https://ntrs.nasa.gov/search.jsp?R=19850015957 2020-03-20T18:36:22+00:00Z

General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

Produced by the NASA Center for Aerospace Information (CASI)

NASA TECHNICAL MEMORANDUM NASA TM-77832

SEVEN-WAVELENGTH PYROMETER FOR DETERMINING SURFACE TEMPERATURE OF ABLATION MATERIALS

Huang Yi

(NASA-TM-77832) SEVEN-WAVELENGTH PYROMETER FOR DETERMINING SURFACE TEMPERATURE OF ABLATION MATERIALS (National Aeronautics and Space Administration) 8 p HC A02/MF A01 CSCL 14B G3/35

N85-24268

Unclas 14787

Translation of "Qibochang gaowenji celiang shaoshi cailiao biaomian wendu," Acta Aerodynamica Sinica, No. 1, 1984, pp. 106-109.

MAY 1985
RECEIVED
NASA STI FACILITY
ACCESS DEPT.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
WASHINGTON, D.C. 20546 APRIL 1985

STANDARD TITLE PAGE

1. Report No. NASA TM-77832	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle SEVEN-WAVELENGTH PYROMETER FOR DETERMINING SURFACE TEMPERATURE OF ABLATION MATERIALS		5. Report Date April 1985
		6. Performing Organization Code
7. Author(s) Huang Yi		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address Leo Kanner Associates Redwood City, CA 94063		11. Contract or Grant No. NASW-4005
		13. Type of Report and Period Covered Translation
12. Sponsoring Agency Name and Address National Aeronautics and Space Administration, Washington, D.C. 20546		14. Sponsoring Agency Code

15. Supplementary Notes

Translation of "Qibochang gaowenji celiang shaoshi cailiao biaomian wendu," Acta Aerodynamica Sinica, No. 1, 1984, pp. 106-109. (A84-37913)

16. Abstract

Results which were achieved by a seven-wavelength pyrometer last year are reported in this paper. These studies are directed toward the development of a method for determining the real surface temperature of thermal protection materials and for evaluating its emittance under varieties of reentry environment. A description of the data processing method and apparatus is also included.

17. Key Words (Selected by Author(s))	18. Distribution Statement Unclassified-Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22.
Unclassified	Unclassified	6	

SEVEN-WAVELENGTH PYROMETER FOR DETERMINING SURFACE TEMPERATURE OF ABLATION MATERIALS

Huang Yi
China Aerodynamic Research and Development Center

I. Foreword /106*

In ablation tests of thermal protective materials, a material surface is impregnated in a high pressure, high temperature gas stream. Surface phenomena are nearly proportional to surface temperture. The accuracy of surface temperature measurements strongly affects the analyses of theoretical calculation and test results.

Due to the complexity of the ablation environment, generally non-contact radiological methods are used to measure the surface temperature of materials. Among techniques frequently used are the chromometry and luminance temperature methods. However, these methods can only yield color temperature and luminance temperature; the difference between these temperatures and the real temperature of the material surface differs to different radiation characteristics of the material surface.(1)

The radiation characteristics of the material surface are a function of chemical components, physical characteristics and the ambient medium. Therefore, these values are difficult to measure, and have not been standardized. Thus, it is required to measure the radiation characteristics while measuring the surface temperature of the material.

There are several methods for simultaneously measuring the surface temperature and radiation characteristics of a material. In our opinion, however, only the multispectrum method has greater practicality in the thermal protective test of a material. The author and his colleagues developed a seven-wavelength pyrometer in 1981.

---

* Numbers in the margin indicate pagination in the foreign text.

The pyrometer was recently used in thermal protection ablation material tests. Thus, data of surface temperature and spectral emissivity of a material were obtained for the first time, proving that this type of pyrometer is practical.

