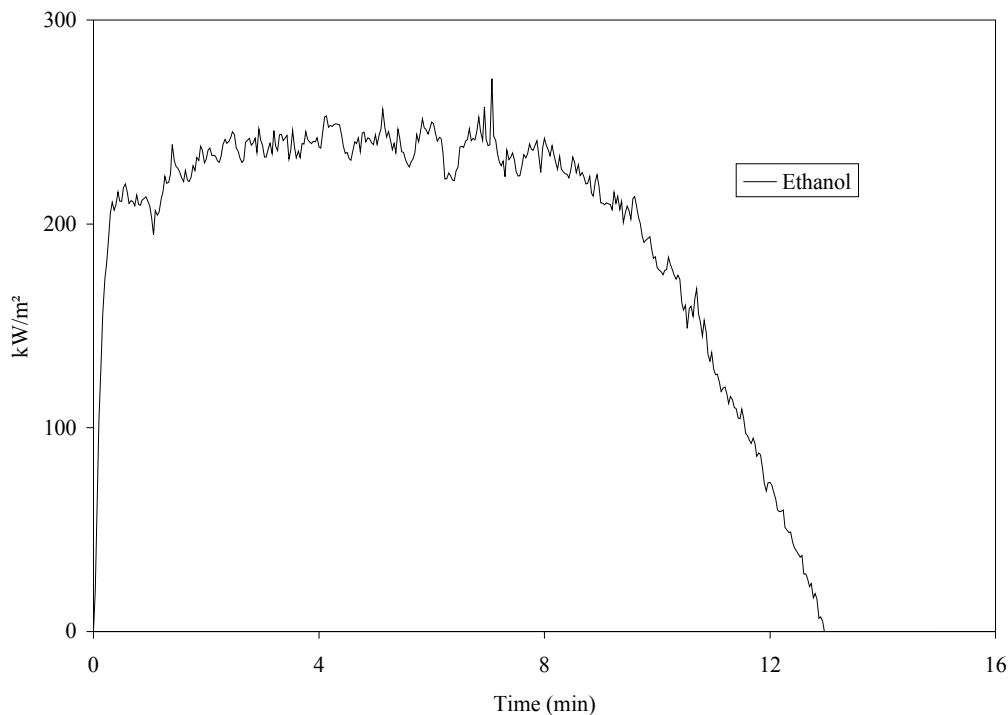
This section includes the first part of the comparison which was done at SP-Fire technology, Sweden.

### 4.1 Calibration by ethanol

The calibration was performed by 69.1 milliliters (54.58g) of ethanol with purity 99.5% by volume was placed in a circular ceramic pan 100mm diameter and 40 mm high with a rounded of bottom. The pan was put underneath the cone with a 50 kW/m<sup>2</sup> radiation applied. Piloted ignition was used. The results are tabulated in Table (2) and the HRR as a function of time are shown in Figure 2.

**Table 2. Cone calorimeter data results of ethanol**

| Parameter                             | Value Ethanol-SP |
|---------------------------------------|------------------|
| t <sub>ign</sub> (s)                  | 5                |
| q <sub>max</sub> (kW/m <sup>2</sup> ) | 271              |
| q <sub>180</sub> (kW/m <sup>2</sup> ) | 221              |
| THR (MJ/m <sup>2</sup> )              | 1.54             |
| ΔH <sub>c</sub> (MJ/kg)               | 24.9             |
| TML (g)                               | 54.6             |



**Figure 2. Heat release rate for ethanol.**

The theoretical total heat release of ethanol = weight of ethanol x heat of combustion of Ethanol = (54.50 x 26.78)/1000 = 1.460 MJ.

With weight of ethanol = 54.58 x 0.9937 (conversion between weight% and volume%)

Total Heat Release of ethyl alcohol resulted from cone = 1.542 x 12.88/13.1 = 1.516 MJ

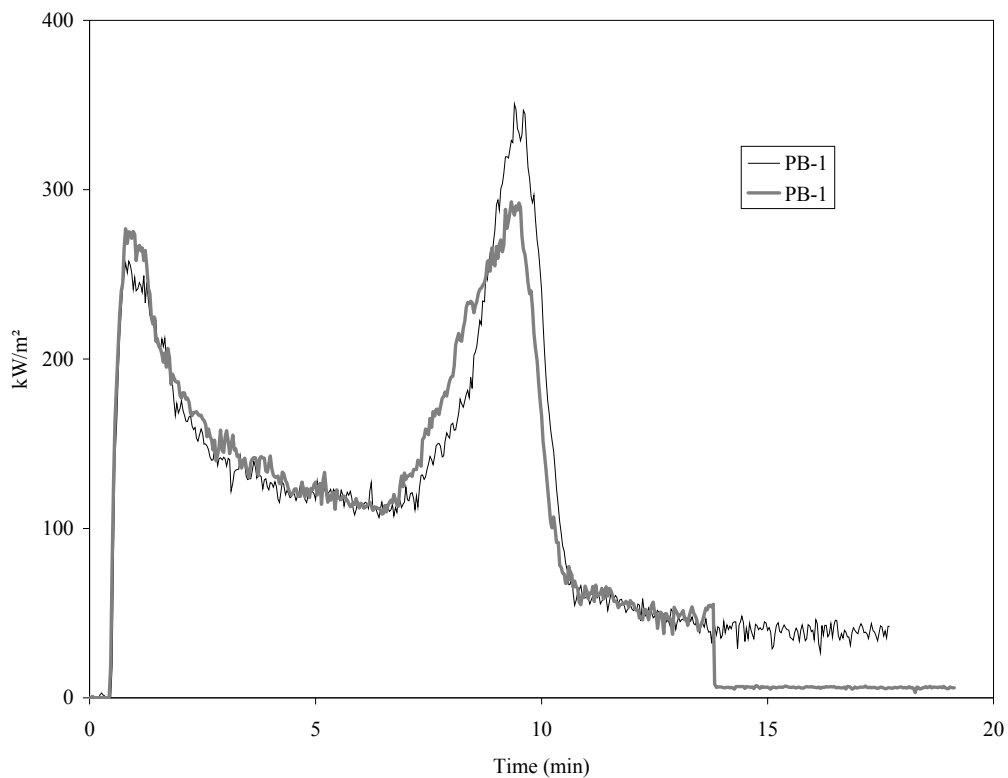
Error percentage = (1.516 - 1.460) / 1.516 = 3.7 %

## 4.2 Particle Board

The cone calorimeter results of two samples of Particle Boards are tabulated in Table (3) and the HRR as a function of time is shown in Figure 4.

