NATIONAL BUREAU OF STANDARDS REPORT

8037

STANDARDIZATION OF THERMAL EMITTANCE MEASUREMENTS

PROGRESS REPORT No. 18

January 1 - March 31, 1963

Contract No. DO(33-616)61-02
Task No. 73603

AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to government agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. Research projects are also performed for other government agencies when the work relates to and supplements the basic program of the Bureau or when the Bureau's unique competence is required. The scope of activities is suggested by the listing of divisions and sections on the inside of the back cover.

Publications

The results of the Bureau's research are published either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau publishes three periodicals available from the Government Printing Office: The Journal of Research, published in four separate sections, presents complete scientific and technical papers; the Technical News Bulletin presents summary and preliminary reports on work in progress; and the Central Radio Propagation Laboratory Ionospheric Predictions provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: Monographs, Applied Mathematics Series, Handbooks, Miscellaneous Publications, and Technical Notes.

A complete listing of the Bureau's publications can be found in National Bureau of Standards Circular 460, Publications of the National Bureau of Standards, 1901 to June 1947 ($1.25), and the Supplement to National Bureau of Standards Circular 460, July 1947 to June 1957 ($1.50), and Miscellaneous Publication 240, July 1957 to June 1960 (includes Titles of Papers Published in Outside Journals 1950 to 1959) ($2.25); available from the Superintendent of Documents, Government Printing Office, Washington 25, D.C.

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NBS PROJECT **NBS REPORT**

1009-11-10491 8037

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The two phases of this project are conducted under the supervision of the following persons, who have approved this report.

Horace M. Joseph Horace M. Joseph
Electronic Engineer, Data Processing Systems Division

W. N. Harrison William N. Harrison - Coordinator
Chief, Metallic Building Materials Section, Building Research Division

to
AERONAUTICAL SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
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NBS

U. S. DEPARTMENT OF COMMERCE
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NOTICES

I. SUMMARY

A new air-purification system was designed, and components were ordered. The system is intended to reduce atmospheric water vapor and carbon dioxide in the optical path of the normal spectral emittance equipment to a point where the absorption in the wavelength range of 32 to 40 microns can be tolerated.

The working standards of normal spectral emittance have been returned to the National Bureau of Standards, and arrangements are being made to offer them for sale to applicant laboratories.

II. INSTRUMENTATION

Air Purification System

In previous reports it was noted that the sources and optical train in the spectrometer used for normal spectral emittance measurements had been enclosed, so that determinations could be made in a dry, CO_2-free atmosphere. This precaution was found necessary for attainment of the desired accuracy, because the specimen beam and comparison beam pass alternately through much of the optical system, under the control of choppers, and the slight time-lag between the compared signals, combined with steep slopes of spectral absorption curves for CO_2 and H_2O, produced significant errors in measured emittance, within the critical wavelength intervals. The enclosure was not designed to be air tight, but rather to permit controlled leakage, so that during a measurement it could be continuously swept out with super-dry nitrogen supplied from a cylinder under slight positive pressure. With this arrangement, relative humidities of less than 5%, as measured with a recording humidigraph, could be easily attained and maintained for several hours.

For satisfactory operation out to 40 microns, it will be necessary to almost completely eliminate water from the optical path, not only as vapor in the atmosphere, but also as adsorbed films on optical elements, particularly the cesium bromide prism and window to the detector. With this in mind the atmosphere-control system has been modified to greatly reduce the water content of the optical path.

The plastic enclosure to the external optics was redesigned to reduce the enclosed volume and all joints in the system were sealed to minimize leakage. A new atmospheric purification system was designed to circulate the atmosphere continuously in the enclosure through a purification train which removes carbon dioxide and water vapor. A diagram of the purification train is shown in figure 1.

