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The Thermal Emittance of Cigarette Coal*

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INTRODUCTION

A recently published temperature determination method is based on the measurement of thermal radiation emitted by the coal of a burning cigarette (1). The correlation between the intensity of thermal radiation in a given spectral band and temperature is defined by the *Stefan-Boltzmann* Law,

$$W_\mu = \varepsilon_\mu \sigma T^4 ,$$

where

W_μ is the total energy radiated in the μ band,
ε_μ is the thermal emittance in the μ band,
σ is the *Stefan-Boltzmann* constant,
T is the absolute temperature.

Thus for the calculation of the temperature of a radiating surface from the measured intensity of radiation, the knowledge of the thermal emittance is required.

Emittance is a property of a specimen, as contrasted to *emissivity*, that is a fundamental property of a material (2). Emittance is dependent on the temperature, the surface finish, the thickness of the material and on the spectral band of the observation. Thus no general "emissivity" values found in the literature can be applied in a specific case. In each case the emittance has to be measured on the same specimen, in the same spectral band and preferably at the same temperature, that will be applied in the calculation of the temperature.
Emittance measurements are based on the *Stefan-Boltzmann* equation. First the radiant energy of the unknown is measured, followed by the measurement of that of an artificial blackbody at the same temperature. From these measurements:

the radiant energy of sample $W_s = \varepsilon_s \sigma T^4$,
the radiant energy of blackbody $W_{bb} = \sigma T^4$,
the emittance of sample $\varepsilon_s = \dfrac{W_s}{W_{bb}}$.

In many cases this method leads to a vicious circle, since the temperature of the sample can be measured only by radiometry. There are methods, however, to break this vicious circle (3). Such a method has been applied to the measurement of the emittance of cigarette coal.

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THE MEASUREMENT METHOD

For the determination of emittance, cigarettes were heated in a constant temperature cell and the emitted radiation was measured. A schematic diagram of the cell is presented in Figure 1. The walls of the cube were made of Teflon. Hot air inlet and outlet were provided at the bottom and on the top respectively. At the center of one of the faces, a cigarette was inserted with a viewing port located at the center of the adjoining face. This face was shielded with a copper plate against surface radiation. The hot junction of a Chromel-Constantan thermocouple was placed near the coal of the cigarette. The entering air was preheated in a resistance wire wound glass tube provided with a temperature sensor-controller.
The specimen was prepared by lighting a cigarette and puffing it three times in a standard smoking machine in order to develop a regular coal. One second after the beginning of the fourth puff, vapors of boiling liquid nitrogen were drawn through the incandescent coal, extinguishing it. By this method the same type of coal was obtained, that was used for temperature measurements in reference 1.

Figure 1. Schematic diagram of the test cell.

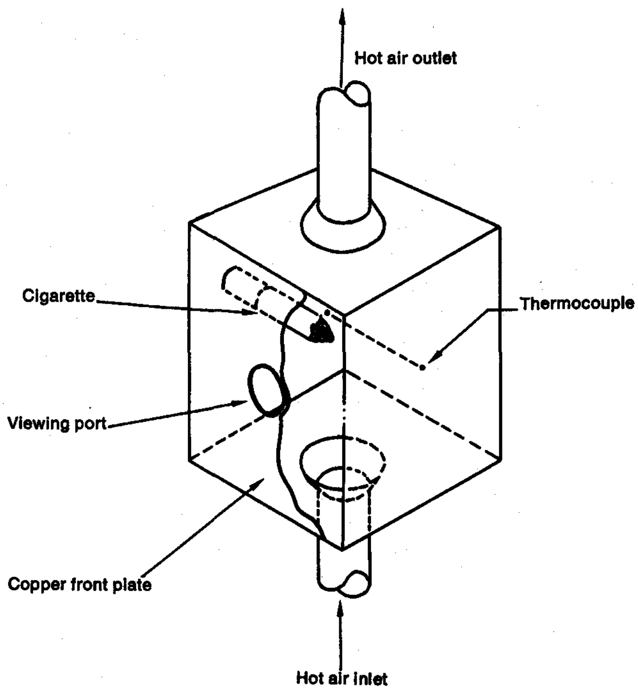
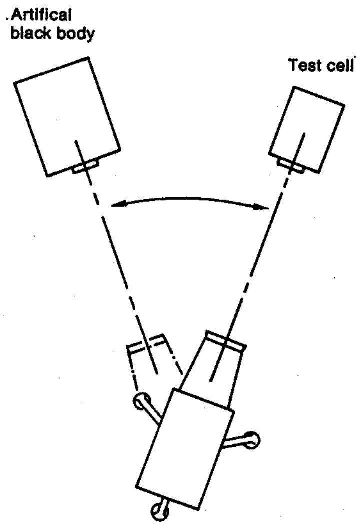


Figure 2. Test arrangement.