**Table 3.** Cone calorimeter data results of two Particle Board samples.

| Parameter                             | PB1-SP | PB2-SP | Average |
|---------------------------------------|--------|--------|---------|
| $t_{\text{ign}}$ (s)                  | 30     | 28     | 29      |
| $q_{\text{max}}$ (kW/m <sup>2</sup> ) | 351    | 293    | 322     |
| $q_{180}$ (kW/m <sup>2</sup> )        | 181    | 191    | 186     |
| THR (MJ/m <sup>2</sup> )              | 117    | 114    | 115.5   |
| $\Delta H_c$ (MJ/kg)                  | 13.7   | 12.9   | 13.3    |
| TML (g)                               | 75.2   | 77.7   | 76.5    |



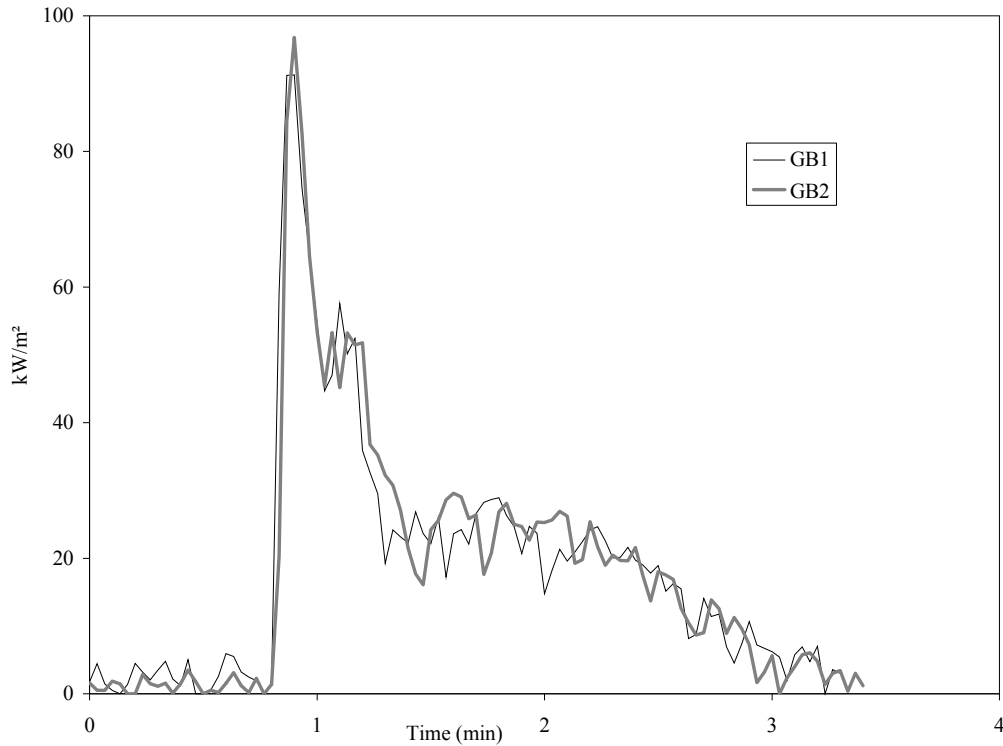
**Figure 4.** Heat release rate versus time curves for two particle board samples.

## 4.3 Gypsum Board

The cone calorimeter results of two samples of Gypsum Board are tabulated in Table (4) and the HRR as a function of time is shown in Figure 5.

**Table 4.** Cone calorimeter data results of two Gypsum Board samples.

| Parameter                      | GB1-SP | GB2-SP | Average |
|--------------------------------|--------|--------|---------|
| $t_{ign}$ (s)                  | 50     | 50     | 50      |
| $q_{max}$ (kW/m <sup>2</sup> ) | 91     | 97     | 94      |
| $q_{120}$ (kW/m <sup>2</sup> ) | 28     | 29     | 29      |
| THR (MJ/m <sup>2</sup> )       | 3.7    | 3.7    | 3.7     |
| $\Delta H_c$ (MJ/kg)           | 5.6    | 5.7    | 5.7     |
| TML (g)                        | 6.5    | 6.6    | 6.55    |

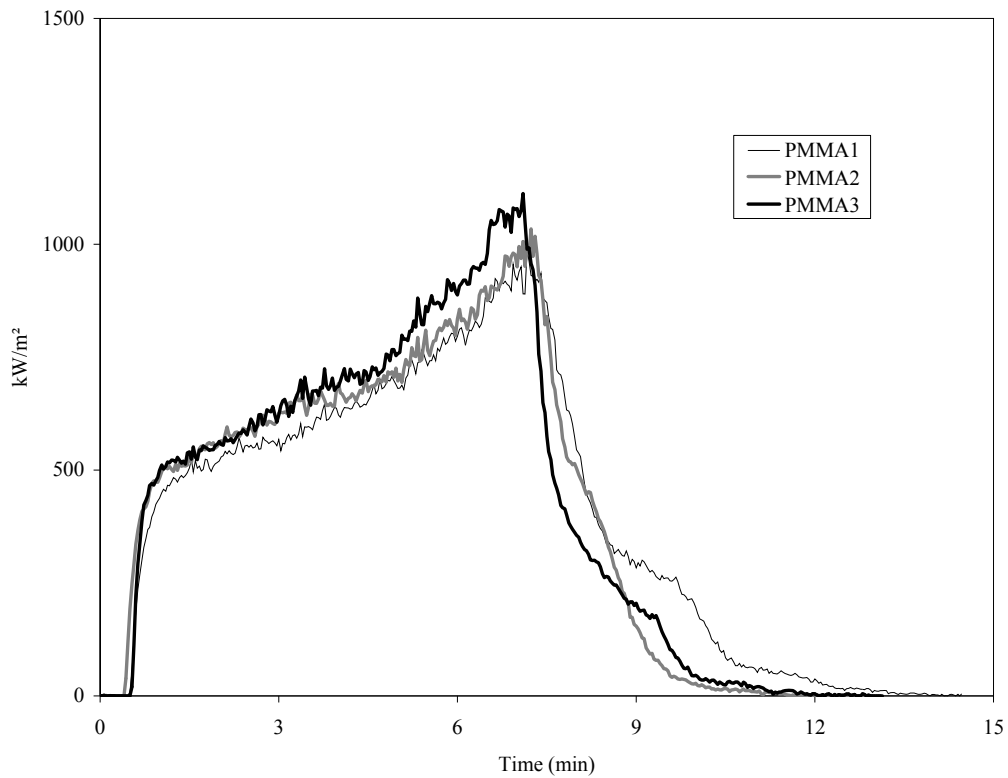
**Figure 5.** Comparison of Heat release rate versus time curves for two Gypsum board samples.

#### 4.4 Polymethylmethacrylate (PMMA)

The cone calorimeter results of three samples of Black PMMA are tabulated in Table (5) and the HRR as a function of time is shown in Figure (6).

**Table 5.** Cone calorimeter data results of three PMMA samples.

| Parameter                      | PMMA1-SP | PMMA2-SP | PMMA3-SP | Average |
|--------------------------------|----------|----------|----------|---------|
| $t_{ign}$ (s)                  | 33       | 27       | 33       | 31      |
| $q_{max}$ (kW/m <sup>2</sup> ) | 987      | 1034     | 1112     | 1044    |
| $q_{180}$ (kW/m <sup>2</sup> ) | 505      | 541      | 557      | 534     |
| THR (MJ/m <sup>2</sup> )       | 341      | 332      | 338      | 337     |
| $\Delta H_c$ (MJ/kg)           | 24.95    | 24.8     | 25.4     | 25      |
| TML (g)                        | 120.7    | 119.6    | 117.8    | 119     |