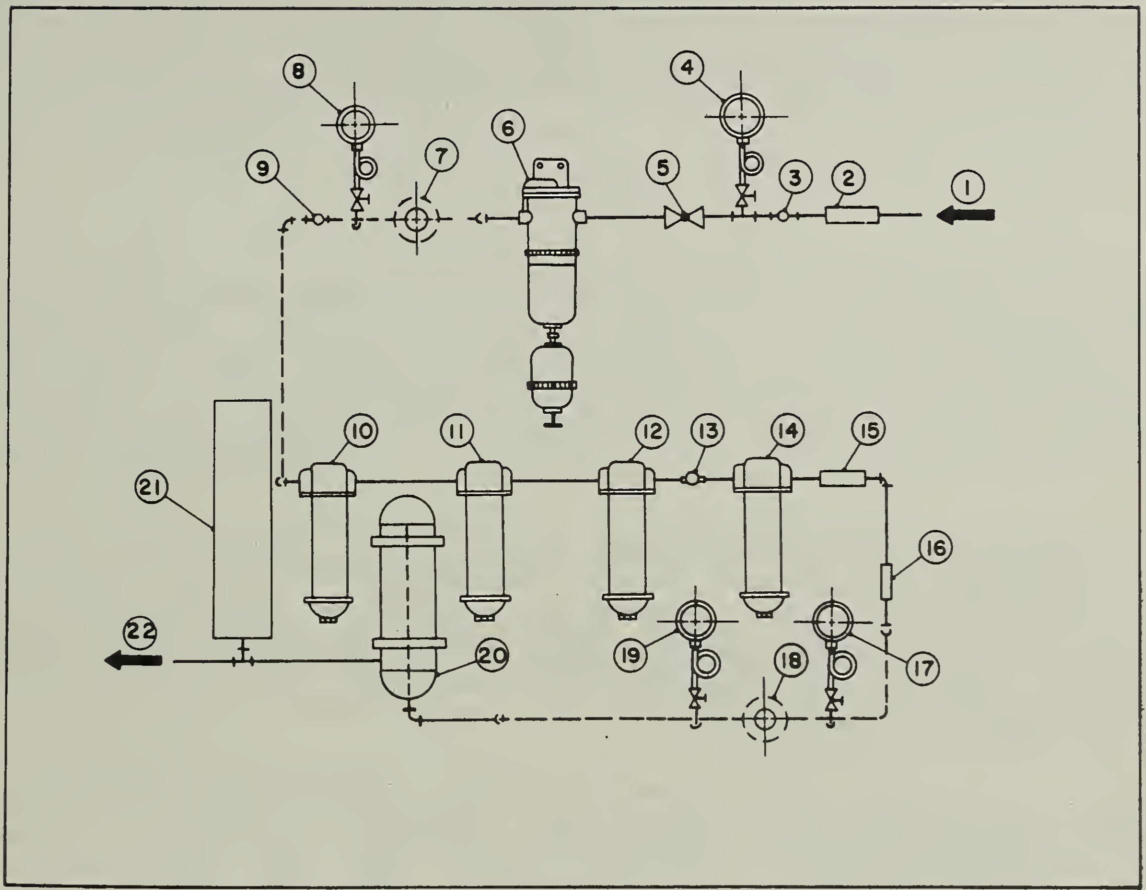

Fig. 1. Schematic diagram of atmosphere purification system. 1. Air inlet from compressor and storage tank. 2. Coarse air filter. 3. Purge valve. 4. Combination temperature and pressure gage. 5. Valve. 6. Air filter. 7. Pressure regulator. 8. Gage, combination pressure and temperature. 9. Safety relief valve. 10. Water filter - silica gel. 11. Carbon dioxide filter, Askerite. 12. Water filter, molecular sieve. 13. Moisture indicator. 14. Oil filter. 15. Dust filter, 11-15 micron. 16. Dust filter, 2-5 micron. 17. Gage, pressure, 0-30 psi. 18. Pressure regulator. 19. Gage, pressure, 0-15 psi. 20. Surge tank. 21. Flow meter. 22. Discharge to spectrometer enclosure.

The system consists essentially of an oilless compressor, a storage tank, a series of scrubbing towers and filters to remove water, carbon dioxide, oil and dust, pressure regulators and valves to control the flow rate, and the necessary traps, gages, etc. Engineers of the Plant Division of NBS, who designed the system, report that it should deliver CO_2-free air at a dew point of less than - 70°C. With this system it will be possible to maintain the controlled atmosphere at all times except for brief periods when the enclosure must be opened to insert new specimens or adjust the equipment.

Filter Circuits

The amplifier of the model 13 spectrometer contains two filter circuits, one for the signal from the I_0 beam, and the other for the signal from the I beam. Each filter circuit reduces noise by averaging the signal over a timer interval, which is a function of the time constant of the circuit. The time constant can be set at any one of four values by means of the "response" dial on the amplifier, which adjusts both filter circuits simultaneously.

