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NBS REPORT
9750

THIRTY-SIXTH PROGRESS REPORT

to

National Aeronautics and Space Administration

on

Cryogenic Research and Development

for

Period Ending December 31, 1969



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U. S. DEPARTMENT OF COMMERCE
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Institute for Basic Standards
Boulder, Colorado 80302

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NBS PROJECT

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Cryogenics Division
Institute for Basic Standards
National Bureau of Standards
Boulder, Colorado

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U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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Task Completed									
For Latest Report or Publication on This Task See	Provisional (P) or Final (F)			(P)		(P)			
	item #								
	page			5		6			
	Quart. Report #			35th		35th			
Est. Completion Date		*	*	10/70	10/70	*	*		
Report in Press									
Report Composition		X	X	X			X		
Data Analysis				X	X				
Data Taking				X	X				
Apparatus Construction									
Apparatus Designing									
Preliminary Planning									
Not Started									
Active Coord. with Lewis, MSFC, LASL		X	X			X	X	X	X
PHASE OF TASK ↑		TASK ↓							
Item Number		1.	Hydrogen Properties	1.1	Tables and Code for Para-hydrogen	1.2	Tables and Code for Equilibrium hydrogen	2.	Cryogenic Properties of Solids
		2.1	Thermal Conductivity	2.2	Electrical Resistivity	3.	Consultation & Advisory Service	3.1	Centaur Program
		3.1.1	Stratification & Pressurization	3.1.2	Test Assistance	3.2	NERVA Program		

* Continuing effort

1. Hydrogen Properties

1.0 Personnel contributing during this period were R. D. McCarty and H. M. Roder.

1.1 Tables for Parahydrogen

1.2 Tables for Equilibrium Hydrogen

As mentioned in the last progress report we have completed and checked the computer decks that describe the properties of hydrogen, both in the para and in the equilibrium modifications. We have mailed out copies of these programs in both the CDC and the IBM machine versions to the following:

Westinghouse Astronuclear Laboratory (CDC)

Aerojet-General Corporation (IBM)

North American Aviation/Rocketdyne Division (IBM)

General Dynamics/Fort Worth Division (IBM)

There are several tasks that remain to be done, some are partially completed, some are only started. We will continue to report progress on these tasks under the section on consultation and advisory services. The tasks are:

- a. TAB code decks of the "L" factors;
- b. An updated description of the decks similar to NBS report 9288; and
- c. Further consultation as required

The "L" factors are a particular combination of variables useful in a variety of heat transfer problems. Specifically, "L" factor = $K^{0.6} C_p^{0.4} / \eta^{0.4}$. We have the PHLFAC program nearly completed, and work on the others started.

2. Cryogenic Properties of Solids

2.1 Thermal Conductivity of Solids

2.1.1 General Comments

The objective of this project is to measure the thermal conductivities of several standard reference materials and to study the conduction mechanisms in alloys from 4 K to 300 K.

Personnel contributing during the current reporting period were J. G. Hust, R. L. Powell, and L. L. Sparks.

2.1.2 Program Status

During the current reporting period measurements have been completed on the second specimen of austenitic stainless steel. Data analysis has begun on these data and preliminary indications are that this material will make a suitable low conductivity, low temperature standard reference material. The conductivities of the two specimens measured differ by less than 1 percent, suggesting very little material variability. We will obtain additional specimens of austenitic stainless steel from OSRM (Office of Standard Reference Materials) for further material variability study to establish it as a standard reference material.

A random sample of SRM (Standard Reference Material) iron specimens, designated SRM 1265, has been obtained from OSRM. Electrical resistivity measurements have been done on four of these specimens; these measurements indicate a material variability of only about 1 percent. The present plans are to establish this SRM iron as a thermal conductivity standard in the medium-to-high conductivity range. The distribution of SRM iron and SRM steel will be handled by OSRM. A report on these measurements will be published in the near future.

During the next reporting period we will complete the measurements and analysis on SRM iron and SRM steel. This will complete the standard reference material phase of our program. In the next period we will also begin the nickel alloy (Inconel 718) and Lorenz ratio study as proposed.