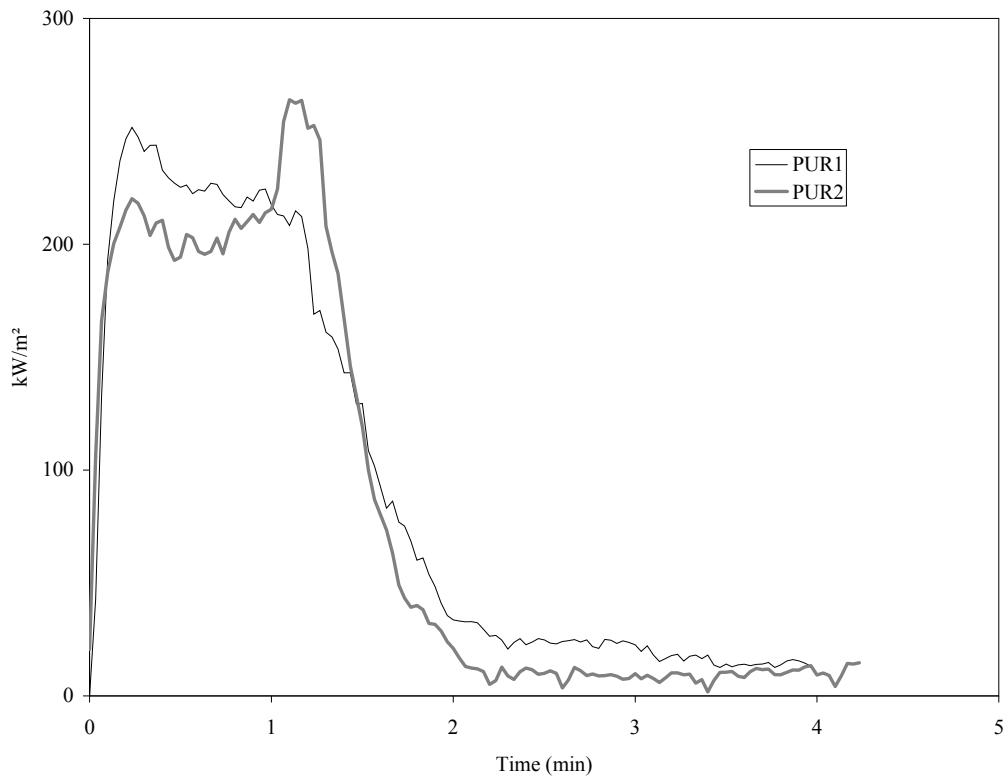
*Figure 6. Comparison of Heat release rate versus time curves for three PMMA samples.*

## 4.5 Polyurethane Foam

The cone calorimeter results of two samples of Polyurethane foam are tabulated in Table 6 and the HRR as a function of time is shown in Figure 7.

*Table 6. Cone calorimeter data results of two PUR samples.*

| Parameter                             | PUR1 | PUR2 | Average |
|---------------------------------------|------|------|---------|
| $t_{\text{ign}}$ (s)                  | 3    | 2    | 3       |
| $q_{\text{max}}$ (kW/m <sup>2</sup> ) | 252  | 264  | 258     |
| $q_{180}$ (kW/m <sup>2</sup> )        | 121  | 113  | 117     |
| THR (MJ/m <sup>2</sup> )              | 22.8 | 21.2 | 21.55   |
| $\Delta H_c$ (MJ/kg)                  | 22   | 20   | 21      |
| TML (g)                               | 9.1  | 9.3  | 9.2     |



**Figure 7.** Heat release rate versus time curves for two PUR samples.

## 5 NIS Results

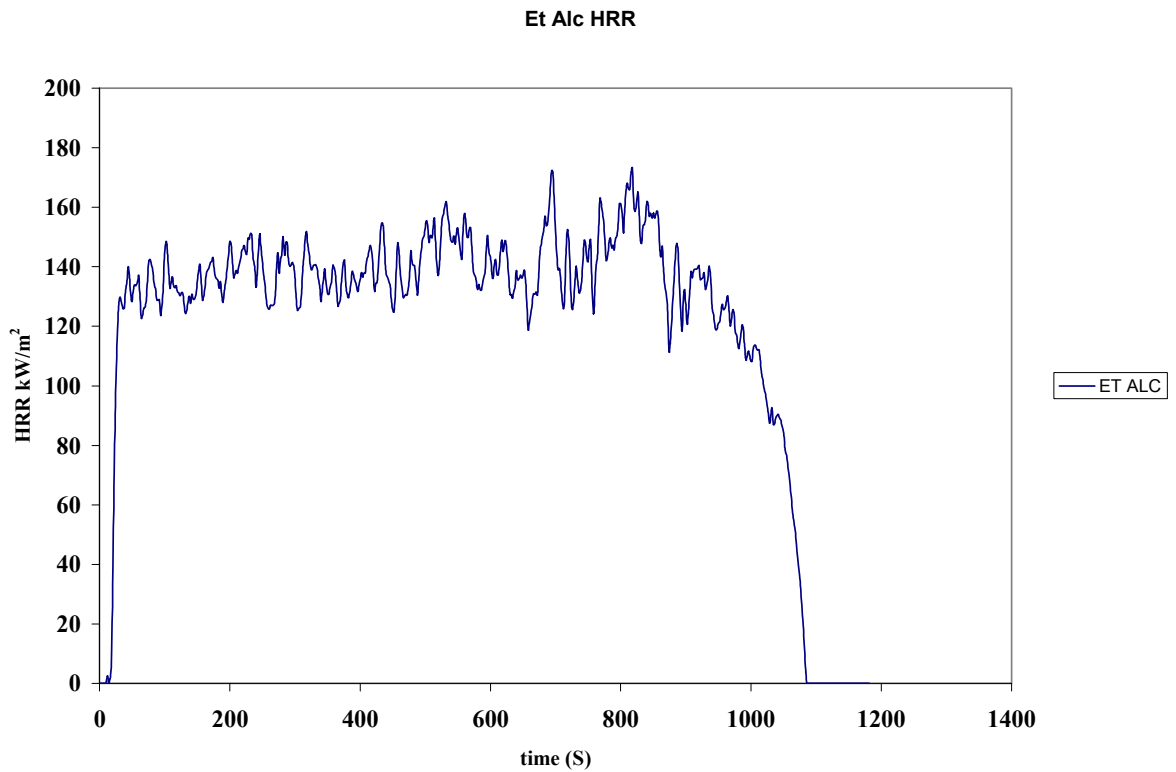
The results from the cone calorimeter tests conducted at NIS are presented in this section.

### 5.1 Calibration by ethanol

The ethanol calibration was performed by 68.8 milliliters (54.33g) of ethanol with purity 99.8% by volume was placed in a circular ceramic pan 100mm diameter and 40 mm high with a rounded of bottom. the pan was put underneath the cone with a 50 kW/m<sup>2</sup> radiation applied. Piloted ignition was used. The cone calorimeter results of the ethanol calibration are tabulated in Table 7 and the HRR versus time is shown in Figure 8.

**Table 7.** Cone calorimeter data results of ethanol.

| Parameter                      | Value Ethanol NIS |
|--------------------------------|-------------------|
| $t_{ign}$ (s)                  | 9                 |
| $q_{max}$ (kW/m <sup>2</sup> ) | 173               |
| $q_{180}$ (kW/m <sup>2</sup> ) | 122               |
| THR (MJ/m <sup>2</sup> )       | 1.42              |
| $\Delta H_c$ (MJ/kg)           | 26                |
| TML (g)                        | 54.6              |



**Figure 8.** Heat release rate for ethanol.

The theoretical total heat release of ethanol = weight x heat of combustion of ethanol  
 $= (54.19 \times 26.78)/1000 = 1.451 \text{ MJ}$   
 With weight of ethanol =  $54.33 \times 0.9975$  (conversion between weight% and volume%)  
 Total Heat Release of ethanol from cone =  $(1.423 \times 12.88)/13.1 = 1.399 \text{ MJ}$   
 Error percentage =  $(1.399 - 1.451) / 1.451 = -3.6 \%$

## 5.2 Particle Board

The cone calorimeter results of three samples of Particle Boards are tabulated in Table 8 and the HRR versus time is shown in Figure 10.

