INFLUENCE OF AIR FLOW IN THE OSU CALORIMETER ON TEST RESULTS

Barbotko S.L., Vorobyov V.N.

The report provides and discusses the results of research into the influence of the rate of air flowed through the OSU calorimeter on the calibration factor of the device and the heat release parameters for materials tested: the total amount of the heat released during the first two minutes of the test, maximum heat release rate and the time it takes to achieve it.

In accordance with the normative documents (FAR-25, or analogous country normative documents), elements of civil aircraft passenger cabins have to meet the requirements set out in paragraph 25.853 regarding fire safety, including those concerning heat emission (Appendix F, part IV). The normative acts point out that testing should be performed at the 0.04 m^3/s rate of the air flowed through the device. The deviation from the permissible air flow during testing should not exceed ?5 %.

The requirements to the stability of the rate during the experiment (calibration and testing) are understandable and cannot be disputed, since air flow influences on the real calibration factor of the device, and with a view to retaining data reproducibility, this value must be one and the same throughout the experiment.

Changing to greater or lesser degree the amount of air flowed to the plant may influence data reproducibility to either good or bad effect, since there can be a change in the combustion conditions for samples and in the impact of the equipment operation characteristics.

While testing aircraft materials which emit comparatively little heat during combustion and, therefore, consume a little quantity of oxygen there is not much point in flowing a large amount of air to the device. The present paper deals with the influence of reduced (ranges from nominal value to 1/5 from the nominal) air flow on the calibration factor and heat release registered, as well as tries to find out in how far the testing with reduced air flow is justified.

Theory

In the process of burning of materials, 12.72 kJ of heat is emitted when 1g of oxygen is consumed[1]. Therefore, during burning specimen of a standard size (150x150mm), with heat release rate of up to 65 kW/m^2, no more than 0.115 g of oxygen per second will be consumed. With standard air flow through the device at 40 l/s, 10 l/s of air passes through the environmental chamber, which works 3 g of oxygen per second. Thus, during testing with the standard air flow, no more than 4 % of oxygen of air from the environmental chamber is used for the material burning and approximately 1.6 % of oxygen is consumed for methane burning in the upper and lower ignition burners. It means that the oxygen concentration in air which flowed through the environmental chamber decreases from 21 down to 19.5 %, which is so little as to be insignificant.

While the calibration the maximum methane consumption amounts to 8 l/min, and during this burning process the rate of oxygen consumption is 16 l/min, which accounts for 12.5 % of the whole oxygen content in the air flowed into the environmental chamber. It means to say that the oxygen concentration in the air flowed through environmental chamber decreases from 21 down to approximately 18 %. Such decrease in oxygen concentration has practically no effect on burning processes which take place under the influence of a powerful heat flow.

It has to be pointed out that calibration with the methane consumption of 7 l/min (maximum flow equal of 8 l/min minus basic flow equal of 1 l/min) corresponds to heat release rate of about 180 kW/m^2, which exceeds the maximum acceptable peak by more than 2.5 times and, theoretically speaking, calibration should be performed with the methane consumption from 1 l/min (basic flow equal to methane consumption by the upper and lower pilot burners) to 4 l/min (since 3 l/min for methane corresponds to heat emission of about 75 kW/m^2).

---

[1] Armstrong G.T., Domalts Ki. "Combustion Fundamentals for Waste Incineration", American Society of Mechanical Engineers, New York, 1974, p. 143 – 182.

When samples are burned, due to the combustion product formation and oxygen consumption, the air chemical composition and weight are changed, and, as a result of it, gas heat capacity is modified.

Calculations have shown that at the heat release rate of 65 kW/m^2 and air flow through the device of 40 l/s the absolute weight growth for the air that passes through the environmental chamber due to the formation of carbon dioxide and water instead of the oxygen consumed during burning is less than 1.5 %, whereas the change in the heat capacity for the flowed air due to the chemical composition alteration is only about 0.2 %.