The time constant of the filter circuit affects the wavelength resolution of the instrument during automatic scanning in single-beam direct mode; highest resolution, and greatest noise, is obtained with the shortest time constant or lowest "Response" setting. The same effect is produced when the instrument is used double-beam in ratio mode, when the two filter circuits have the same time constants, as they normally do.

Checking of the filter circuits revealed that deterioration of components, particularly condensers, had occurred, and that the two filter circuits no longer had the same time constants. Carefully balanced filter circuits have been order to replace those that were found to be defective.

III. DATA-PROCESSING EQUIPMENT

The computer program for correcting normal spectral emittance, referred to in the last quarterly report, was checked out and found to perform satisfactorily. The input to the computer is the punched paper tapes prepared by the data-processing attachment representing (1) the uncorrected normal spectral emittance, (2) the 100% calibration line, and (3) the zero calibration line. This program was used in reducing data on the oxidized Inconel working standards, referred to in Section IV of this report.

The automatic correction feature of the data-processing attachment is not yet operating in all respects. There are several different circuits involved in its operation. In experimental establishment of a calibration curve, the pulses produced by the recording potentiometer shaft encoder are amplified and recorded on the magnetic tape. All of the components in this circuit are now operating satisfactorily, and the calibration curves are properly recorded on the magnetic tape. During recording of the specimen curve, the pre-recorded magnetic tape is played back synchronously with the automatic wavelength scanning of the spectrometer, and the pulses from the tape should drive the 100%- and zero-potentiometers up or down as required to correct for the instrumental errors. This function has so far not been performed satisfactorily.

Each circuit from the tape recorder to the stepping motor consists of five components: the tape reader, tape amplifier, gating circuit, power amplified and motor. Tests so far have indicated that the tape reader and motor operate satisfactorily. A new power amplifier was supplyed by the manufacturer, and appears to be satisfactory. A remaining malfunction has been found in the tape amplifier, and there is an indication of possible trouble in the gating circuits. The manufacturer is still cooperating, and it is hoped that the remaining deficiencies can be corrected soon.

IV. WORKING STANDARDS OF NORMAL SPECTRAL EMITTANCE

The platinum, oxidized Kanthal and oxidized Inconel working standards of normal spectral emittance that had been transmitted to the Physics Laboratory, A.S.D., were returned to the National Bureau of Standards with a request that the Bureau make arrangements to distribute them to other laboratories as requested. Such arrangements are now being worked out, and it is anticipated that the working standards will be sold at a cost that will partially compensate the Bureau for the cost of preparation and calibration of similar additional working standards.

The 0.484-inch-diameter disc working standards of platinum-13% rhodium alloy and oxidized Inconel have been prepared and given the required annealing and oxidation treatment. Measurements have been completed on the six 1/4 x 8-inch strip specimens cut from the same sheet as the Inconel discs, and the data are ready to be reduced and analyzed statistically. Measurements will be made in the near future on the 1/4 by 8-inch strips of platinum-13% rhodium alloy.

V. EQUATIONS RELATING SPECTRAL EMISSIVITY OF METALS TO OTHER PROPERTIES

A summary of the background and current status of this phase of the work follows. Equations relating the emissivity of metals to their electrical resistivities have been available for many years. The earliest attempts by Hagen and Rubens have been modified through the years to produce relations that are generally applicable in the longer wavelength and elevated temperature regions. While this approach to prediction of properties has been very successful for restrictive conditions, it is not satisfactory for explaining the inflections and irregularities observed in experimental emissivity (reflectivity) data.

A more realistic approach to prediction of the property must consider the mechanism of the transport process to be characterized by more than one family of free electrons. Recent publications by Roberts [1] and T. R. Harrison [2] have given equations that are applicable or adaptable, including the effects of several families of free and bound electrons on the transport process. This classical approach is in harmony with quantum mechanism, as electrons in different energy zones are shown to have different behaviors.

The equations suggested by Harrison, with terms to provide for the effects of free and bound electron families, have been considered. Attempts were made to compute good values of the equation parameters from reliable normal spectral reflectivity values of the metal rhodium at room temperature. As stated in a previous report, first only one category of free electrons and one of bound were used. Within the wavelength range of visible radiation a curve obtained in this way gave a very creditable fit, and followed the inflection corresponding to a maximum in emittance of about 0.45 micron. In the attempt to extend the range of good fit out to about 10μ, it became evident that additional parameters, making at least 10 in all, would be required for insertion into more than one term for free electrons and more than one for bound electrons.