**Table 8.** Cone calorimeter data results of two Particle Board samples

| Parameter                      | PB1-NIS | PB2-NIS | PB3-NIS | Average |
|--------------------------------|---------|---------|---------|---------|
| $t_{ign}$ (s)                  | 29      | 33      | 27      | 30      |
| $q_{max}$ (kW/m <sup>2</sup> ) | 314     | 348     | 308     | 323     |
| $q_{180}$ (kW/m <sup>2</sup> ) | 144     | 163     | 165     | 158     |
| THR (MJ/m <sup>2</sup> )       | 108     | 111     | 108     | 109     |
| $\Delta H_c$ (MJ/kg)           | 13.6    | 13.4    | 13.3    | 13.4    |
| TML (g)                        | 79      | 83      | 81      | 81      |

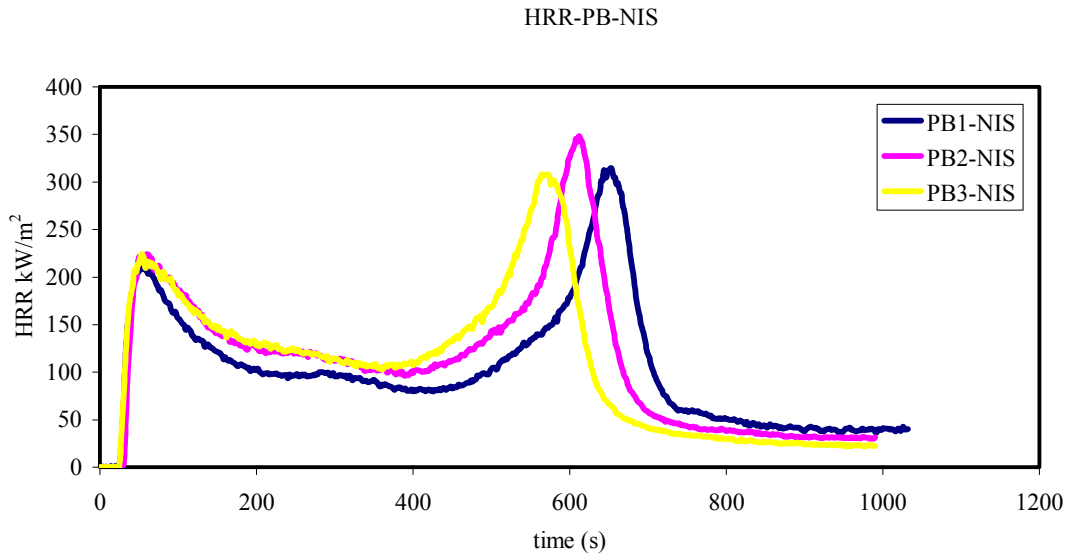


Figure 10. Heat release rate curves for three particle board samples.

### 5.3 Gypsum Board

The cone calorimeter results of two samples of Gypsum Board are tabulated in Table 9 and the HRR is shown in Figures 11.

Table 9. Cone calorimeter data results of two Gypsum Board samples.

| Parameter                      | GB1-NIS | GB2-NIS | GB3-NIS | Average |
|--------------------------------|---------|---------|---------|---------|
| $t_{ign}$ (s)                  | 35      | 35      | 35      | 35      |
| $q_{max}$ (kW/m <sup>2</sup> ) | 79      | 88.5    | 95      | 88      |
| $q_{120}$ (kW/m <sup>2</sup> ) | 14.4    | 19.1    | 17.5    | 17.1    |
| THR (MJ/m <sup>2</sup> )       | 2.0     | 2.8     | 2.4     | 2.4     |
| $\Delta H_c$ (MJ/kg)           | 4.3     | 4.5     | 3.6     | 4.1     |
| TML (g)                        | 4.3     | 5.5     | 6.6     | 5.5     |

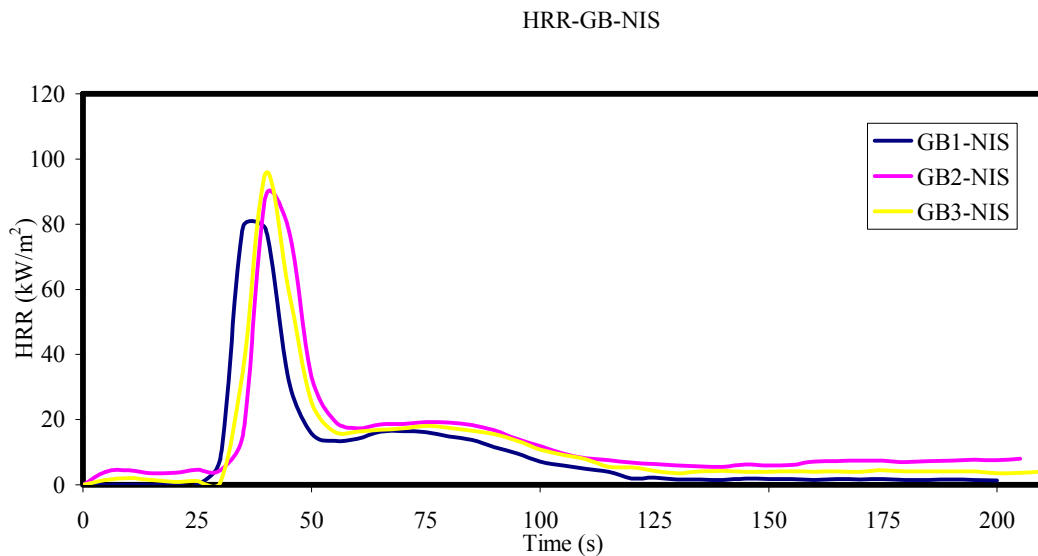


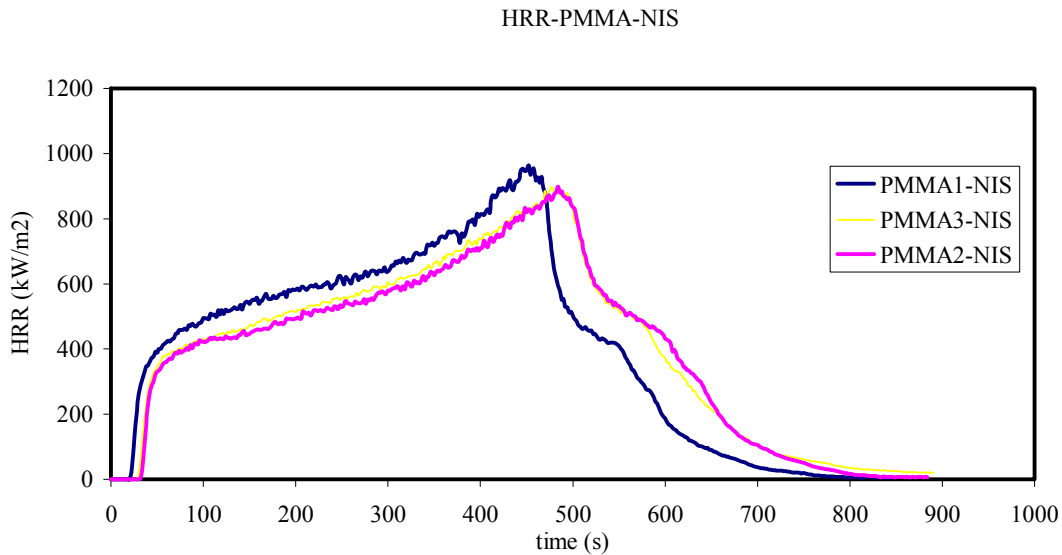
Figure 11. Comparison of Heat release rate curves for three Gypsum board samples.

