



Public Project Report

EGOLF Round Robin

concerning the
Determination of a Building Product's Propensity
to Undergo Continuous Smouldering

acc. to **EN 16733:2016**

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Abbreviations

LOI: Loss on ignition
TC: Thermocouple

1. Background

Round robin exercises are important for the determination of trueness and precision of fire test methods. National accreditation bodies request that accredited fire laboratories participate in such exercises as a part of their documentation about their instrumentation. Therefore, a round robin on EN 16733:2016 [1] was arranged by EGOLF. This test method had only recently been introduced in 2016 into the canon of reaction-to-fire tests, and it is still slowly being adopted and evaluated in EGOLF test laboratories.

This round robin had been launched after the EGOLF Technical Committee 1 meeting of April 2018 in Cambridge where the need for a coordinated round robin on this method was formulated, and after initially 19 laboratories in total had expressed their interest in participation.

This round robin was prepared in 2019. Laboratories were conducting experiments mainly starting in summer 2019 until summer 2020.

2. Objectives

The main objective for this project was to conduct a round robin exercise among the EGOLF members on EN 16733.

This project aimed to:

- try to find as of yet undetermined causes for unsatisfactory repeatability that has been observed by early adopters of the standard by comparing the test equipment,
- build a common frame of experience as a base for discussion of this relatively new test method among EGOLF members,
- determine how well EGOLF laboratories are able to perform testing according to EN 16733 in a proper way,
- give information about the reproducibility and repeatability of the test method,
- give an indication of each participating laboratory's performance regarding the test method as required by national accreditors,
- give information regarding possible improvements of the test method.

3. Organisation

The round robin was organized by Prüfinstitut Hoch (Germany), MPA NRW (Germany) and MPA Braunschweig (Germany).

In particular, MPA NRW was responsible for the selection and acquisition of the test materials. PI Hoch prepared instructions for the participating labs and coordinated the instrument data collection from them. They also performed the data analysis and the preparation of the reports. Quality assurance and report design for the proficiency test was conducted by MPA Braunschweig.

To ensure a double-blind test design, direct contact between the project organisers and the laboratories was prevented, and the general secretary of EGOLF was acting as intermediate between the participants and the project group. The laboratories submitted their results not under their name, but under an anonymous code consisting of a letter and

a number (e.g. "A2"), which only the Secretary General could reattribute to the laboratories.

The project was delayed, first due to manufacturing constraints of the supplier of the mineral wools for proficiency tests, and particularly by the SARS-CoV pandemic that began in 2020 which led to many laboratories shutting down operation at least in part for long periods of time.

All collected data was collected in spreadsheet files. The raw data of all test results was handed over to EGOLF Executive as a digital copy.

4. Test Method

4.1. Experiment stages for the laboratories

The experiments conducted by the laboratories were divided into two work packages.

4.2. First stage: Instrumentation and heat output

In the first stage, all participating laboratories were instructed to evaluate their equipment, especially documenting the dimensions of their burner in detail, the gas flow measurement device, the housing of the test equipment, the thermocouples, and the air flow conditions in the vicinity of the samples. The answers were collected in a questionnaire and used for further evaluation.

Afterwards, they conducted a series of measurements of the heat output of the burner. For this cause, a calcium silicate panel compliant with EN 13238 was used as a sample in which thermocouples were inserted at defined positions. Completion of this stage was mandatory for each laboratory before continuing with the material tests in the second stage. Figure 1 shows the setup for this test.

