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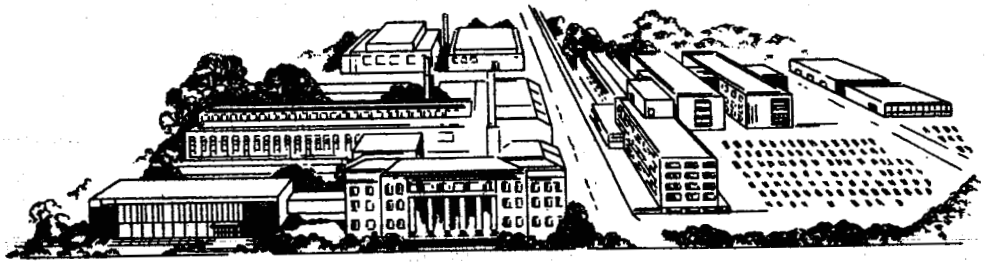

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TWELFTH QUARTERLY REPORT
(Covering the Period: July 1
through September 30, 1963)

on

ENGINEERING PROPERTIES OF POTASSIUM AND CESIUM

to

NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION

by

Alexis W. Lemmon, Jr.

October 30, 1963

Contract NAS 5-584

Technical Management
NASA-Lewis Research Center
Space Electric Power Office

BATTELLE MEMORIAL INSTITUTE
505 King Avenue
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Requests for copies of this report
should be referred to:

National Aeronautics and Space Administration
Office of Scientific and Technical Information
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TABLE OF CONTENTS

TWELFTH QUARTERLY REPORT

on

ENGINEERING PROPERTIES OF POTASSIUM AND CESIUM

by

Alexis W. Lemmon, Jr.

INTRODUCTION

This program at Battelle is being performed for the National Aeronautics and Space Administration (NASA) to investigate the engineering properties of potassium and cesium. Since the preceding quarterly report, the scope has been enlarged to include selected properties of cesium, as well as the work on potassium previously under way. All work is being performed under Contract NAS 5-584, and this report is the twelfth quarterly report of progress, covering the period from July 1 through September 30, 1963.

Many of the thermodynamic and transport properties of potassium, both liquid and vapor, have been measured in the temperature range from 900 to 2100 F. Experimental values for vapor pressure, specific heat of liquid, thermal conductivity of liquid, viscosity of liquid, and P-V-T characteristics have been obtained. Currently the experimental program for measuring the thermal conductivity of potassium vapor is in progress. Experimental techniques for the direct measurement of the specific heat of potassium and for the measurement of the viscosity of the vapor have also been of interest. The latent heat of vaporization, enthalpy, entropy, and specific heat of potassium vapor have been computed from some of the data obtained.

Just being started are measurements of the enthalpy, viscosity, and thermal conductivity of cesium liquid. At a later date, it is expected that the thermal conductivity of cesium vapor also will be determined. It is anticipated that the information derived will be useful in the design, testing, and operation of nuclear electric-power generating systems for use in space, for which either potassium or cesium would be the working fluid.

SUMMARY

Measurements of the viscosity, vapor pressure, thermal conductivity, and heat content of liquid potassium have been concluded. In addition, the compressibility of potassium vapor has been measured in the P-V-T apparatus. Also concluded has been the design study of equipment for the direct determination of the specific heat of potassium vapor. The vapor pressure and compressibility data for potassium were used to derive a virial equation of state which, in turn, was used for the computation of enthalpy, entropy, and the specific heat of the vapor. Experimental effort on potassium is currently limited to making the final preparations of the bare-wire probe apparatus in

anticipation of the measurements which will be made during the next 3 months. Activity on the newly begun cesium phase includes preparation of experimental equipment previously used for the potassium measurements and the procurement of purified cesium and the Nb-1Zr alloy needed for the cesium containment vessels.

Equipment for measuring the thermal conductivity of potassium vapor has been assembled. In the initial attempts at operation with air, the values obtained were about 30 per cent low. However, many difficulties were encountered with the electronic circuitry. These difficulties have now been resolved to the point where measurements will begin with purified nitrogen, for calibration purposes, and then with potassium.

Materials procurement for the cesium program is under way. The commercial supplier for the Nb-1Zr alloy has been selected. Additional quality requirements for some items, consisting of ultrasonic and dye-penetrant tests to assure surface soundness, have been imposed. Sources for the purchase of purified cesium suitable for the measurements are being explored.

Enthalpy measurements for cesium liquid will be made in the Bunsen ice calorimeter, which is being cleaned and readied for operation. Rechecking its operation with standard Al_2O_3 is planned prior to the cesium drops.