## 5.4 Poly methyl methacrylate (PMMA)

The cone calorimeter results of three samples of black PMMA are tabulated in Table (10) and the HRR is shown in Figures (12).

**Table 10.** Cone calorimeter data results of three PMMA samples.

| Parameter                      | PMMA1-NIS | PMMA2-NIS | PMMA3-NIS | Average |
|--------------------------------|-----------|-----------|-----------|---------|
| $t_{ign}$ (s)                  | 26        | 37        | 34        | 32      |
| $q_{max}$ (kW/m <sup>2</sup> ) | 964       | 899       | 899       | 921     |
| $q_{180}$ (kW/m <sup>2</sup> ) | 484       | 422       | 436       | 447     |
| THR (MJ/m <sup>2</sup> )       | 348       | 353       | 361       | 354     |
| $\Delta H_c$ (MJ/kg)           | 26.4      | 26.4      | 28        | 27      |
| TML (g)                        | 116       | 116       | 114       | 115     |



**Figure 12.** Comparison of Heat release rate versus time curves for Three PMMA samples.

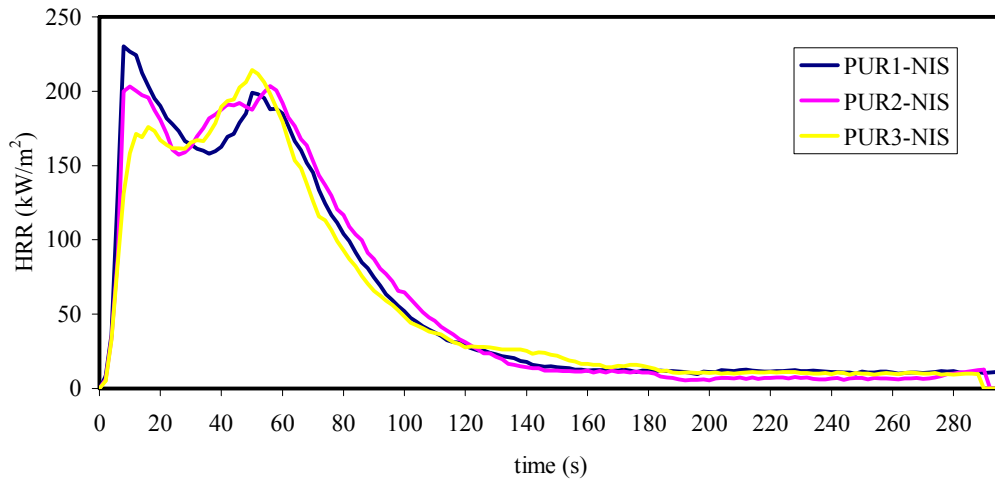
## 5.5 Poly Urethane Foam

The cone calorimeter results of two samples of Poly urethane foam are tabulated in Table (11) and the HRR versus time is shown in Figure 13.

**Table 11.** Cone calorimeter data results of three PUR samples

| Parameter                      | PUR1-NIS | PUR2-NIS | PUR3-NIS | Average |
|--------------------------------|----------|----------|----------|---------|
| $t_{ign}$ (s)                  | 4        | 4        | 5        | 4       |
| $q_{max}$ (kW/m <sup>2</sup> ) | 203      | 214      | 230      | 216     |
| $q_{180}$ (kW/m <sup>2</sup> ) | 80       | 87       | 87       | 85      |
| THR (MJ/m <sup>2</sup> )       | 17.6     | 17.55    | 16.85    | 17.3    |
| $\Delta H_c$ (MJ/kg)           | 20.55    | 18.3     | 17.05    | 18.6    |
| TML (g)                        | 7.55     | 8.4      | 8.7      | 8.2     |

## HRR-PUR-NIS



**Figure 13.** Heat release rate versus time curves for three PUR samples

## 6 Comparison

Five cone parameters were chosen for the comparisons, i.e. time to ignition, peak heat release rate, average heat release rate three minutes after ignition, total heat release and average heat of combustion.

### 6.1 Ethanol comparison

The ethanol calibrations performed showed that the SP total heat released results were slightly higher than the theoretical value (3.7 %) while the NIS results were slightly lower than the theoretical value (3.8%).

### 6.2 Particle Board comparison

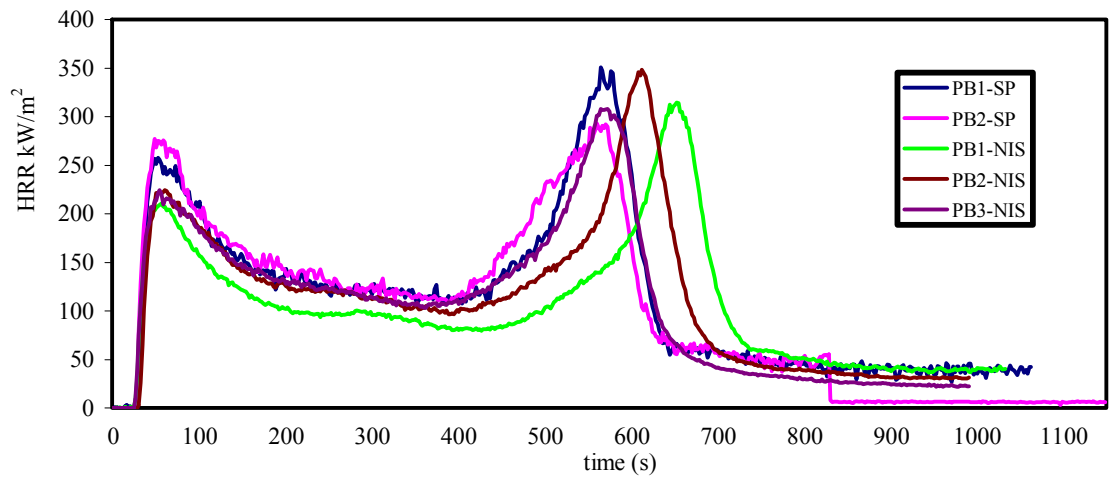
Two samples were tested in the cone calorimeter located at SP- Sweden and three samples were tested in the cone calorimeter located at NIS-Egypt. The resulted cone data are tabulated in table 12 and heat release rate versus time is graphically represented in figure 14.