The heated air passing interval (delay time) from the sample to thermocouples at the room temperature and with the standard air flow is about 4 seconds. With the heat flow of 35 kW/m^2 the environmental chamber air warms up to 250?300 ?C, i.e. in practice the delay time is about 2 seconds. With the air flow reduced by 2 times, the environmental chamber air warms up nearly twice as high, that is why the delay time increases only by 1 second and amounts to about 3 seconds.

Too high air flow level through the device can lead to undesirable consequences. Excess rate of the air flow can result in flame blow-off from the surface of the burning sample and inflammable products thermal degradation being carried away past the flame of the upper burner. Due to this less heat release rate of the material sample tested will be registered.

With the increase in the air flowed into the device, calibration factor value is going to grow proportionally, since the calorimetric gauge signal value falls down. With the increase air flow into the device the valid signal value decreases while the parasite signal (‘noise’) remains the same, i.e. greater error while determining the heat release rate value.

Thus, changing to the greater or lesser degree the amount of air flowed into the plant will produce either positive or negative effect the extent of which depends on the direction and degree of air flow change as compared to the standard.

Experiment

To perform an experiment, the HRR-3 device made by “Atlas Device Company” USA, 1996 was used.

Since the maximum level of the air flow is determined by the structure of a compressor employed and in fact could not be considerably higher than standard one, experiments were mainly carried out to study the influence of a reduced air flow level on the heat release parameters registered.

The characteristics of the samples used are adduced in Table 1.

The experimental data of changing the calibration factor value versus different levels of air flow through the device are presented in Fig.1 and Table 2. As experiments have shown, reduction in air flow ranging from nominal value to its half, the calibration factor smoothly and practically linearly decreases, the average value of the standard deviation for the calibration factor remains generally the same, which points to stable and ordinary equipment operation. When the level of air flow is further reduced to 1/5 of the nominal value, decrease in the calibration factor value is more sharp and considerable increase is observed in the average value of the calibration factor standard deviation which exceeds the maximum acceptable value (5 %).

Standard samples (Standard core panel) provided by the Technical Center FAA USA in 1998, were used to study the influence of air flow value on the following heat release parameters registered: time of initial heat emission, maximum heat release rate (peak) and time it takes to achieve it, as well as the total amount of heat released during the first two minutes of the test. The experiments performed have shown (Fig.2 and Table 3) that with the air flow rates ranging from the nominal one to the ½ of the norm, as was expected, the time which is needed to achieve the maximum heat release rate increases insignificantly, whereas values for the peak and the total amount of heat emitted remains unchanged. If the air flow level is further reduced to 1/5 of the norm (8 l/s), the peak significantly falls down, it becomes more sloping, the total heat released during the first two minutes of the test decreases, the time before the initial heat emission increases and the peak time.

The investigation into the heat emission value without a sample (‘zero’ line jitter) enables noise signal value to be specified and its change during variation of air flow through the calorimeter. The data adduced in Table 4 show that the decrease in the air flow level from 45 to 20 l/s causes noise to diminish, while further decrease results in the increase in noise.

The investigation carried out on the panel samples on the phenol binder has shown that the reproducibility of heat emission data are better in a number of parallel tests conducted for five samples with reduced air flow (27 l/s), as compared to the standard air flow level (Table 5).

Conclusions

On the basis of the theoretical and experimental work performed it is possible to draw the following conclusions:

? ?In case of continuous air flow through the device throughout the experiment (from calibration up to the end of the testing) changing air flow, as compared with the nominal level 40 l/s, to 27?20 l/s does not worsen the equipment operation; the average standard deviation value for the calibration factor remains unchanged;

? ?Decrease in air flow causes the time of span from beginning experiments to the peak to increase; changing air flow from the nominal to ½ of the standard level makes practically no impact on the registered maximum heat release rate and the total amount of heat emitted during the first two minutes of the test; further reduction in the air flowed leads to the lowering of the heat release values (those of the peak and the total heat), the peak shape alternates – it becomes more sloping;

? ?Decrease in the air flow from nominal level to 2/3 of the its does not affect the test data reproducibility.