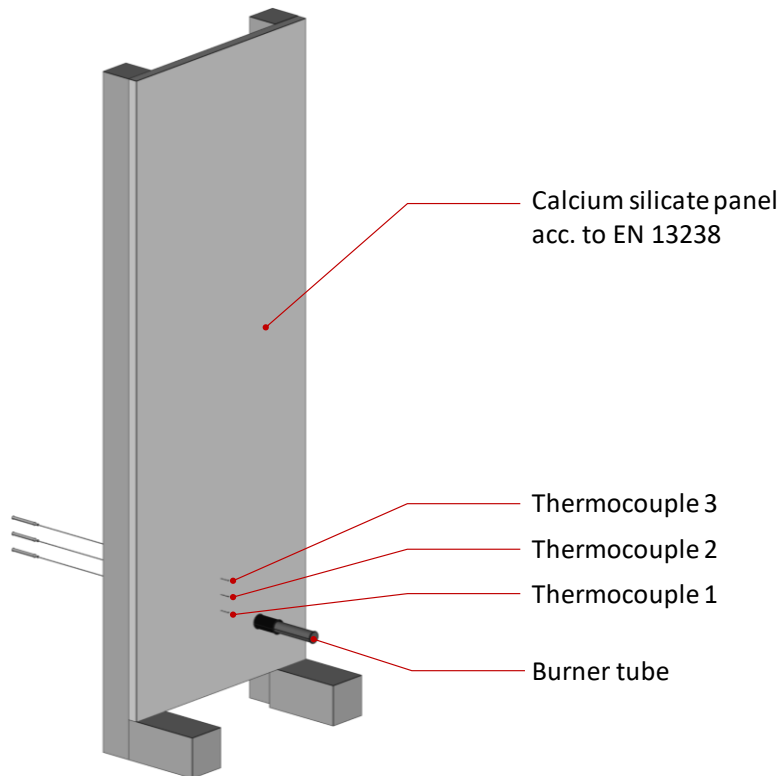


Figure 1: Overview of setup for the heat output test.

A calcium silicate panel in accordance with EN 13238 and a thickness of 12 mm was to be cut to 800 × 300 mm². The drill holes in the vertical middle axis of the sample were to be introduced in the sample as shown in Figure 2. They should have a diameter of 1.5 mm up to 2 mm and a vertical distance of 20 mm. The lowermost drill hole was to be in the axis of the burner.

Into these drill holes, three sheathed thermocouples of type K with an outer diameter of 1.5 mm were to be inserted. This is the same type of thermocouples as described for the tests in EN 16733. The enumeration of the thermocouples started at the lowermost one.

The thermocouples should perpendicularly protrude (12 ± 0.5) mm from the panel surface that was impinged by flame (see Figure 2). This way, cooling effects from the panel were deemed to be negligible.

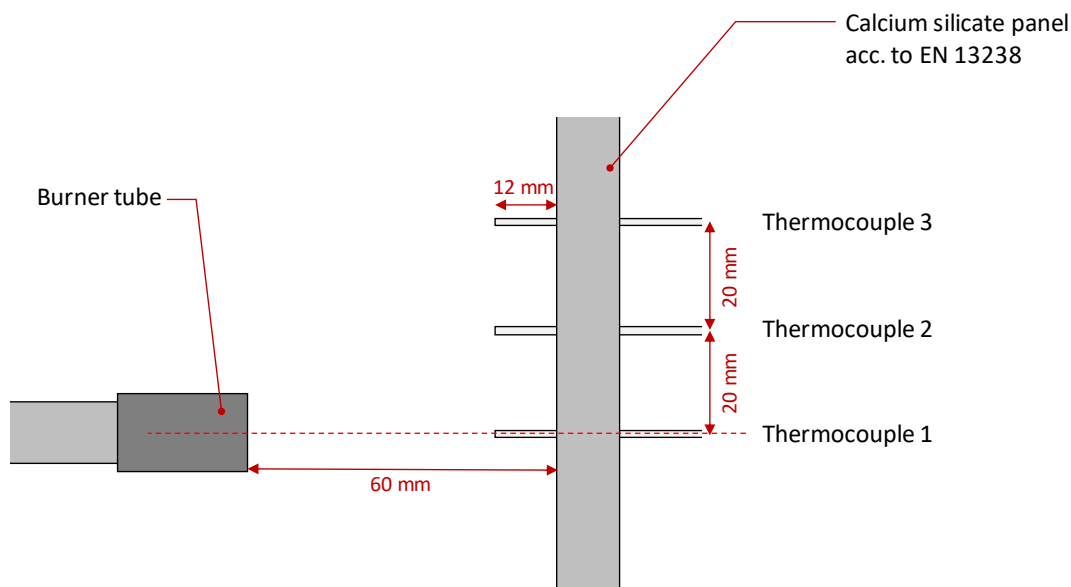


Figure 2: Schematic drawing of the comparison test for the heat output.

This test procedure was directly derived from section 8 of EN 16733: While the burner was already ignited and data logging (measurement frequency: at least once per 3 seconds) switched on for the three thermocouples, the burner was to be left burning two minutes for stabilisation. The regulator for the air supply of the burner was to be fully opened. Afterwards, it should have been moved into the measurement position, i.e. at a distance of 60 mm from calcium silicate panel to burner tube.

The burner was to be left in the measurement position for six minutes. A constant level of temperature had to be recorded by the thermocouples by then, otherwise the burner was left in place until a constant level was observed. The burner was to be pulled back afterwards. After cooling down of the equipment to ambient conditions, this test was repeated one further time.