The average time to ignition for the SP samples was 29 seconds while that for NIS samples was 30 seconds. There was no big difference between the results of heat of combustion of NIS samples (13.4 MJ/kg) in comparison with the value of SP (13.3 MJ/kg). In addition was the average  $q_{max}$  very similar for the two labs, i.e. 322 and 323 respectively. The spread in the results was also very similar. In case of the other parameters the values of NIS samples results are lower than that of SP samples. The peak heat release rate value (average of three samples) of NIS particle board samples is less than one percent higher than the SP results. The difference between the values of average HRR 180s after ignition of NIS and SP is about 28 kW/m<sup>2</sup>. The total heat release of NIS samples is 6 % lower than the SP results.

**Table 12. Comparison between SP & NIS results for Some of Cone results of PB samples**

| sample      | Time to ignition (s) | $q_{max}$ (kW/m <sup>2</sup> ) | $q_{180}$ (kW/m <sup>2</sup> ) | Total Heat release (THR)(MJ/m <sup>2</sup> ) | Heat of combustion ( $\Delta H_c$ ) (MJ/kg) |
|-------------|----------------------|--------------------------------|--------------------------------|--|---|
| PB1-SP      | 30                   | 351                            | 181                            | 117  | 13.7  |
| PB2-SP      | 28                   | 293                            | 191                            | 114  | 12.9  |
| Average-SP  | <b>29</b>            | <b>322</b>                     | <b>186</b>                     | <b>115.5</b>                                 | <b>13.3</b>                                 |
| PB1-NIS     | 29                   | 314                            | 144                            | 108  | 13.6  |
| PB2-NIS     | 33                   | 348                            | 163                            | 111  | 13.4  |
| PB3-NIS     | 27                   | 308                            | 165                            | 108  | 13.0  |
| Average-NIS | <b>30</b>            | <b>323</b>                     | <b>158</b>                     | <b>109</b>                                   | <b>13.4</b>                                 |

PB-HRR Comparison

**Figure 14. Comparison between HRR versus time curves of PB samples samples tested at SP and NIS.**

### 6.3 Gypsum Board comparisons

The results are tabulated in table 15 and the curves are shown in figure 17. Figure 17 shows the different results obtained in the institutes. Only the peak HRR values are similar. The other results showed a difference of about 30 %.

**Table 15. Comparison between SP & NIS for Some Cone results for the GB samples.**

| Sample         | Time to ignition (s) | $q_{max}$ (kW/m <sup>2</sup> ) | $q_{120}$ (kW/m <sup>2</sup> ) | Total Heat release (MJ/m <sup>2</sup> ) | Heat of combustion (MJ/kg) |
|----------------|----------------------|--------------------------------|--------------------------------|---|----------------------------|
| GB1-SP         | 50                   | 91                             | 28                             | 3.7                                     | 5.6                        |
| GB2-SP         | 50                   | 97                             | 29                             | 3.7                                     | 5.7                        |
| <b>Average</b> | <b>50</b>            | <b>94</b>                      | <b>28.5</b>                    | <b>3.7</b>                              | <b>5.7</b>                 |
| GB1-NIS        | 35                   | 79                             | 14.4                           | 2.0                                     | 4.3                        |
| GB2-NIS        | 35                   | 88.5                           | 19.1                           | 2.8                                     | 4.5                        |
| GB3-NIS        | 35                   | 95                             | 17.5                           | 2.4                                     | 3.6                        |
| <b>Average</b> | <b>35</b>            | <b>88</b>                      | <b>17.0</b>                    | <b>2.4</b>                              | <b>4.1</b>                 |

## HRR-GB-SP-NIS comparison

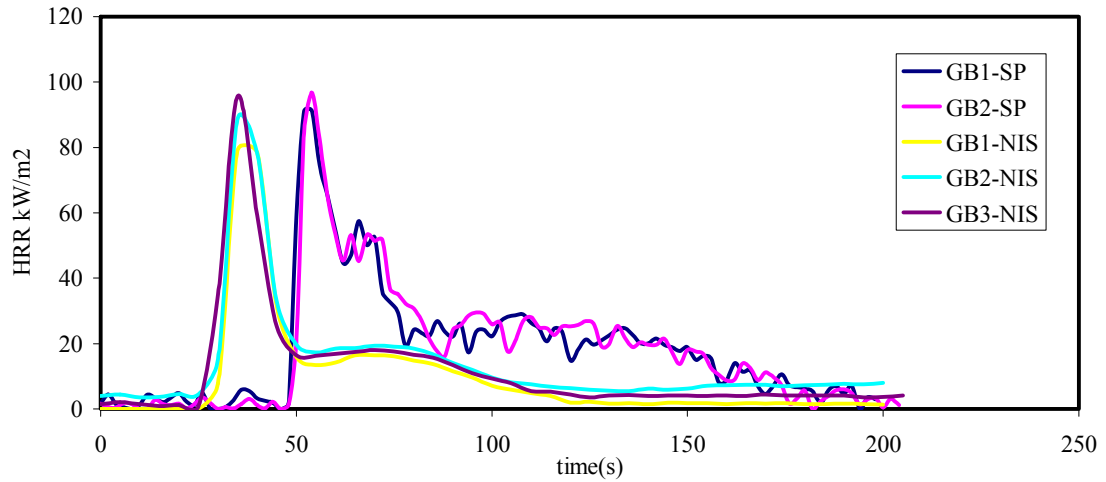


Figure 17. Comparison between HRR versus time curves of GB samples tested at SP and NIS.

## 6.4 PMMA Comparison

Some of The PMMA combustion parameters which were calculated from the cone results for both institutes are tabulated in table 13. The heat release curves of the different samples are graphically represented in figure 15. The time to ignition for the samples tested in SP and NIS are nearly the same. A difference of about 12 % in peak heat release results and 8% in heat of combustion is detected. A 5 %increase in the value of total heat release of NIS samples in comparison with the value of SP is observed. Figure 15 shows a difference between the HRR of both samples during the first 3 minutes in accordance with the difference in average HRR  $q_{180}$  results, i.e. the SP value is 19% higher than the NIS value.

Table 13. Comparison between SP & NIS for Some of Cone results Of PMMA samples.

| Sample             | Time to ignition (s) | $q_{max}$ (kW/m <sup>2</sup> ) | $q_{180}$ (kW/m <sup>2</sup> ) | Total Heat release (MJ/m <sup>2</sup> ) | Heat of combustion (MJ/kg) |
|--------------------|----------------------|--------------------------------|--------------------------------|---|----------------------------|
| PMMA1-SP           | 33                   | 987                            | 505                            | 341                                     | 24.95                      |
| PMMA2-SP           | 27                   | 1034                           | 541                            | 332                                     | 24.8                       |
| PMMA3-SP           | 33                   | 1112                           | 557                            | 338                                     | 25.4                       |
| <b>Average SP</b>  | <b>31</b>            | <b>1044</b>                    | <b>534</b>                     | <b>337</b>                              | <b>25</b>                  |
| PMMA1-NIS          | 26                   | 964                            | 484                            | 348                                     | 26.4                       |
| PMMA2-NIS          | 37                   | 899                            | 422                            | 353                                     | 26.4                       |
| PMMA3-NIS          | 34                   | 899                            | 436                            | 361                                     | 28                         |
| <b>Average NIS</b> | <b>32</b>            | <b>921</b>                     | <b>447</b>                     | <b>354</b>                              | <b>27</b>                  |