At the 9th Thermal Conductivity Conference at Iowa State University in October, 1969, preliminary discussions were held to set up an informal information exchange between the more active researchers in the field. Although significant communication does take place at these relatively infrequent conferences, it is hoped that more can be accomplished between the times of such meetings.

At the WANL Radiation Effects Meeting in October, specimens of Armco iron and of austenitic stainless steel were requested for use by WANL, ORNL, and BMI as standard reference specimens. The Armco iron specimen has been forwarded to Payton Moore (ORNL) and the stainless steel specimen to Peter Gaal (WANL). The ice point resistivities of these specimens were remeasured before shipment, and the agreement with previous measurements was within 0.1 percent indicating no change within experimental uncertainty.

At the WANL meeting, we offered assistance to Bruce Morrison (LASL) in the analysis of some ATJ Graphite data with which he was having difficulty. Results of this work are indicated partially by the four curves which follow. Another joint effort, with Paul Wagner (LASL), is nearing completion; the paper is in editorial process.

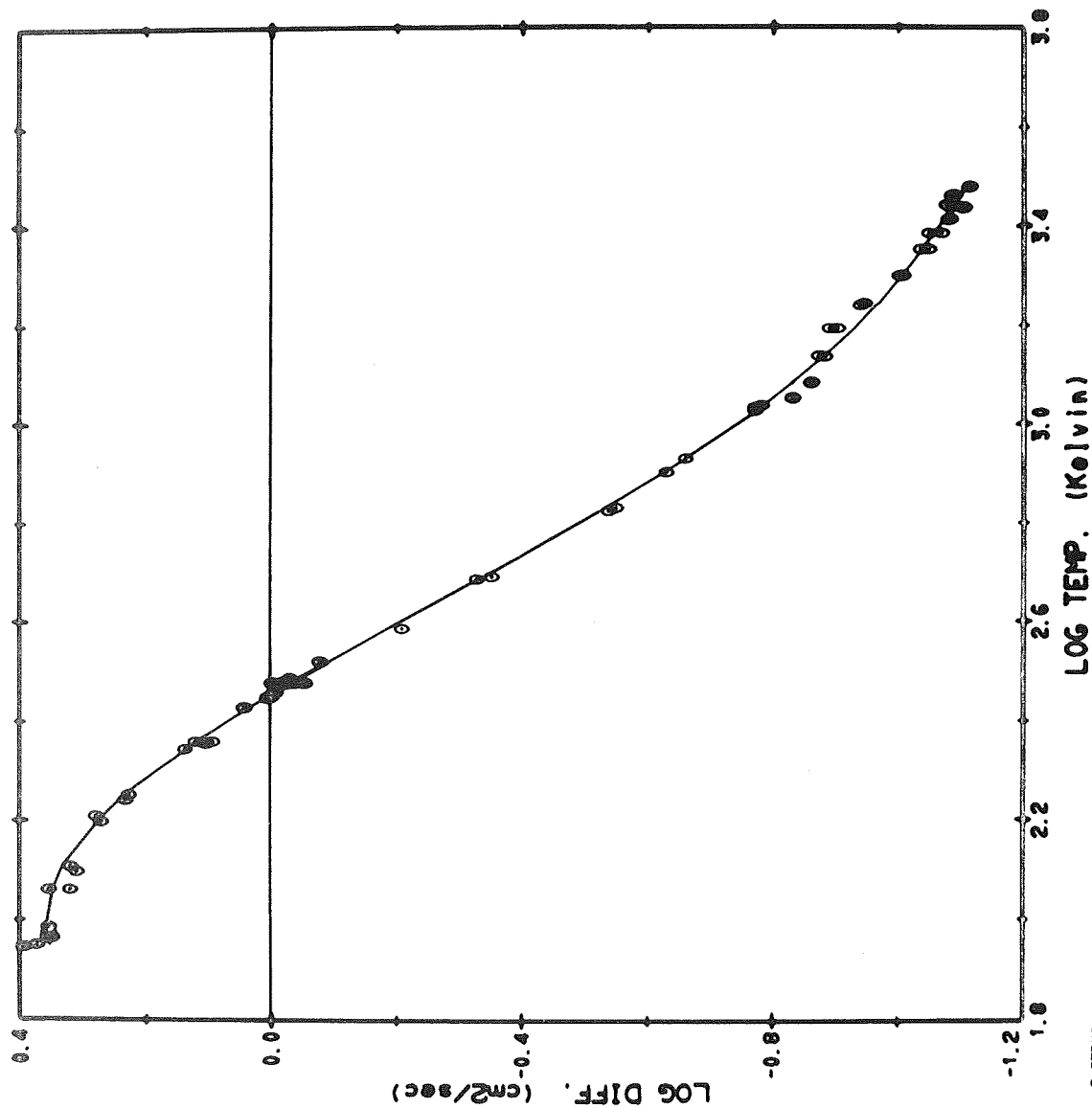
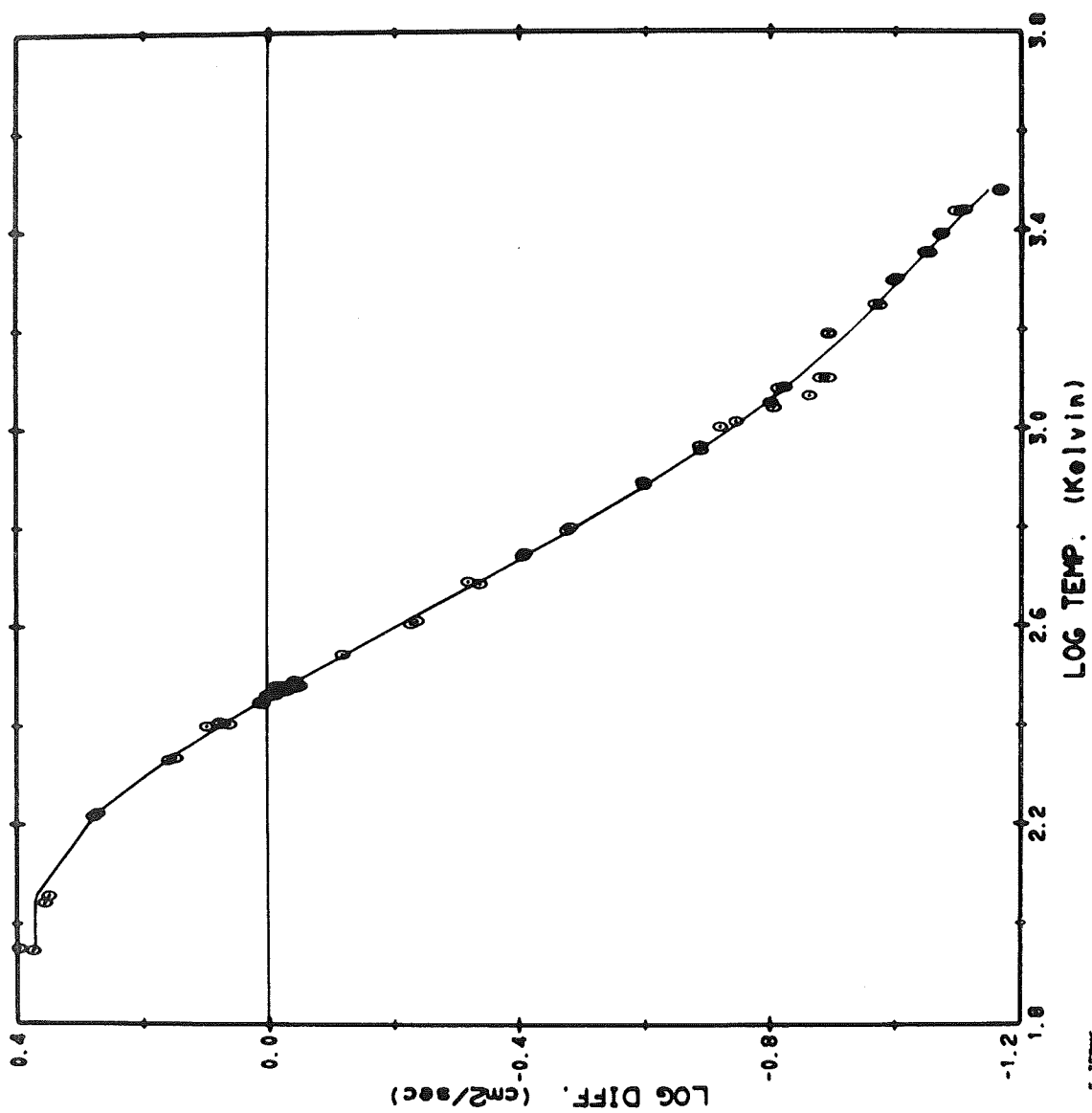