A standardized spreadsheet file was distributed to collect the measurement results. Laboratories showing deviations from permissible testing equipment were informed if necessary.

4.3. Second stage: Proficiency testing

In the second stage, two mineral wools were selected as building products to be used in the round robin by the organisers for comparative material tests. These were deliberately chosen as they were expected to show rather unambiguous results. As the final result of EN 16733 tests will only be a binary verdict (results would either be "a tendency" or "no tendency" towards smouldering combustion), products with an unclear behaviour were not deemed preferential when trying to evaluate this method in its still early stages.

The test materials were distributed to the participating laboratories, together with additional instructions on preparation, measurements, photos and recording of test results. A homogenous test report was distributed to facilitate the comparison of the results coming from the individual test laboratories.

The mineral wools were specially tailored for this round robin test series, they were not products publicly available on the market. This decision was made to have defined organic contents throughout all samples, and also to have to different organic contents to compare for the round robin. One of the samples was meant to have an ensured smouldering effect, the other was to be certainly non-smouldering.

MPA NRW determined the following characteristics for the samples:

Sample	Gross density	LOI (EN 13820)
Material A	124 kg/m ³	5.2 %
Material B	117 kg/m ³	3.7 %

5. Participants

The following 22 laboratories applied for participation in the round robin.

Country	Participating laboratories
Austria	IBS Linz
Czech Republic	Pavus
France	CSTB LNE
Germany	MPA Dresden BAM MPA Braunschweig PI Hoch TU München MFPA Leipzig MPA Univ. Stuttgart ift Rosenheim
Lithuania	FRC
Netherlands	Efectis NL
Poland	ITB
Romania	CNSIPC
Slovenia	ZAG
United Kingdom	Warringtonfire

6. Results regarding the instrumentation (Stage 1)

6.1. Misleading burner description in the test standard

When evaluating the standard text, the organisers found that paragraph 5.1.3 from EN 16733 [1] could easily be misunderstood:

"[...] The straight part of the burner tube shall have a length of 100 ± 10 mm, the conical part shall have a length of 35 ± 3 mm. [...]"

As the burner tube consists of both a straight and a conical part, the total length of the burner tube should be the sum of those two lengths, i.e. about 135 mm.

However, as the scheme in Figure 7 of EN 16733 is to scale, one can already assume that the total length of the burner tube is actually supposed to be 100 mm instead of 135 mm. This corresponds with the measured burner tube lengths of all participating laboratories (see Figure 3). This is not surprising as nearly all Teclu burners used originate from the same manufacturer.

Therefore, CEN should review the wording in paragraph 5.1.3.



Figure 3: Teclu burner as used by nearly all of the participating laboratories. The actual total length of about 100 mm can be discerned.

6.2. Maximum opening of burner air supply

Paragraph 5.1.3 of the test standard [1] further states:

"[...] The air supply to the burner shall be fully open. [...]"

This statement remains very vague. During this round robin, the actual possible opening of the air supply was measured by the laboratories (see Figure 4).



Figure 4: Air supply opening at the bottom of the burner.

An opening too small might restrict the air influx and hinder the complete combustion of propane gas. The measured results cover a wide range of possible maximum openings which greatly depend on the exact subtype of the employed burner and the way it is assembled in the test rig. Figure 5 shows the distribution of the maximum air supply openings found in the participating laboratories. This topic is further explored in paragraph 6.6.

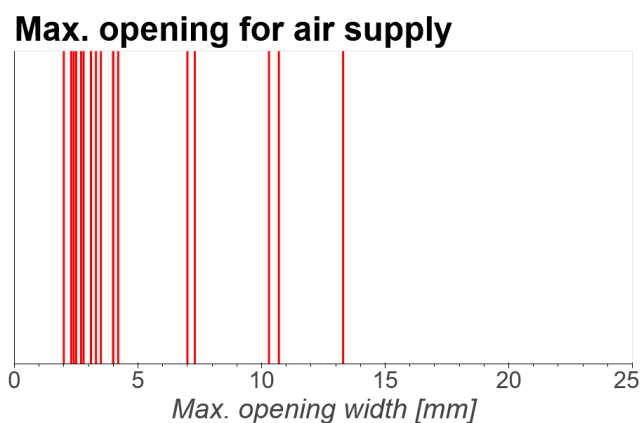


Figure 5: Distribution of measured maximum air supply openings in the laboratories.