HRR-PMMA-Comparison

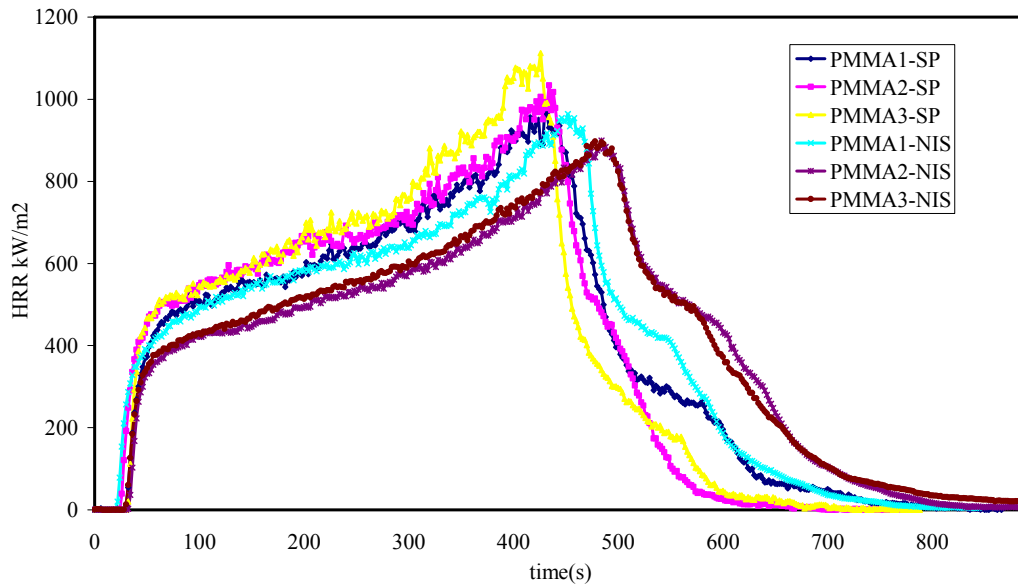


Figure 15. Comparison between HRR versus time curves of PMMA samples carried out AT SP & NIS.

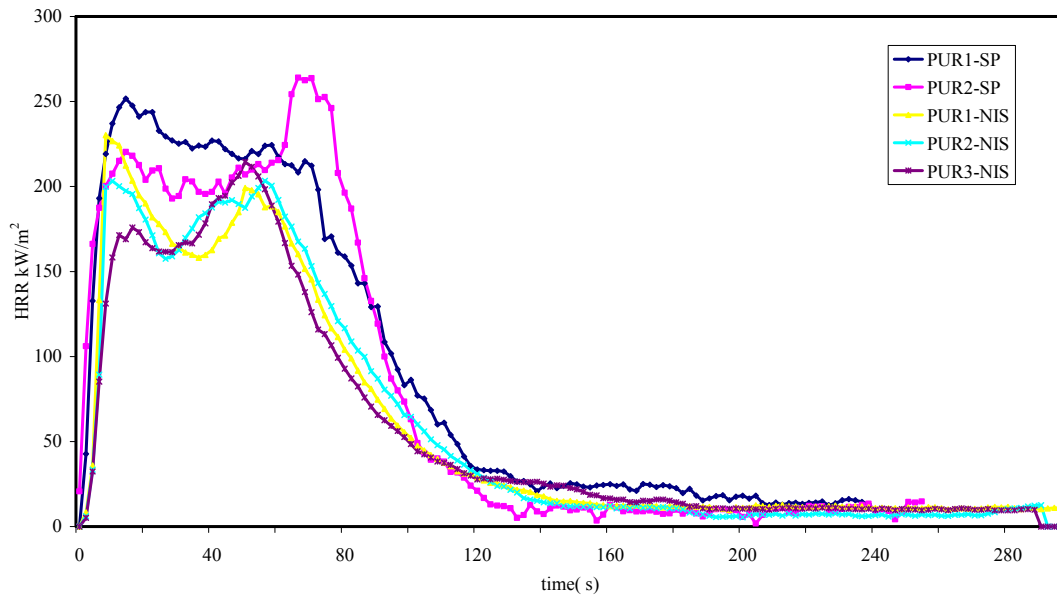
## 6.5 PUR foam samples comparisons

There is a difference between the results for most of the measured parameters of about 15 % except the average HRR 180 seconds after ignition which differs by 27 % as shown in Table 14. The SP samples take a longer time until completely burned off in comparison with the NIS samples as illustrated in Fig.16.

Table 14. Comparison between SP & NIS for Some Cone results for the PUR samples.

| Sample         | Time to ignition (s) | $q_{\max}$ (kW/m <sup>2</sup> ) | $q_{180}$ (kW/m <sup>2</sup> ) | Total Heat release (MJ/m <sup>2</sup> ) | Heat of combustion (MJ/kg) |
|----------------|----------------------|---------------------------------|--------------------------------|---|----------------------------|
| PUR1-SP        | 3                    | 252                             | 121                            | 22.8                                    | 21.2                       |
| PUR2-SP        | 2                    | 264                             | 113                            | 21.2                                    | 20                         |
| <b>Average</b> | <b>3</b>             | <b>258</b>                      | <b>117</b>                     | <b>22.0</b>                             | <b>21</b>                  |
| PUR1-NIS       | 4                    | 203                             | 80                             | 17.6                                    | 21                         |
| PUR2-NIS       | 4                    | 214                             | 87                             | 17.55                                   | 18                         |
| PUR3-NIS       | 5                    | 230                             | 87                             | 16.85                                   | 17                         |
| <b>Average</b> | <b>4</b>             | <b>216</b>                      | <b>85</b>                      | <b>17.3</b>                             | <b>19</b>                  |

HRR-PUR-SP-NIS Comparison



**Figure 16.** Comparison between HRR versus time curves of PUR samples tested in the cone calorimeter at SP and NIS.

## 6.6 Comparison by means of average values

The average value for peak heat release, total heat release and effective heat of combustion is calculated in order to facilitate the comparison of the results. The average value is calculated as follows:

$$\text{Average PHRR} = (\text{Average PHRR of SP} + \text{Average PHRR of NIS}) / 2$$

The results of SP and NIS are compared with these average values are tabulated in tables 16, 17 and 18.

**Table 16.** Comparison of average Peak Heat Release Rate for the different samples .

| Sample | Average $q_{\max}$ (kW/m <sup>2</sup> ) | SP results | SP Deviation % | NIS results | NIS Deviation % |
|--------|---|------------|----------------|-------------|-----------------|
| PB     | 322.5                                   | 322        | -0.15          | 323         | 0.15            |
| PMMA   | 982.5                                   | 1044       | +6.3           | 921         | -6.3            |
| PUR    | 237                                     | 258        | +8.9           | 216         | -8.9            |
| GB     | 91                                      | 94         | +3.3           | 88          | -3.3            |

The comparison of the average maximum HRR for each lab and material shows a very good agreement for Particle board (0.15%) as seen in Table 16 while the difference is larger for the other materials, the difference is however in the same order of magnitude as the difference for the ethanol comparison.

**Table 17. Comparison of Total Heat Release Rate (THR) of different samples to the average values**

| Sample | Average Value of THR | SP results | SP Deviation % | NIS results | NIS Deviation % |
|--------|----------------------|------------|----------------|-------------|-----------------|
| PB     | 113                  | 115.5      | +3.1           | 109         | -3.1            |
| PMMA   | 345.5                | 337        | -2.5           | 354         | +2.5            |
| PUR    | 19.445               | 21.55      | +11            | 17.34       | -11             |
| GB     | 3.05                 | 3.70       | +21            | 2.40        | -21             |

It is clearly seen from the comparison in Table 17 of total heat release of different samples to the mean values that the deviation percentage is in the accepted range for PB and PMMA. On the other hand for the PUR and GB samples the deviations were 10.8 & 21.3 % respectively.

