SUPERPRESSURE

NBS RATE OF RISE
CALORIMETER 4-5803

Customer Name:________________________

Purchase Order #:________________________

Sales Order#:________________________

Serial #:________________________

Date of Manufacture:________________________

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The 4-5803 Superpressure NBS Rate of Rise Calorimeter design is based on the original calorimeter procedure developed by T. G. Lee, Fire Scientist at the National Bureau of Standards, for the calibration of the NBS Smoke Density Chamber radiometer. The original calorimeter was employed to calibrate all of the 4-5801 radiometers manufactured by the American Instrument Company until 1977. The present design and updated procedure is based on ASTM E662.

The current procedure using 4 plotted values rather than 2 to determine the slope (d(mV) /d1) eliminates much of the uncertainty from the original apparatus and procedure. Additional improvements in design help in assuring maximum service life and stability.

The principle of operation is based on measuring the rate of rise from a suspended copper disc of known weight, specific heat, exposed area and amount of absorption when exposed to constant furnace irradiance. This value is then used to calculate equivalent radiant flux, for four different stabilized furnace voltages.

The calorimeter factor G/K should remain constant unless the front black coating is scratched, altered or blistered; the thermocouple is broken or loses its electrical integrity with the disc, or if the disc is otherwise damaged or shifted. This factor is multiplied by the measured d(mV)/d1 at each voltage setting to determine the radiant flux value.

In the actual calibration procedure at Superpressure the radiant flux is determined at each of the selected voltages with the calorimeter. The calorimeter is then removed without changing the voltage settings and the radiometer being calibrated is immediately placed in position in front of the furnace. The radiometer is permitted to stabilize its output with the body temperature held at 200E ± 5E F and the output in mVs noted. The radiometer is then removed and the calorimeter is again inserted to determine the radiant flux at other selected voltages. This is repeated for each of the four voltages and the four values for radiometer output (mV) values are plotted on a square grid graph of Radiant flux (w/cm2) vs Radiometer Output (mV). A best straight line is drawn through the four plotted points. The proper setting for the radiometer for resetting the smoke density chamber furnace, at 2.5 w/cm2 is found at the plotted line's intersection with the 2.5 w/cm2 value on the graph. This value for setting the furnace voltage continues to be used until the radiometer is recalibrates.

Since the radiometer is used regularly, it is subject to visible and hidden damage which could alter the calibrated setting and require recalibration. Where extreme care is taken to immediately remove the radiometer and to store it where damage is not likely, recalibration should be done every 3 months. Where conditions of operation or storage are not ideal or where damage is suspected, recalibration will be required more often.

Retouching of the blackened surface of the radiometer or the calorimeter will alter the absorptivity from the original. Unless all of the coating is first removed, the energy absorptivity value will not be the same.

While altering the coating by touch-up on the calorimeter is not recommended without complete recoating, careful touch-up of the radiometer surface may be done if the user discards all previous calibration data for the particular radiometer. The touch-up will alter the absorptivity and therefore the signal obtained.

The radiometer electrical output lead is soldered to the center of its Copper-Constant thermopile plate and overheating could soften the solder and change the output characteristics or even produce a
cold-joint with an intermittent loss of signal. Radiometer thermopile plates should not be recoated without rechecking the solder connections. At **Superpressure**, the plate is always replaced in its entirety together with its electrical lead, whenever recalibration is requested or indicated.

When using the 68086031100 recorder presently offered as an accessory to the 4-5800-115V, AND 4-5800-230V **Superpressure**-NBS Smoke Density Chamber select the 30 CM/Minute speed setting and the 1mV range. At 30cm the chart speed would be equivalent to 0.5 cm/sec. or 2.0 sec./cm./ Since only the initial nonlinear portion of the plot is disregarded and since the calorimeter disc should no t be allowed to overheat, the recorder should be started with calorimeter output leads connected before installing the calorimeter on the sample support rod centered on the pre-set furnace. The rate of rise (mV/sec) is obtained from the 6 to 10 seconds of linear rise. Immediately remove the calorimeter from the chamber and allow to cool to room temperature before reinserting whether to recheck a value or to obtain a new value.

ASTM E 5.21 PROCEDURE

Approved Draft No. 8
1978

(See - ASTM E662 Procedure)

A 1.2.0 Radiometer

The radiometer is calibrated by comparing its voltage output when exposed to heat from the furnace to that of a copper disc calorimeter (See Fig. 7) (primary standard) when the latter is exposed to the same heat flux. The calibration is made at four furnace settings, two above and two below the normal 2.5-W/cm2 set point of the test method. From this a graph is drawn plotting the heat flux received by the radiometer against voltage output. The procedure and calculations are as follows.

A 1.2.1 With the furnace operating at a voltage setting between 90 and 95 volts the radiometer is placed on the support rods so that it is positioned and oriented exactly as a test specimen relative to the furnace. The air flow to the radiometer cooler is adjusted to maintain the body temperature of the radiometer at 200° ± 5°F (93°± 3° C).

A 1.2.2 The furnace and radiometer output and body temperature are allowed to equilibrate until a steady-state, millivolt-output of the radiometer is obtained.

A 1.2.3 The radiometer is removed and a cool rate-of-heat rise copper disc calorimeter (Fig. 7) is placed promptly in front of the furnace in the same position as in A 1.2.1 above. Immediately thereafter, a short (5-15 second record) of the temperature rise of the disc is obtained. This temperature rise of the calorimeter is determined by measuring the electrical output of the thermocouple attached to the back of the disc, employing a recording potentiometer operating at a fast speed. The calorimeter is removed and allowed to cool back to room temperature.