Work will continue on the rhodium data until parameters for proper theory-data comparison can be better determined. Special consideration will be given to the effect on the parameters of uncertainties in the reflectivity data. Optical constants determined from the parameters derived from reflectivity data will be computed and examined to determine the physical credibility of this approach.

With the fraction of total effort on this study that could be devoted to this aspect, no set of parameters has yet been found that will produce a normal spectral reflectivity curve which fits the observed data over a wide wavelength interval both generally and in detail. However the findings have not been negative and show promise that further exploration could produce some useful results.

VI. REFERENCES

[1] Roberts, S. Phys Rev 100, 1667 (1955); 114, 104(1959); 118, 1509(1960).

[2] Harrison, T. R. "Radiation Pyrometry and its Underlying Principles of Radiant Heat Transfer" pp 28-62 and Appendix D. John Wiley & Sons(1960).

U. S. DEPARTMENT OF COMMERCE
Luther H. Hodges, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside of the front cover.

WASHINGTON, D. C.

Electricity. Resistance and Reactance. Electrochemistry. Electrical Instruments. Magnetic Measurements. Dielectrics. High Voltage. Absolute Electrical Measurements.

Metrology. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Volume.

Heat. Temperature Physics. Heat Measurements. Cryogenic Physics. Equation of State. Statistical Physics.

Radiation Physics. X-ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

Analytical and Inorganic Chemistry. Pure Substances. Spectrochemistry. Solution Chemistry. Standard Reference Materials. Applied Analytical Research. Crystal Chemistry.

Mechanics. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Rheology. Combustion Controls.

Polymers. Macromolecules: Synthesis and Structure. Polymer Chemistry. Polymer Physics. Polymer Characterization. Polymer Evaluation and Testing. Applied Polymer Standards and Research. Dental Research.

Metallurgy. Engineering Metallurgy. Metal Reactions. Metal Physics. Electrolysis and Metal Deposition.

Inorganic Solids. Engineering Ceramics. Glass. Solid State Chemistry. Crystal Growth. Physical Properties. Crystallography.

Building Research. Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials. Metallic Building Materials.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics. Operations Research.

Data Processing Systems. Components and Techniques. Computer Technology. Measurements Automation. Engineering Applications. Systems Analysis.

Atomic Physics. Spectroscopy. Infrared Spectroscopy. Far Ultraviolet Physics. Solid State Physics. Electron Physics. Atomic Physics. Plasma Spectroscopy.

Instrumentation. Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

Physical Chemistry. Thermochemistry. Surface Chemistry. Organic Chemistry. Molecular Spectroscopy. Elementary Processes. Mass Spectrometry. Photochemistry and Radiation Chemistry.

Office of Weights and Measures.

BOULDER, COLO.

CRYOGENIC ENGINEERING LABORATORY

Cryogenic Processes. Cryogenic Properties of Solids. Cryogenic Technical Services. Properties of Cryogenic Fluids.

CENTRAL RADIO PROPAGATION LABORATORY

Ionosphere Research and Propagation. Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services. Vertical Soundings Research.

Troposphere and Space Telecommunications. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Spectrum Utilization Research. Radio-Meteorology. Lower Atmosphere Physics.

Radio Systems. Applied Electromagnetic Theory. High Frequency and Very High Frequency Research. Frequency Utilization. Modulation Research. Antenna Research. Radiodetermination.

Upper Atmosphere and Space Physics. Upper Atmosphere and Plasma Physics. High Latitude Ionosphere Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

RADIO STANDARDS LABORATORY

Radio Standards Physics. Frequency and Time Disseminations. Radio and Microwave Materials. Atomic Frequency and Time-Interval Standards. Radio Plasma. Microwave Physics.

Radio Standards Engineering. High Frequency Electrical Standards. High Frequency Calibration Services. High Frequency Impedance Standards. Microwave Calibration Services. Microwave Circuit Standards. Low Frequency Calibration Services.

Joint Institute for Laboratory Astrophysics - NBS Group (Univ. of Colo.).

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