6.3. Air velocities in sample vicinity

The air velocities were measured at the four measurement points described in the test standard (in front of and behind the sample in heights of 100 mm and 600 mm above the sample floor). The measurements were conducted for the test setup of the heat output test of stage 1. The results are shown in Figure 6. None of EGOLF laboratories seems to have a problem achieving the requirement of air velocities at these points that must not exceed 0.2 m/s.

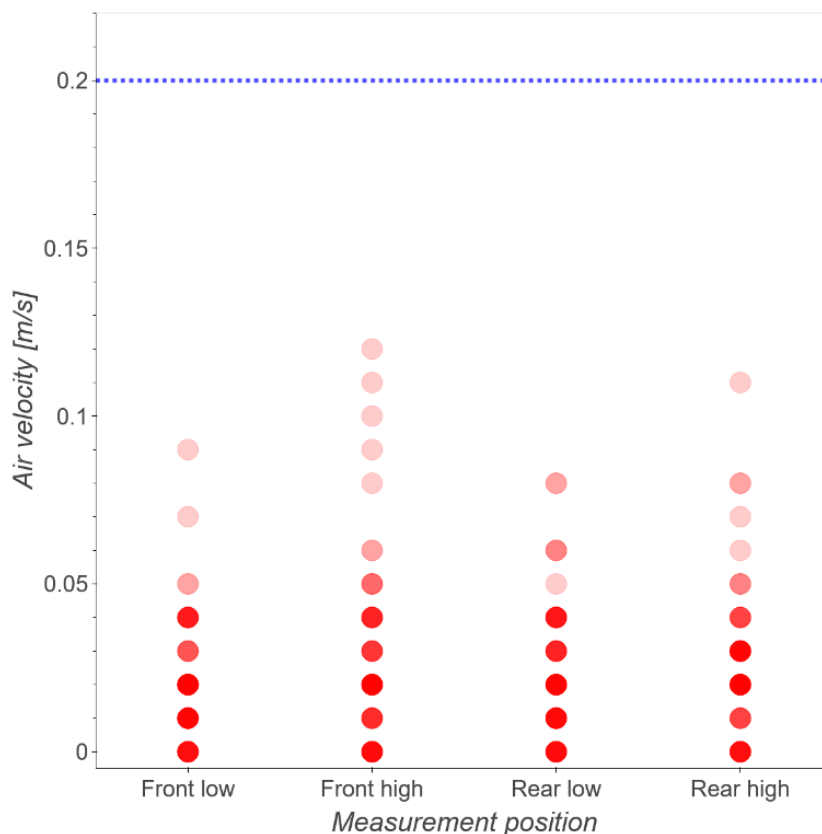


Figure 6: Air velocities in sample vicinity during the first experiment stage. The darker a spot is, the more measurements with the corresponding values were recorded.

6.4. Housing of test rig

The test rig might or might not be encased in a closed housing that might or might not prevent sufficient oxygen influx for the propane flame. The test standard does not mention any details about this factor. The laboratories were therefore questioned whether their test rig was at all encased in an own housing, and if yes, what the volume of this housing was. Those laboratories that viewed their test equipment as "encased" reported the encasement volumes given in Figure 7. As shown, there are also reported encasement volumes of 20 m³ and above. These volumes are in the range of large rooms or halls and would not have to be counted as encasement that might hinder gas flow. Therefore, these encasements with high volumes were not counted as encasements.

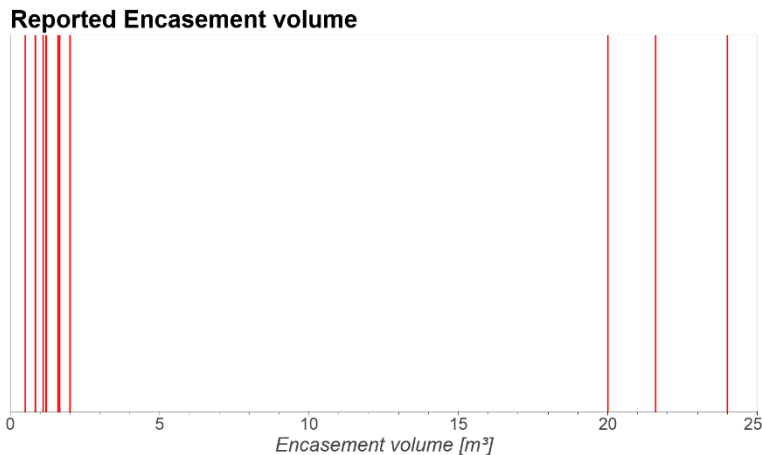


Figure 7: Those laboratories that reported their test rig as "encased" estimated these encasement volumes.