**Table 18. Comparison of Effective Heat of Combustion  $\Delta H_c$  for the samples to the average values**

| Sample | Average Value of $\Delta H_c$ | SP results | SP Deviation % | NIS results | NIS Deviation % |
|--------|-------------------------------|------------|----------------|-------------|-----------------|
| PB     | 13.35                         | 13.3       | -0.5           | 13.4        | +0.5            |
| PMMA   | 26.0                          | 25.0       | -3.5           | 27.0        | +3.5            |
| PUR    | 20.0                          | 19         | -5.0           | 21.0        | +5.0            |
| GB     | 4.65                          | 5.70       | +23            | 3.60        | -23             |

The effective heat of combustion is compared in Table 18. In case of the PB samples the difference from the average values was only  $\pm 0.5$  % while the value for the PMMA and PUR is a factor of 3.5 and 5 % deviation from the average values. The main big difference between the mean values and the results of the individuals were found in case of GB samples ( $\pm 23$  %)

## 7 Discussion and conclusions

From the comparison of the test results we can see that in most cases the heat release levels are within 10% compared to the average between both institutes. Generally the HRR curves from NIS are lower compared to the levels from SP. Taking into account the fact that the calibration with ethanol was slightly higher at SP and slightly lower at NIS it can be concluded that the HRR levels are within the expected deviation between the laboratories. The repeatability for both laboratories is also acceptable.

A major difference between the laboratories was found in the ignition time of the gypsum board. A possible explanation can be the fact that there is a difference in spark ignition system or in preconditioning. NIS has not conditioned the Gypsum Board in their conditioning room and therefore it is not known at what humidity etc. the material was stored and tested in. SP utilises a conditioning room where the material is stored before test and then tested in a not as controlled atmosphere. The conditions in the test room are however recorded in the test and no test is conducted when the conditions are outside the allowed conditions according to the standard.

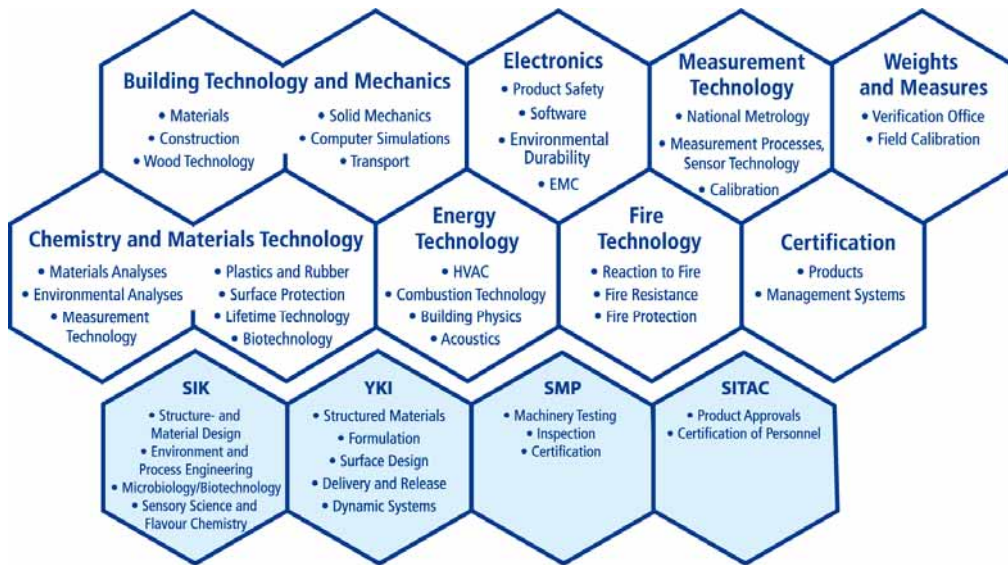
## 8 References

1. Wickström U. and Göransson U, Full-Scale/Bench-Scale Correlations of Wall and Ceiling linings”, Journal of Fire and Materials, vol. 16, 1992.
2. Göransson U. and Wickström U, Prediction of heat release rates of surface materials in large-scale fire test based on cone calorimeter results, Journal of testing and evaluation 1987
3. Sumathipala K., Kim A. and Lougheed G, A comparison of ASTM and ISO Full-Scale RoomFire”, NFL/NRCC, Fire and Materials 2<sup>nd</sup> international conference and exhibition, Washington September 1993.
4. Björn Karlsson, Modeling Fire Growth on Combustible Lining Materials in Enclosures, Report TVBB-1009, Lund 1992.
5. T. Hakkarainen, Correlation studies of SBI and Cone Calorimeter test results Interflam proceedings 2001 pp 519-530, Interscience communications Ltd, London 2001.
6. Steen Hansen, P. Hovde, Prediction of smoke production based on statistical analyses and mathematical modelling, Interflam proceedings 2001 pp 113-124, Interscience communications Ltd, London 2001. B. Messerschmidt, P. Van Hees, U. Wickström, Prediction of SBI (Single burning item) test results by means of Cone Calorimeter Test results, Interflam proceedings 1999 pp 11-22, Interscience communications Ltd, London 1999.
7. P. Van Hees, A. Steen Hansen, Development of a screening method for the SBI and Room Corner Test based on the Cone Calorimeter, Nordtest project 1479-00, to be published 2002.
8. FIPEC – Fire Performance of Electric Cables, Final Report on the Europeans Commission, SMT Programme SMT4-CT96-2059, 410pp, ISBN 0 9532312 5 9, London, 2000.
9. P. Van Hees, J. Axelsson, Mathematical modelling in the European Union Project FIPEC, Fire and Materials Journal 25 nr 4 pp 169, 2001.
10. Sundström, Björn, Grayson, Stephen J and van Hees, Patrick. ”An Overview of the Findings of the Combustion Behaviour of Upholstered Furniture Project”, Fire and Materials, Vol 20, No 4, p 205-211.
11. Van Hees, Patrick. ”Mathematical Models for Wind-Aided Flame Spread of Floor Coverings”, The Fifth International Symposium on Fire Safety Science, Melbourne, Australia, 3-7 March, 1997.
12. ISO 5660-1:2002. Fire tests -- Reaction to fire -- Part 1 Heat release, smoke production and mass loss rate – Heat release rate, International Organization for Standardisation, 2002.
13. ISO 5660-2:2002. Fire tests -- Reaction to fire -- Part 2: Reaction to fire tests – Heat release, smoke production and mass loss rate - Smoke production rate, International Organization for Standardisation, 2002
14. ISO/TR 5660-3:2003. Fire tests -- Reaction to fire -- Part 3: Reaction to fire tests – Heat release, smoke production and mass loss rate - Guidance document, International Organization for Standardisation, 2003.

15. ISO 17554: 2005. Fire tests -- Reaction to fire – Mass loss measurement, International Organization for Standardisation, 2005.
16. Van Hees, Patrick “How to use the cone calorimeter for prediction of fires and fire test results and for use as a product development and quality control tool - new developments”, Proceedings of Fire and materials 2005 conference pp253-266, San Francisco, Interscience communications, 2005.

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