The liquid-thermal-conductivity apparatus is being cleaned to remove contaminating potassium which leaked out during previous measurements. Also, some damaged components are being replaced. The thermal conductivity of the new Nb-1Zr alloy material, to be used as the reference heat-flow meter, will be measured prior to the measurements on cesium.

Readying of the liquid-viscosity apparatus for use with cesium includes a review of the building-vibration problem. Measurements are expected to begin shortly after the receipt of the Nb-1Zr alloy and purified cesium.

EXPERIMENTAL MATERIALS

(Joseph F. Walling)

A decision has been made to fabricate from the Nb-1Zr alloy the new test cells for the various items of equipment to be used for the measurements. Therefore, the needed items of the Nb-1Zr alloy have been ordered from the most appropriate supplier. Handling and acceptance procedures will be, in general, the same as those used previously in the potassium work. Some extra requirements (ultrasonic and dye-penetrant tests) have been imposed for the thermal-conductivity bar stock to help in assessing the surface soundness of this piece.

The preparation and analysis of the cesium to be procured is discussed in a later section of this report.

DETAILS OF INDIVIDUAL PROGRAMS

At present, most experimental and analytical activities on the potassium portion have been concluded with but one exception, the measurement of the thermal conductivity of potassium vapor. Consequently, the concluded portions are no longer being reported here. For those who desire information on previous results, reference is made to the topical reports listed in the final section of this report.

Phase I – Item 4. Measurement of Viscosity of (Potassium) Vapor

(E. H. Hall and J. M. Blocher, Jr.)

Activity on this item has been indefinitely suspended; no significant values have been obtained.

Phase III – Measurement of Thermal Conductivity of (Potassium) Vapor

(Joseph Matolich, Jr., and Herbert W. Deem)

The thermal conductivity of potassium vapor is to be measured over a temperature range from 480 to 1150 C (900 to 2100 F). A dynamic method using a bare-wire probe is being used to make the measurements.

During this work period, the vacuum-chamber heaters and related apparatus have been completed, assembled, and tested satisfactorily to 1150 C (2100 F).

The electrical measuring circuit as described and shown in the Eleventh Quarterly Report[1]* has been assembled. Measurements have been started using a stainless steel probe chamber and boiler to check the response of the circuit. The first measurements were made with the probe filled with air, for which thermal-conductivity values are reasonably well known. The first data taken yielded thermal-conductivity values about 30 per cent low.

Several operational difficulties contributed to the error. The main power switch used to start the measurements proved to be "noisy" and erratic and will be replaced. Difficulty was experienced with the timing marker in which standard commercial decade counters were used. This circuit proved to be too sensitive to changes of amplifier load with change in gain. Difficulties with the timer will be corrected because uncertainties in time add to the error of the measurements. A malfunction of the d-c amplifier added to the difficulties. During these difficulties, however, experience was gained on the over-all operation of the probe.

Purified nitrogen will next be used as a reference gas to check the operation of the apparatus. Reliable literature values are available for nitrogen and, as soon as the apparatus yields good thermal-conductivity values for nitrogen, measurements will be started on potassium vapor.

*See page 5 for references.

The stainless steel probe assembly will be used for thermal-conductivity measurements to about 750 C on potassium vapor, during which time the Nb-1Zr alloy apparatus will be assembled. Measurements will then be extended to about 1150 C.

Phase IV – Item 1. Preparation and Analysis of Cesium

(Joseph F. Walling)

The matter of obtaining pure, analyzed, and properly sized ampoules of cesium suitable for direct loading into the various apparatuses is being explored. Commercial suppliers now seem to be more amenable to accepting purity requirements for material purchased than they were 2 years ago when potassium was needed for these studies. Hopefully, the cesium needed can be purchased in a pure enough state that further purification will not be necessary.

Phase IV – Item 2. Measurement of Specific Heat of Liquid Cesium

(Edward A. Eldridge and Herbert W. Deem)

The enthalpy and specific heat of liquid cesium are to be measured to 1150 C. Enthalpy measurements will be made in the Bunsen ice calorimeter previously described.(2)

The Nb-1Zr alloy, from which capsules will be made to hold the cesium, has been ordered. The calorimeter wells and mercury-accounting systems are now being cleaned and made ready for use.

Effort during the next work period will be directed toward rechecking the operation of the calorimeter by measuring the enthalpy of National Bureau of Standards Al_2O_3 and machining and filling the capsules with cesium.

Phase IV – Item 3. Measurement of Thermal Conductivity of Liquid Cesium

(Joseph Matolich, Jr., and Herbert W. Deem)

The thermal conductivity of liquid cesium is to be measured from 100 to 1150 C (212 to 2100 F). The method, apparatus, and techniques will be the same as those used for liquid potassium, as previously described.(3)

Work on this phase was initiated late in this quarter. During the potassium measurements, the specimen container leaked and the apparatus is now being cleaned. It will be necessary to replace the titanium guard cylinder, heaters, cooling coils, and thermocouples.