The number of laboratories that have significant encasements around their test equipment is shown in Figure 8 in comparison with the number of laboratories that have no real encasement but have their test rigs open in large halls or rooms.

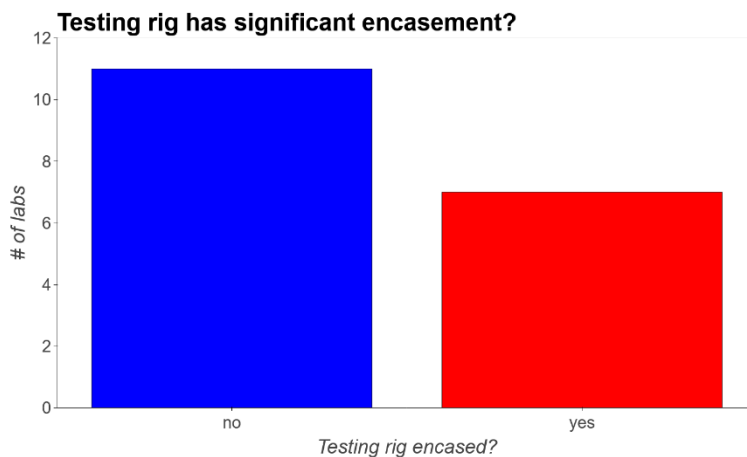


Figure 8: Number of laboratories having encased or not-encased testing equipment.

There are obviously discrepancies on the surrounding of the sample during the test. About a third had air volumes of up to 2 m³ around their test rig. One laboratory even had only 0.5 m³ available to house the test rig. Said laboratory however could not find any significant differences in the developed temperatures in the heat output test (stage 1) nor in the proficiency tests (stage 2). So therefore, the available volumes are still large enough that no significant influence on test results had to be assumed.

6.5. Heat output test

Each laboratory measured the temperature of the burner exhaust gases at specific points in front of a calcium silicate panel (refer to Figure 2).

The average equilibrium temperatures were calculated in a time window from 40 s to 80 s after the beginning of the test for each of the three measurement positions: TC1 in the height of the burner, TC2 20 mm and TC3 40 mm above the burner axis. In this time frame, all thermocouples had reached an equilibrium temperature that was sufficiently

constant. As this test was conducted twice by each laboratory, the bars in Figure 9 show two distinct values as results.

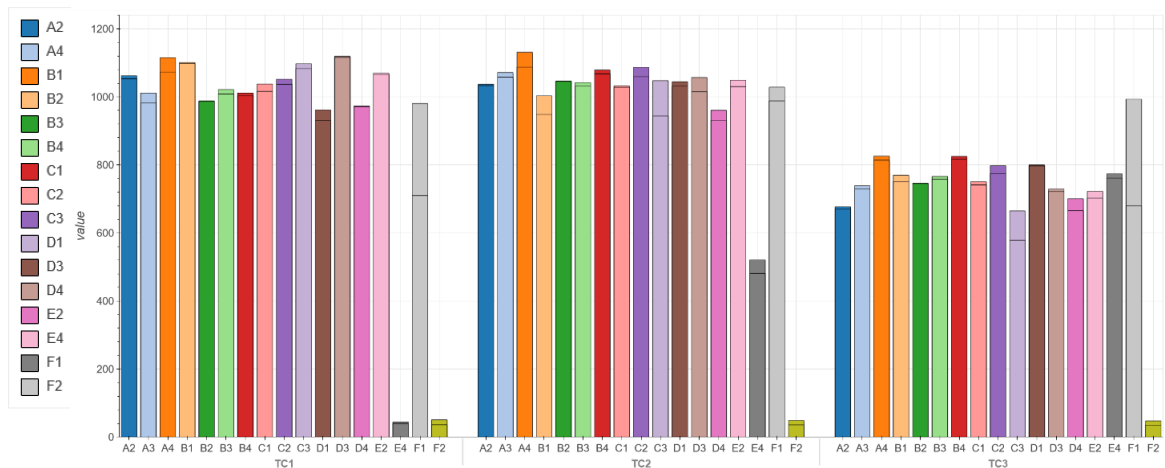


Figure 9: Average equilibrium temperatures during heat output tests in height of the burner (TC1) as well as 2 cm (TC2) and 4 cm above the burner axis (TC3). Two measurements were performed by each lab, depicted by the total length of the bars and a further line near the top of each bar.