Thus, decrease in the amount of the air delivered to the calorimeter to 2/3 ? 1/2 of the nominal has no negative effect on the of the measuring equipment operation and on the value of the normalized heat emission characteristics.

Table 1

Samples characteristics

Sample supplier	Sample description	Thickness, mm
TC FAA USA	Standard sample for checking equipment operation (Standard core panel)	3.5
VIAM Russia	Composition panel: Skin: 2 layers of fiberglass + binder of a phenol type. Decorative coating – epoxyfluorine enamel	0.45

Table 2

Calibration factor value for the HRR-3 calorimeter at different levels of air flow through the device

Air flow through the device, l/s	Calibration factor average value, Kh, kW/mV	Average value for calibration factor standard deviation, %	Number of calibration tests
8	0,129	3,8	2
14	0,161	6,7	2
20	0,191	4,7	1
27	0,218	4,1	More then 10
32	0,235	3,4	1
40	0,259	3,0	More then 10
45	0,272	2,7	1

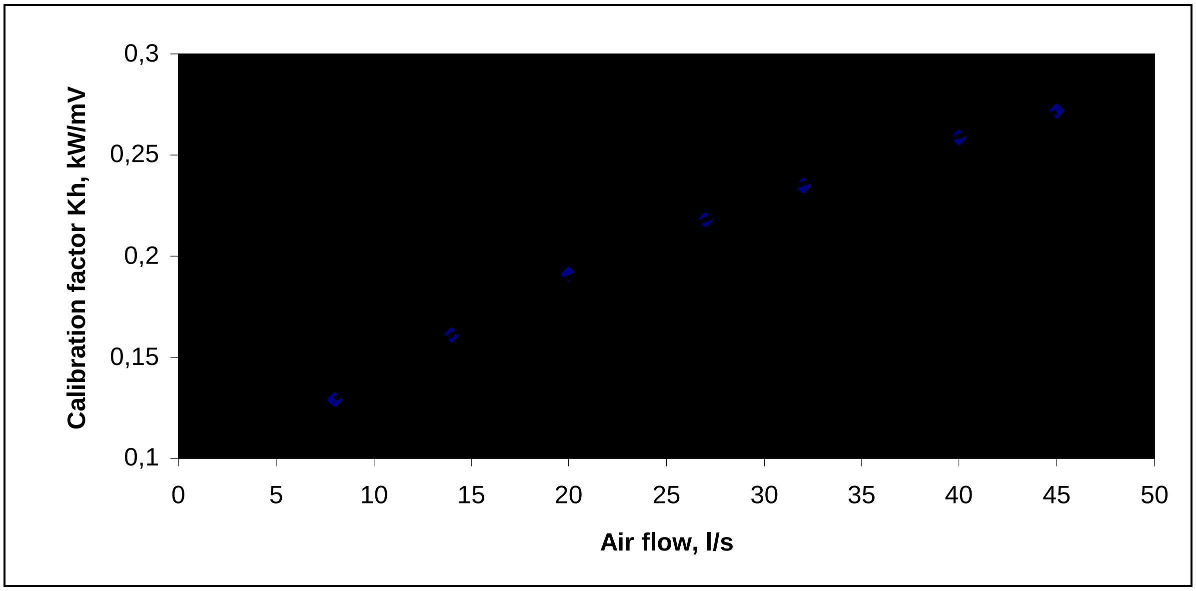

Fig. 1 The calibration factor value of the HRR-3 calorimeter versus air flow through the device