A 1.2.4 The furnace voltage is adjusted to three additional settings and steps A 1.2.1 through A 1.2.3 are repeated for each setting.

A 1.2.5 The furnace settings shall be chosen so that the output of the radiometer, expressed in W/cm2 of radiant heat received, brackets the value 2.50 W/cm2.

A 1.2.6 The output of the radiometer, expressed in mV, shall be related to the linear portion of the temperature rise of the copper disc, for each furnace setting by the following calculations:

Dimension

Qr = radiant heat received by radiometer — W/cm2

= radiant heat received by copper disc

$$= G\frac{dT}{d\Theta} = \frac{G}{k}\cdot\frac{d(mV)}{d\Theta}$$

where $\frac{dT}{d\Theta}$ = rate of temperature rise of copper disc — $°C \cdot s^{-1}$

$\frac{d(mV)}{d\Theta}$ = slope of thermocouple millivolt output on recording potentiometer — $mV \cdot s^{-1}$

k = thermocouple conversion constant

= $0.040\ mV \cdot °C^{-1}$ for chromel-alumel between 20°C and 40°C — $mV \cdot °C^{-1}$

and G = constant for particular disc used

$$= \frac{Kmc}{An\ a}$$

K = conversion factor

= 4.184 — $W \cdot S \cdot cal^{-1}$

m = mass of copper disc, uncoated — g

c = specific heat of copper = 0.0927 (±1%) — $cal \cdot g^{-1}\ °C^{-1}$

An = net area of exposed (blackened) face of copper disc — cm²

= Ag - nAh

Ag = gross area of exposed face — cm²

n = number of holes for supporting wires

Ah = area of each hole

α = radiation absorption of black coating on face of disc*

As an example of the procedure proposed, the equation for the radiant heat absorbed by a particular copper disc may be simplified, as follows:

* Nextel Velvet 101-C10 supplied by 3-M Company has been found useful as a coating for this purpose. For this material, ∀ = 0.98.

Note: The above is an example only and applies to a disc weighing 29.78 gms and having a net area of 11.37 cm².

Assume, As an Example

$M = 29.78$ g

$Ag = 11.40$ cm²

$N = 4$

$Ah = 0.008$ cm²

$An = 11.37$

$C = 0.0927$ cal. $g^{-1} \cdot °C^{-1}$

(±1% Based on Chemical Engr. Handbook at 36°C.)

Then

$K = 4.184$ cal. $g^{-1} \cdot °C^{-1}$

$k = 0.040$ $mv \cdot °C^{-1}$

$\alpha = 0.98$

from which $$Qr = \frac{4.184 \times 29.78 \times 0.0927}{11.37 \times 0.98 \times 0.04} \frac{d(mV)}{d\Theta}$$

$$= 25.91 \frac{d(mV)}{d\Theta}$$

A 1.2.6.2 The use of this copper disc calorimeter in calibrating a radiometer is illustrated by the following example:

$$\frac{d(mV)}{d\Theta}$$

Furnace Setting T (°F)	Radiometer (mV)	Slope of Disc-Thermocouple Output (mV/s)	Qr (W/cm²)
1320	3.72	0.043	1.11
1380	7.30	0.081	2.10
1420	9.50	0.105	2.7
1460	10.13	0.108	2.80

From the above, the following graph is obtained by drawing a best straight line through the plotted points and selecting the indicated output intersecting the line at 2.5 W/cm².

RADIOMETER OUTPUT mV

From the graph, the output of the radiometer corresponding to a radiant heat flux of 2.50 W/cm² is obtained; in this case the value is 8.8 mV.

A 1.2.7 Under normal continuous conditions, the radiometer should be calibrated at least once every three months. Annual recalibrations should be required in all cases.

A 1.2.8 The blackened face of the radiometer should be inspected frequently. In case the coating is blistered, cracked, discolored, or broken; the coating should be removed, the face of the radiometer cleaned and a new coating applied. In this case, the recoated radiometer should be recalibrated before being used.

A 1.2.9 The copper disc standard should be carefully handled when in use, and protected from surface contamination and mechanical abuse when stored. If the blackened surface shows alterations as in 1.2.8 the coating should be removed and the face cleaned. The disc should then be reweighed and recoated and any appropriate corrections made in the calibration constant, G, before it is used again.

Since the copper disc must be weighed and measured before attaching thermocouple, applying the black coating and assembly into place, these are determined prior to assembly. The net weight is stamped on the disc.

For the sake of convenience, **Superpressure** has assigned "Z" as the identification for the Constant, which includes everything other than the mV/second (d(mV)/d1) in the formula.

$$Qr = \frac{K \times m \times c}{An \times \forall \times k} \times \frac{d\,(mV)}{d1}$$

In the example cited, a value of 25.91 is given for this constant which is then multiplied by the measured rate of rise d(mV) /d0. The user of each calorimeter therefore simply multiplies the "Z" value assigned, by the mV/sec, rate of rise to obtain the Qr at each level of voltage.

Qr = "Z" x Rate of Rise (mV/second)

INSPECTION REPORT

4-5803 Rate of Rise Calorimeter
Serial No.

The subject Calorimeter has been found to conform with the specifications.

Weight of uncoated disc ____gms

Z value =

To obtain effective irradiance Qr = Z x d(mV) /d1

By:
Date:

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