II. Principle of Multispectrum High Temperature Technique

Thermal radiation of a material obeys the Planck radiation law. When $C_2/\lambda T >> 1$, the Wien approximation equation can be applied:

$$L_\lambda(T) = \varepsilon_\lambda(T) C_1 \lambda^{-5} \exp\left(-\frac{C_2}{\lambda T}\right) \quad (1)$$

In the equation, λ is wavelength; T is absolute temperature; C_1 is the first radiation constant; C_2 is the second radiation constant; $\varepsilon_1(T)$ is the monochromatic radiation coefficient of the material surface at temperature T and wavelength λ. $\varepsilon_1(T)$ is not only related to the wavelength and surface temperature of the material, but is also related to chemical composition, physical characteristics and environment of the material surface. To a single measurement, however, $\varepsilon_1(T)$ is only the function of wavelength. Mathematically, we can assume(2):

$$\varepsilon_\lambda(T) = \exp \sum_{j=0}^{n} a_j \lambda^j \quad (2)$$ /107

T and $\varepsilon_\lambda(T)$ can be derived by solving the following equation:

$$\sum_{i=1}^{>2n+2} \left[L_{\lambda_i}(T) - C_1 \lambda_i^{-5} \exp\left(-\frac{C_2}{\lambda_i T} + \sum_{j=0}^{n} a_j \lambda_i^j\right)\right]^2 = \text{minimum} \quad (3)$$

In other words, the surface temperature and spectral emissivity of a material can be obtained by using the method of least squares after measuring the monochromatic radiant luminance of the material at more than (2n+2) wavelengths.

III. Brief Introduction to Seven-Wavelength Pyrometer

ORIGINAL PAGE IS
OF POOR QUALITY

The seven-wavelength pyrometer is one component in the MSTC-E 16 multispectrum pyrometer. Figure 1 shows the theoretical block diagram of the seven-wavelength pyrometer.

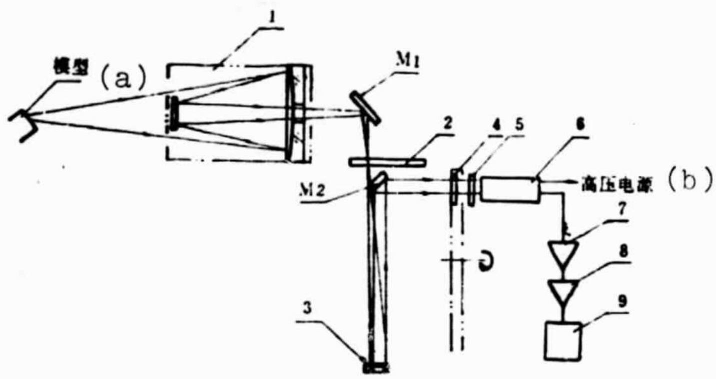

Fig. 1. Block diagram of seven-wavelength pyrometer (in theory): 1 - Cassegrain telescope; 2 - Incidence disk with small holes; 3 - Plane level mirror; 4 - Interference filter group; 5 - Opacifying glass plate; 6 - Photoelectric multiplier tube; 7 - Prime amplifier; 8 - Main amplifier; 9 - Oscillograph; M_1 and M_2 - Front-surface level reflector; (a) Model; (b) High voltage power supply.

The material surface imaging is projected onto an incidence disk (2) with small holes by using a Cassegrain telescope. Six small holes are drilled along the circumference of the incidence disk. The minimum effective diameter of the holes is 0.82 millimeter. The selection of small holes can restrict the size of the surface element to be measured. Radiation entering the small holes is collimated by mirror (3). Through the interference filter group (4) and opacifying glass plate (5), light reaches the cathode sensitive surface of a GDB-239 type photoelectric multiplier tube. The interference filter group (4) is installed at the circumference of the rotating disk. The rotating disk is driven by a synchronous motor. The peak wavelengths of the filters are 4970, 5990, 6510, 6990, 8010, 8990 and 9978 angstroms. The glass plate matching the spectral distribution of the measured object, and the spectral sensitivity of the photoelectric multiplier tube are used in order for the opacifying glass plate (5) to have the functions of reducing the dynamic range of the anode output of the photoelectric multiplier tube, and also in operating the photoelectric multiplier tube in the linear zone. In addition, the system precision is enhanced compared to the adoption of logarithmic amplifier in the original proof scheme. Since the logarithmic amplifier is influenced by its logarithmic elements, only a precision of 1 percent can be attained at present. The output signals of the photoelectric multiplier tube are amplified by a prime amplifier, a main amplifier, and finally displayed by an electron oscillograph with photographing record by a camera.