Figure 2.1.1. Thermal Diffusivity vs. Temperature.
ATJ-S Graphite (Piece 1)



S. TEMES
01/07/70

Figure 2.1.2. Thermal Diffusivity vs. Temperature.
ATTJ-S Graphite (Piece 2)

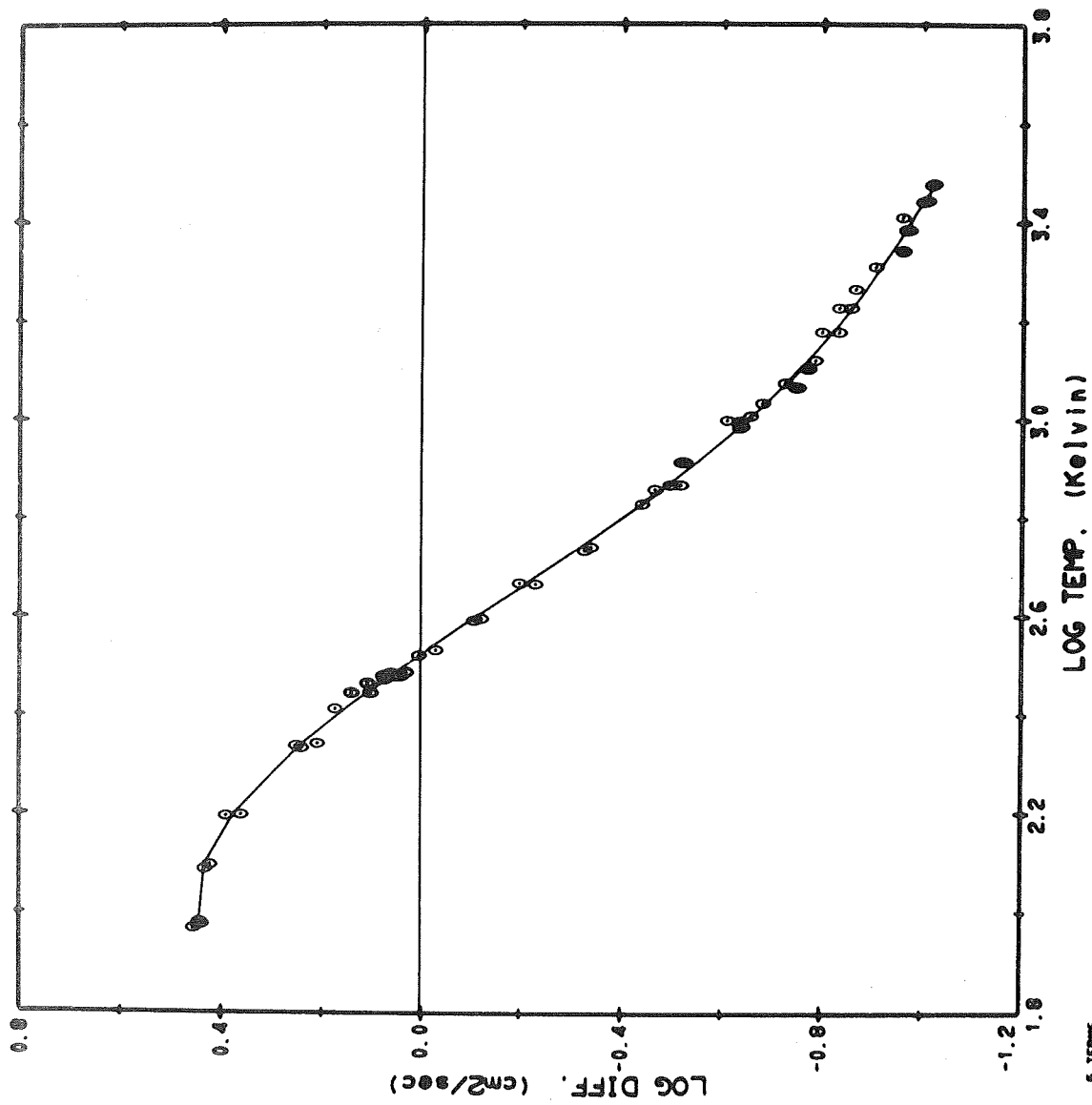
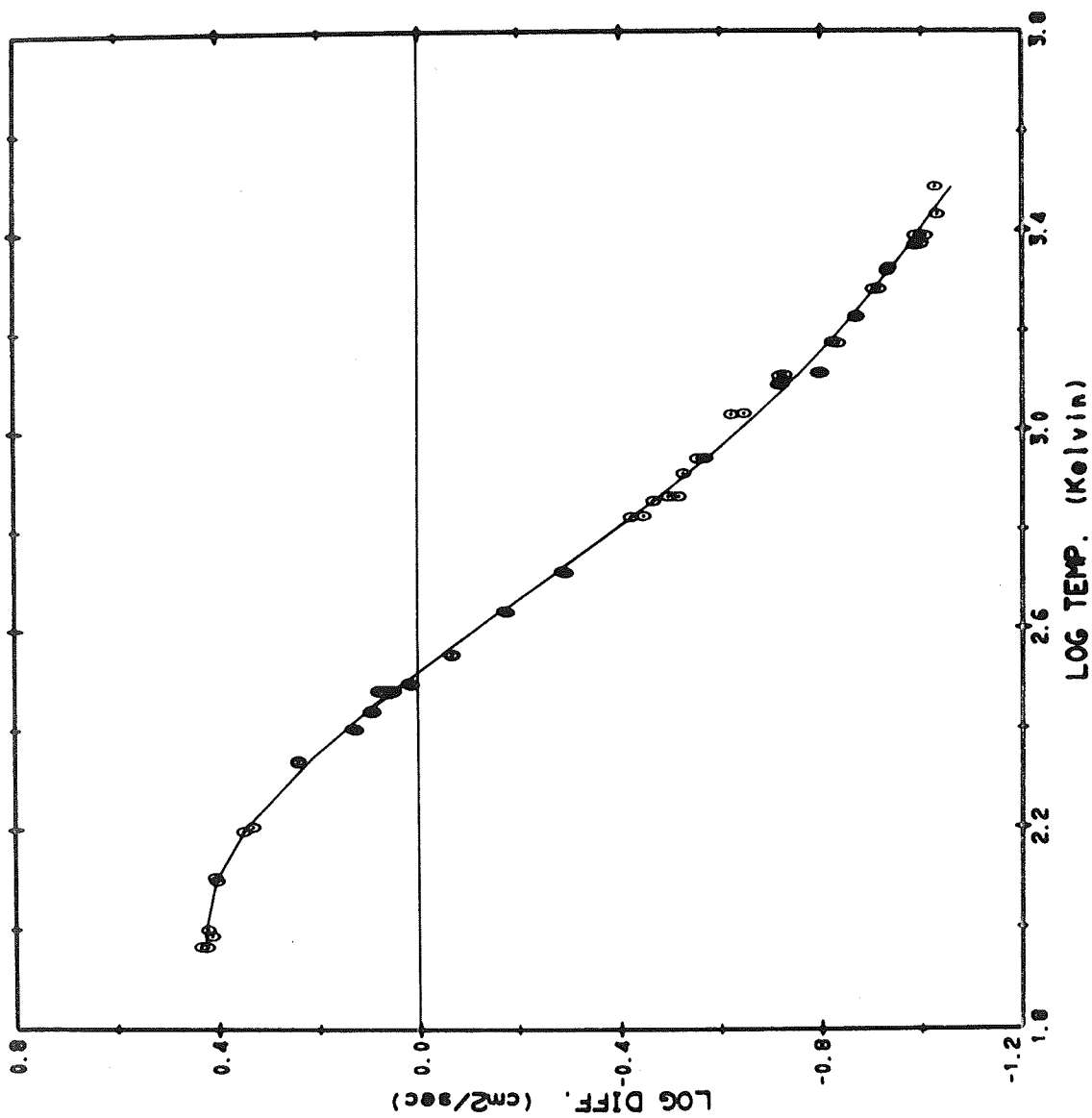