The arrangement of the measuring instrumentation is shown in Figure 2. The radiation measuring instrument was an AGA Thermovision Model 669, the same scanning radiometer that was used for the coal temperature measurements. It measures radiation in the 2—5.4 μ band. The reference artificial blackbody was a Barnes Engineering Model 1120T Infrared Radiation Reference Source.

The radiometer was mounted on a tripod equidistant to the cell and the artificial blackbody. By turning the radiometer it was possible to measure the radiation emitted by the sample and by the reference blackbody alternately.

After the sample was inserted into the preheated test cell, a few minutes were allowed for reaching thermal equilibrium. Following this, readings were taken on the radiometer at 15-second intervals viewing the sample and the reference alternately.

The process was repeated at several, increasing temperatures up to 125° C. Above this temperature exothermic reactions in the tobacco invalidate the *Stefan-Boltzmann* correlation, since the surface of the cut tobacco does not have a well defined temperature.

EXPERIMENTAL RESULTS

The results reported in the following tables represent the average of at least ten readings.

Using the same method the emittance of the empty test cell was found to be 0.510 at 124° C.

Table 1. Cigarette coal profile in focus.

Temperature level (°C)	Radiometer printout averages in mV		ε
	Blackbody	Cigarette coal	
50	152.8	150.2	0.983
80	635.3	627.3	0.987
100	1184.0	1139.6	0.963
123	1994.2	1987.6	0.997

Table 2. Flat front of sectioned cigarette coal facing instrument.

Temperature level (°C)	Radiometer printout averages in mV		ε
	Blackbody	Cigarette coal	
50	155.3	146.3	0.942
80	632.8	573.3	0.906
100	1154.0	1142.0	0.990
125	2113.5	2105.4	0.996

Table 3. Flat front of an unlit cigarette facing instrument.

Temperature level (°C)	Radiometer printout averages in mV		ε
	Blackbody	Cigarette front	
50	154.5	140.1	0.906
80	650.3	635.7	0.977
100	1177.6	1096.8	0.931
125	2152.8	2071.8	0.962

CONCLUSIONS

The reported experimental data prove that the emittance of the cigarette coal, determined at different temperatures, closely approximates the emittance of a blackbody.

It is, therefore, justified to use the infrared method without emittance correction for measuring the temperature of the incandescent cigarette coal, and that of the cut tobacco.

SUMMARY

The radiation intensity emitted by the surface of an extinguished cigarette coal in a heated environment was compared with the radiation intensity of an artificial blackbody at the same temperature.

The experiments were carried out at several temperature levels between 50° C and 125° C. The results indicate that the emittance of the cigarette coal is close to unity. The calculated values based on data obtained within the limits of the experiments varied between 0.997 and 0.91 (average 0.97).

ZUSAMMENFASSUNG

Die von der Oberfläche gelöschter Cigarettenkohle bei erhöhter Umgebungstemperatur ausgehende Strahlungsintensität wurde mit der Strahlungsintensität eines künstlichen schwarzen Körpers gleicher Temperatur verglichen.

Die Versuche wurden bei mehreren Temperaturen zwischen 50° C und 125° C durchgeführt. Die Ergebnisse zeigen, daß die Ausstrahlung der Cigarettenkohle nahe

eins ist. Die berechneten Werte, die auf Daten basieren, welche innerhalb der Versuchsgrenzen erhalten wurden, variieren zwischen 0,997 und 0,91 (Durchschnitt: 0,97).

RESUME

On a comparé dans un milieu chauffé l'intensité de radiation émise par la surface du charbon de cigarette éteint avec l'intensité de radiation d'un corps noir artificiel à la même température.
Les expériences ont eu lieu à différents degrés de température, compris entre 50° C et 125° C. De celles-ci résulte une émission du charbon de cigarette proche de l'unité. Les valeurs calculées tirées de données obtenues en deçà des limites de ces expériences varient de 0,997 à 0,91 (la moyenne est de 0,97).

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