It can be seen that most laboratories achieve very similar equilibrium temperatures in these time frames, and can also reproduce this in a second test.

6.6. Correlation between air supply opening and heat output

When comparing the average equilibrium temperatures for each of the thermocouples TC1, TC2, and TC3 with the maximum possible air supply opening at the burners, it was expected that smaller air supply openings could lead to a decrease of the average temperatures due to the hindered air influx.

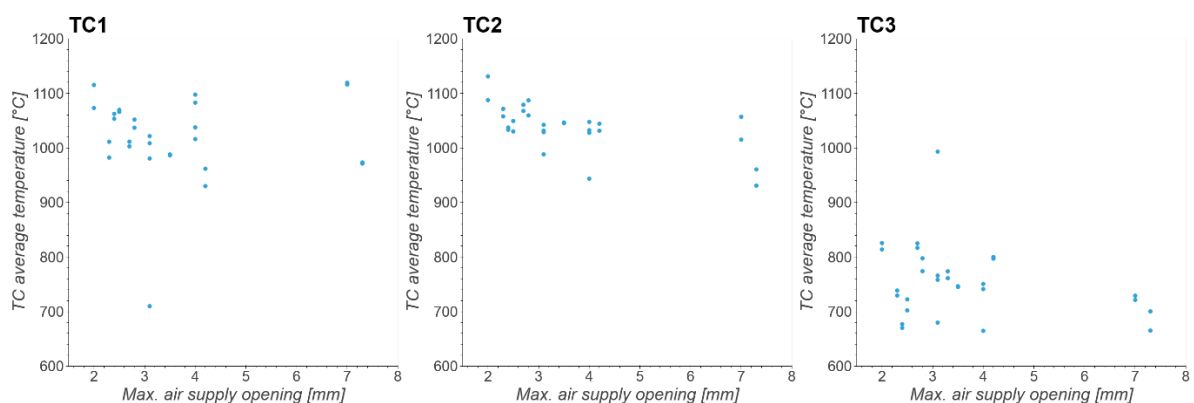


Figure 10: Plots showing the maximum air supply opening of each laboratory over the measured average equilibrium temperatures in all heat output tests. The stray outliers were removed.

As shown in Figure 10, a correlation is hard to find, but if forced, it would not be a positive correlation, but a negative one, meaning that smaller air suppliers correlate with a higher temperature.

6.7. Other correlations with heat output

Regarding other parameters polled in the questionnaire about instrumentation, no other significant correlations with the average equilibrium temperature were found.

7. Results regarding the proficiency testing (Stage 2)

7.1. General

During the proficiency tests, each laboratory did two measurements of each of the two materials A and B according to their own standard procedures which should be in accordance with the test standard [1]. Apart from MPA NRW who procured and distributed the samples, no other laboratory (including the other organisers) was made aware upfront about differences in composition or expectations regarding the results.

All results were collected in standardised form. In cases where results were not following this form (e.g. time axis reported in minutes instead of seconds), the organisers tried to correct these mistakes as far as they were obvious and the results were still feasible.

7.2. Result parameters for the performance evaluation

The test standard lists in section 10 four observations that would lead to the conclusion that a test material would fail the test and show a tendency for continuous smouldering:

- sustained flaming at the top or either vertical side of the specimen not caused by a visible spread of flame on the sample surface,
- re-ignition of the specimen occurring on any surface or edge 5 or more minutes after burner removal and after all sustained flaming on the specimen surface had sustained,
- thermocouple 6 showing a temperature rise after burner removal of more than 250 °C in comparison to the initial temperature,
- after the maximum test duration of 6 hours, any thermocouple showing a temperature of more than 50 °C or a temperature rise during the final 60 minutes.

Each of the laboratories reported their observations for these four evaluation parameters. The cumulated reports for each effect can be found in Figure 11.