The signal cycle of this pyrometer is 10 milliseconds. An assumption is implied: the surface temperature and radiation characteristics of the material remain constant within 10 milliseconds. As proved by the measurement result, this assumption is correct. When the ablation is in a steady state, the signal variation between cycles is small.

IV. Measurement Results /108

The measurement proceeded following a series of preparatory steps. First, several calibrating measurements were made on known temperature sources by using the seven-wavelength pyrometer. Thus, experience was accumulated in instrument usage and the resulting calculations. From the calibration and testing of an arc heater, interference in the pyrometer caused by the intense electromagnetic field of the arc heater was observed; the appropriate anti-interference measures were adopted. Then, several ablation models were measured on the site, and the operating state of the entire system was examined in obtaining the signal magnitudes. Before the measurement, the pyrometer was calibrated; the standard source was the standard tungsten-belt temperature lamp of the Academy of Metrology. The spectral emissivity of the tungsten belt uses De Vos' data[3]. Based on the calculation results of the radiation standard energy lamp by using Equation (3), no calibration was used for the transmissivity of the glass shell of the temperature lamp.

Figure 2 shows the emissivity data of typical spectra in different batches for two types of materials. The measurement precision of the temperature is about 2.5 percent, mainly owing to precision of the recording instrument. With the subsequent use of an instantaneous recording instrument, the measurement precision of the temperature can be considerably enhanced. Spectral emissivity is not calculated by using the Equation (3). Instead, Equation (4) is used after calculating the temperautre from Equation (3).

$$\varepsilon_\lambda(T) = \frac{L_\lambda(T)}{L_\lambda^b(T)} \qquad (4)$$

In the equation, $L_\lambda^b(T)$ is the monochromatic radiant luminance of a blackbody at temperature T under the same conditions. The precision of $\varepsilon_\lambda(T)$ is approximately equal to 25 percent. We can realize the following: When an absorption medium (including scattering and reflection, among other modes) exists in the light path between the material surface (to be measured) and the pyrometer, $\varepsilon_\lambda(T)$ also includes the effect of the absorption medium. Therefore, it is difficult to say that $\varepsilon_\lambda(T)$ is the real spectral emissivity of the material surface under very complex environmental conditions. Precisely because of this, the superiority of the multispectrum method is evident.

We can see from Fig. 2 that the variations of GCC and GCD models in their radiation characteristics of seven chosen wavelengths are not evident with wavelength; however, the variation among CCD models is greater.

V. Conclusion

In the radiological method of measuring the surface temperature of a material, the system error of the measurement method can be eliminated only by knowing the radiation characteristics of the material surface, and the influence of the ambient medium. By adopting the multispectrum high temperature technique, one is

ORIGINAL PAGE IS
OF POOR QUALITY

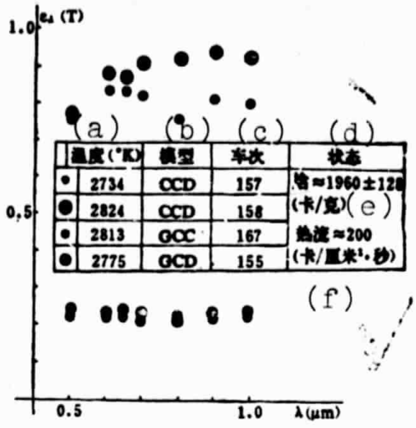

Fig. 2. Spectral emissivity at material surface: (a) Temperature; (b) Model; (c) Batch number; (d) Condition; (e) Enthalpy~1960±128 (calories per gram); (f) Heat flow ~ 200 (calories/centimeter^2·second).

actually seeking an optimal function to match the radiation characteristics of the real material. Relative to ablation tests of thermal protective materials, this is a method yielding relatively precise results.

Through this measurement, the radiation characteristics of thermal protective materials are revealed for the first time. This proves that the seven-wavelength pyrometer is practical.

Comrade Zhang Yong also took part in measurements.

This paper was received on 26 June 1983; the revised version was received on 24 August.

REFERENCES /109

1. Huang Yi, Several Problems in Surface Temperature Measurement of Ablation Materials, China Aerodynamic Research and Development Center, 1978, 8.

2. Sevet, D. Ya., High temperature, high pressure, 8, 493-498 (1977).

3. De Vos, J. C., Physica, 20, 690 (1954).