The Nb-1Zr alloy and cesium metal required for the determination have been specified.

During the next work period, the apparatus will be made ready for measurements, and as soon as the Nb-1Zr alloy is received, its thermal conductivity will be determined, since it will be used as the reference material for the cesium measurements.

Phase IV – Item 4. Measurement of Viscosity of Liquid Cesium

(Elton H. Hall and John M. Blocher, Jr.)

The apparatus used for measurement of the viscosity of liquid potassium has been readied for the study of liquid cesium.

A review of the vibration problem is in progress to determine whether another type of mounting might be more effective in minimizing the effect of building vibrations on the oscillation of the liquid-filled cylinder.

The Nb-1Zr alloy required for fabrication of the cylinder and the cesium is on order and work will be continued as soon as the materials are received.

Phase IV – Item 5. Measurement of Thermal Conductivity of Cesium Vapor

(Joseph Matolich, Jr., and Herbert W. Deem)

These measurements are being postponed pending the outcome of the corresponding measurements for potassium vapor.

REFERENCES

(1) Lemmon, Alexis W., Jr., Eleventh Quarterly Report, "Engineering Properties of Potassium", (Covering the Period April 1 through June 30, 1963), Battelle Memorial Institute, April 30, 1963.

(2) Deem, H. W., Eldridge, E. A., and Lucks, C. F., "The Specific Heat From 0 to 1150 C and Heat of Fusion of Potassium", Topical Report BATT-4673-T2, Battelle Memorial Institute, August 31, 1962.

(3) Matolich, J., Jr., and Deem, H. W., "The Thermal Conductivity and Electrical Resistivity of Liquid Potassium and the Alloy Niobium-1 Zirconium", Topical Report BATT-4673-T6, Battelle Memorial Institute, April 30, 1963.

LIST OF REPORTS COVERING CONTRACT NAS 5-584 ENGINEERING PROPERTIES OF POTASSIUM

(July 30, 1963)

"Engineering Properties of Potassium" by Alexis W. Lemmon, Jr., Battelle Memorial Institute.

(a) First Quarterly Report (Covering the Period: October 1 through December 31, 1960), January 30, 1961.

(b) Second Quarterly Report (Covering the Period: January 1 through March 31, 1961), April 30, 1961.

(c) Third Quarterly Report (Covering the Period: April 1 through June 30, 1961), August 3, 1961.

(d) Fourth Quarterly Report (Covering the Period: July 1 through September 30, 1961), October 30, 1961.

(e) Fifth Quarterly Report (Covering the Period: October 1 through December 31, 1961), January 30, 1962.

(f) Sixth Quarterly Report (Covering the Period: January 1 through March 31, 1962), April 30, 1962.

(g) Seventh Quarterly Report (Covering the Period: April 1 through June 30, 1962), July 30, 1962.

(h) Eighth Quarterly Report (Covering the Period: July 1 through September 30, 1962), October 30, 1962.

(i) Ninth Quarterly Report (Covering the Period: October 1 through December 31, 1962), January 30, 1963.

(j) Tenth Quarterly Report (Covering the Period: January 1 through March 31, 1963), April 30, 1963.

(k) Eleventh Quarterly Report (Covering the Period: April 1 through June 30, 1963), July 30, 1963.

Hall, Elton H., and Blocher, John M., Jr., "The Viscosity of Saturated Liquid Potassium from 70 to 1150 C by the Oscillating-Cylinder Method", Topical Report BATT-4673-T1, Battelle Memorial Institute, August 31, 1962.

Deem, H. W., Eldridge, E. A., and Lucks, C. F., "The Specific Heat from 0 to 1150 C and Heat of Fusion of Potassium", Topical Report BATT-4673-T2, Battelle Memorial Institute, August 31, 1962.

Walling, Joseph F., Nuzum, Harry K., and Lemmon, Alexis W., Jr., "The Vapor Pressure and Heat of Vaporization of Potassium from 480 to 1150 C", Topical Report BATT-4673-T3, Battelle Memorial Institute, April 30, 1963.

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Walling, Joseph F., Nuzum, Harry K., Kim, Byung C., and Lemmon, Alexis W., Jr., "Design and Evaluation of an Instrument for Measuring the Specific Heat of Potassium Vapor", Topical Report BATT-4673-T5, Battelle Memorial Institute, April 30, 1963.

Deem, H. W., and Matolich, J., Jr., "The Thermal Conductivity and Electrical Resistivity of Liquid Potassium and the Alloy Niobium-1 Zirconium", Topical Report BATT-4673-T6, Battelle Memorial Institute, April 30, 1963.

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