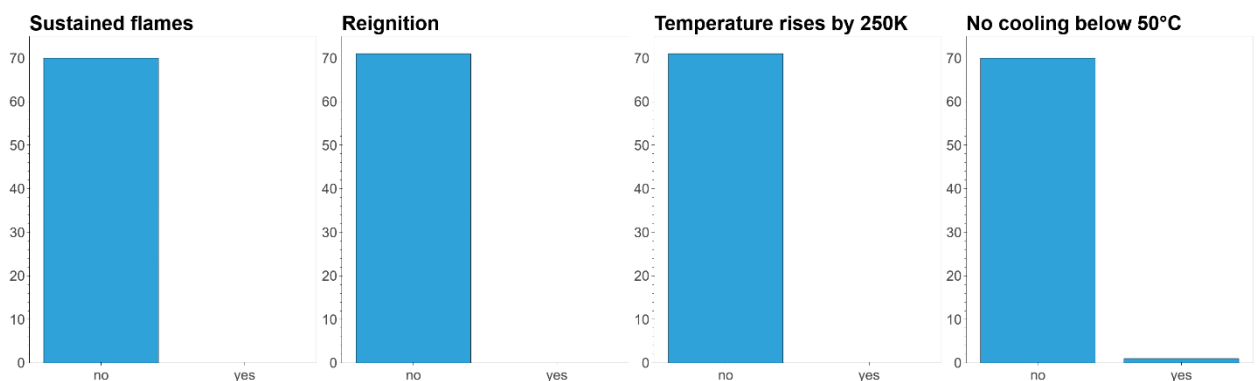


Figure 11: Compilation of the number of all reported observations of the evaluation parameters for continuous smouldering for both materials combined.

The total number of observations should be 72 (i.e. four observations from each of the 18 laboratories). As some of the observations had to be removed from the evaluation due to several mistakes, the total number is slightly lower.

Figure 12 shows that none of the laboratories had to perform a test for the full duration of 6 hours, because in all tests, all activity in the samples had ceased much earlier. This was discerned by proxy of the internal temperature in a test sample being cooler than 50 °C for more than an hour.

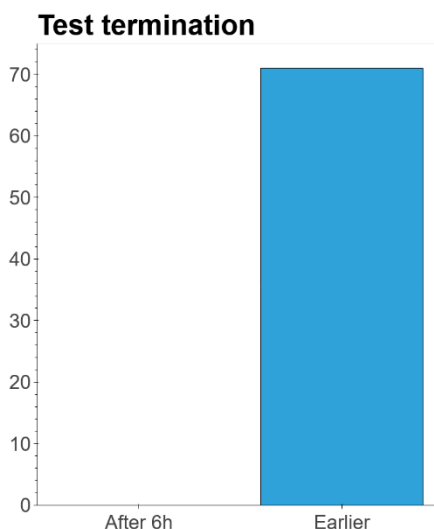


Figure 12: All performed tests were ended early because all smouldering activity in the samples had prematurely ceased.

The reported observations of the relevant evaluation parameters stated above would have led to all laboratories reporting **no propensity of both materials for continuous smouldering**. The observations are therefore very homogeneous.

7.3. Application of the extinguishing board

The proficiency testing discovered a source for confusion for some laboratories regarding the use of the extinguishing board after the removal of the burner flame. The test standard describes the following in section 8.6.2:

"After 15 minutes the burner shall be removed. The fire extinguishing board shall be applied to the face of the specimen for a period of 20 s."

This wording does not make any differentiation as to whether the sample actually shows flames that need extinguishing regarding the first use of the extinguishing board. The same section however continues describing further applications of this board that are dependent on whether the sample actually ignites and shows flames.

This means that the extinguishing board has to be applied at least once in each test. The first application is mandatory while the further possible applications depend on the sample re-igniting or continuing burning.