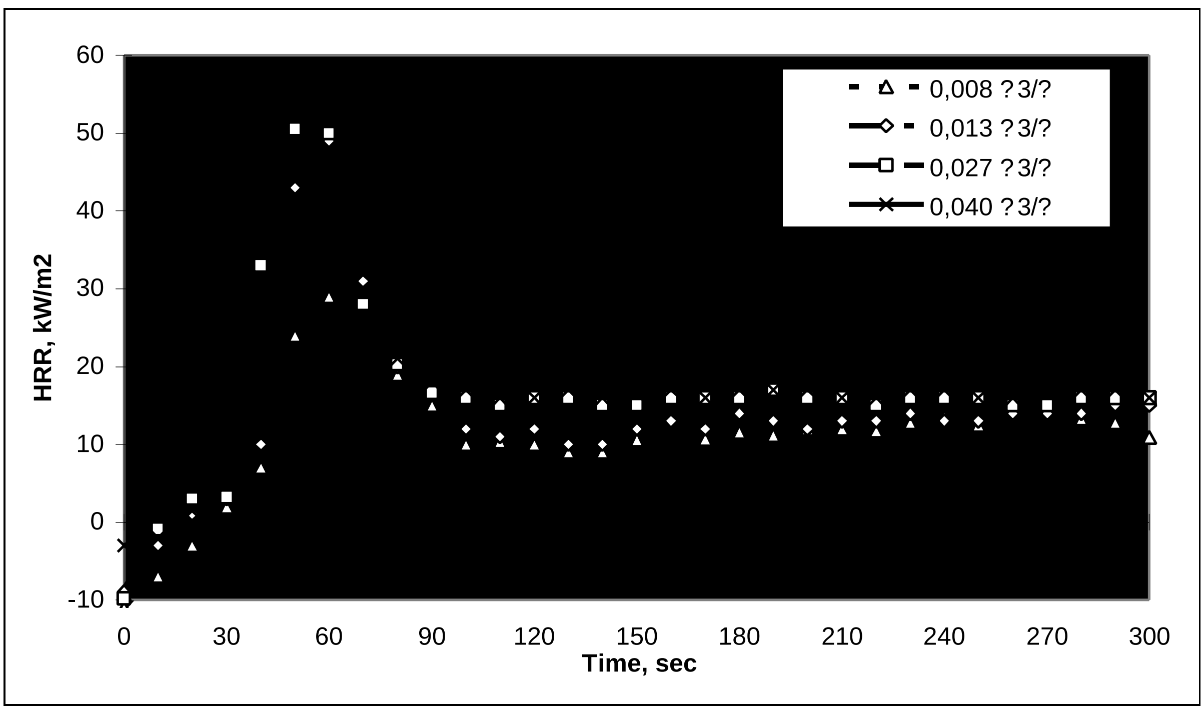

Fig.2 Heat release chart for a standard core panel at different air flow through the device

Table 3

Heat release rates for a standard core panel at different air flow

Air flow, m^3/s	HRR initial time, s	Peak time, s	Peak, kW/m^2	Total heat release, kW?min/m^2
0,008	29	62	29	22
0,013	21	55	49	33
0,027	19	52	51,7	35,5
0,04	19	50	53	37

Table 4

Basic line deviation value from the average value at different air flow levels through the device

Air flow, l/s	Deviation value, kW/m^2
20	$\pm$ 4
27	$\pm$ 3
32	$\pm$ 3
40	$\pm$ 4
50	$\pm$ 4,5

Table 5

Results reproducibility at different air flow levels

Air flow, l/s	Standard deviation for peak, %	Standard deviation for total heat release, %
27	2,6	2,8
40	6,2	3, 4

About the authors

Vorobyov Vladimir Nikolayevich

Born in 1939, Doctor of Chemical Sciences, chief scientific worker, works in VIAM SE as a leading scientific worker on “Investigation into fire safety for aviation materials and structure elements”.

Barbotko Sergei Lvovich

Born in 1961, works in VIAM SE as a chief scientific worker. In 1999 he defended a Master’s thesis in the area of technical sciences. Specialization – investigation into fire safety of new materials under development and those already in use for airliner interior.