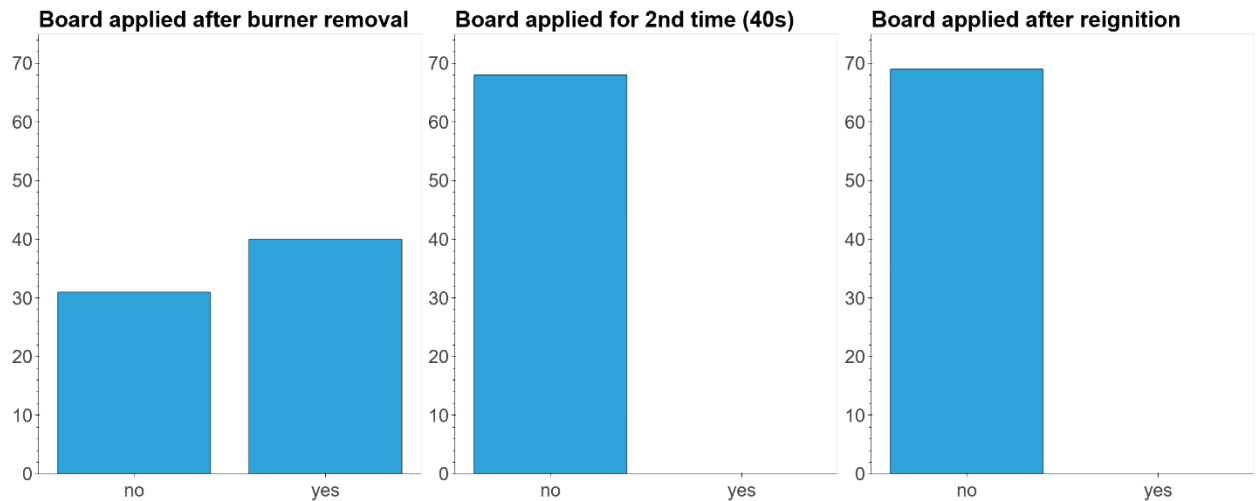


Figure 13: This figure show whether the laboratories applied the extinguishing board to the sample surface according to the provisions of section 8.6.2 from the test standard.

Figure 13 shows that not all laboratories are aware of this detail. EGOLF should therefore propose to CEN that the test standard shall more clearly state that the first application of the extinguishing board is mandatory, or clarify this matter otherwise.

For the further assessment of this round robin, this deviation should not influence the results as the samples had not ignited on the surface that was attacked by flames, anyway.

8. Precision of the test method

This test method leads to a binary verdict about the propensity of material to undergo continuous smouldering with the two possible results being YES or NO. For this binary measurand, the test standard [1] itself defined a degree of uncertainty U . By comparing the counted occurrences N_{YES} and N_{NO} for each of the possible results YES and NO, the degree of uncertainty was calculated as twice the percentage of the less prominent result:

$$U = 2 \times \min \left(\frac{N_{YES}}{N_{YES} + N_{NO}}; \frac{N_{NO}}{N_{YES} + N_{NO}} \right)$$

This would mean that the degree of uncertainty U would be 0 % if all results are the same, i.e. if all laboratories reported the same result for all tests of a material. And U would be 100 % if the number of report YES verdicts would be equal to the number of reported NO verdicts.

The following table sums up all verdicts of all labs for each of the possible result parameters that would influence the verdict (see paragraph 7.2), regarded individually for each of the two materials.

Observation	Material A		Material B	
	YES	NO	YES	NO
Sustained flaming at top edge or vertical sides	0	35	0	35
Re-ignition 5 minutes after flame source removal	0	36	0	35
250 K temperature rise at thermocouple 6	0	36	0	35
50 °C exceeded after maximum test duration	0	36	0	35

This would lead to the following results and degrees of uncertainties for each of the observations:

Observation	Material A		Material B	
	Result	U	Result	U
Sustained flaming at top edge or vertical sides	NO	0 %	NO	0 %
Re-ignition 5 minutes after flame source removal	NO	0 %	NO	0 %
250 K temperature rise at thermocouple 6	NO	0 %	NO	0 %
50 °C exceeded after maximum test duration	NO	0 %	NO	0 %

Both materials A and B would therefore be assessed as showing no propensity to undergo continuous smouldering by each of the laboratories.

This result could well mean that the test method has good reproducibility and a good repeatability. But it could also be due to the choice of the tested samples, the reason for which is given in 4.3. The test standard itself states in Annex A that *“the variability of the yes/no response for each product is generally a function of the product itself rather than the test method.”* Another conclusion could be that the test method itself is not very sensitive.

9. Summary

The round robin has shown that the test method shows a very good reproducibility and very good repeatability, at least for a certain material class. The degree of uncertainty was quantified in accordance with Annex A of the test standard.

By taking a synoptical approach comparing details of the measurements and also by comparing the instrumentation first, a few laboratories with problems could be identified and notified to improve their procedures.

During the round robin, several points were identified that would need improvement in the standard text:

- The technical description of the burner is misleading and contradictory to the diagrams in the standard (refer to paragraph 6.1).
- The wording for the usage of the extinguishing board is still too unclear and maybe counterintuitive (refer to paragraph 7.3).
- Several other factors stated in section 6 regarding the instrumentation could be more clearly defined.

It is also unclear whether the sensitivity of the test method should be evaluated. Further research would be needed, and the results stated in this report cannot indicate toward an answer due to the deliberate choice of samples that would more easily permit finding problems in the laboratories rather than finding problems with the test method.

10. References

- [1] EN 16733:2016 "Reaction to fire tests for building products – Determination of a building product's propensity to undergo continuous smouldering", European Committee for Standardization, Brussels, Belgium.