Figure 2.1.3. Thermal Diffusivity vs. Temperature.
ATJ-S Graphite (Piece 3)

S. TERMS
01/07/70



5 TEMPS
01/07/78

Figure 2.1.4. Thermal Diffusivity vs. Temperature.
ATJ-S Graphite (Piece 4)

2.2 Electrical Resistivity

2.2.1 General Comments

The objectives of this project are to measure the low temperature electrical resistivity of selected alloys needed for cryogenic design and to study their material variability, and also to perform precision measurements of resistivity of a few pure materials to improve understanding of the basic electron scattering mechanisms and improve the reliability of standard reference data.

A paper reporting the results and interpretation of the engineering resistivity data has been submitted to Cryogenics for publication. Initial planning for the material variability studies has begun. Further precision measurements were made on the copper samples, preliminary results are reported, and a computer program for data reduction has been written.

Personnel contributing during this period were A. F. Clark, O. J. Berven, M. B. Kasen, and W. H. German.

2.2.2 Program Status

The progress report presented at the 1969 Cryogenic Engineering Conference has been accepted for publication in Vol. 15 of "Advances in Cryogenic Engineering." The paper reporting the complete results and containing the detailed analysis and interpretation has cleared NBS editorial review and has been submitted to "Cryogenics" for publication. This completes the engineering resistivity data phase of the program. Planning for the reliability and material variability study using the engineering resistivity measurements of a large statistical sampling of common aerospace alloys has begun. Samples will be purchased from different melts of the same alloy, from different parts of the same melt, and from different manufacturers and measurements performed on each. Similar tests will be done for various heat treat-

ments. Thermal conductivity measurements on some of the same alloys will be performed by J. G. Hust for correlation of these results to the thermal conductivity by the Lorenz ratio.

More data have been accumulated on the precision resistivity of the pure copper samples and some preliminary curves are shown in Figure 2.2.1 with only representative data points shown. More data have to be taken over the entire range although the range around the ice point and room temperature is reasonably well covered. A preliminary interpolation to the ice point (273.15 K) yields a value of $0.015445 \mu\Omega\text{m}$ where the previously accepted value has been $0.01545 \mu\Omega\text{m}$ which is excellent agreement.

Several problems have occurred which have been remedied. The germanium thermometer current supply had some subtle instabilities and a significant a.c. output. Redesign of the circuit has eliminated the problem. The mechanical automatic current reversing switch has been replaced with an electronic one for the sample current. A wider range of precision resistors were calibrated and installed in the same circuit for a more accurate determination of the sample current.

A computer program was written, debugged, and is now operational for data reduction. The program calculates the resistance and resistivity and the standard error for the measurement. It automatically makes the calibration corrections for the six-dial potentiometer and thermal contraction correction for the resistivity calculation. The program also determines the temperature from the resistance thermometer readings using an interpolation program of J. G. Hust. The thermometer calibration tables were also converted from the old temperature scales, NBS 55 and IPTS 48, to the new IPTS 68.

The techniques of the aluminum sample preparation have been worked out by M. B. Kasen and W. H. German and work on the final samples has begun.

In the next reporting period plans for the material variability will be complete, stock material purchased and sample preparation begun. The precision resistivity of copper should also be completed.

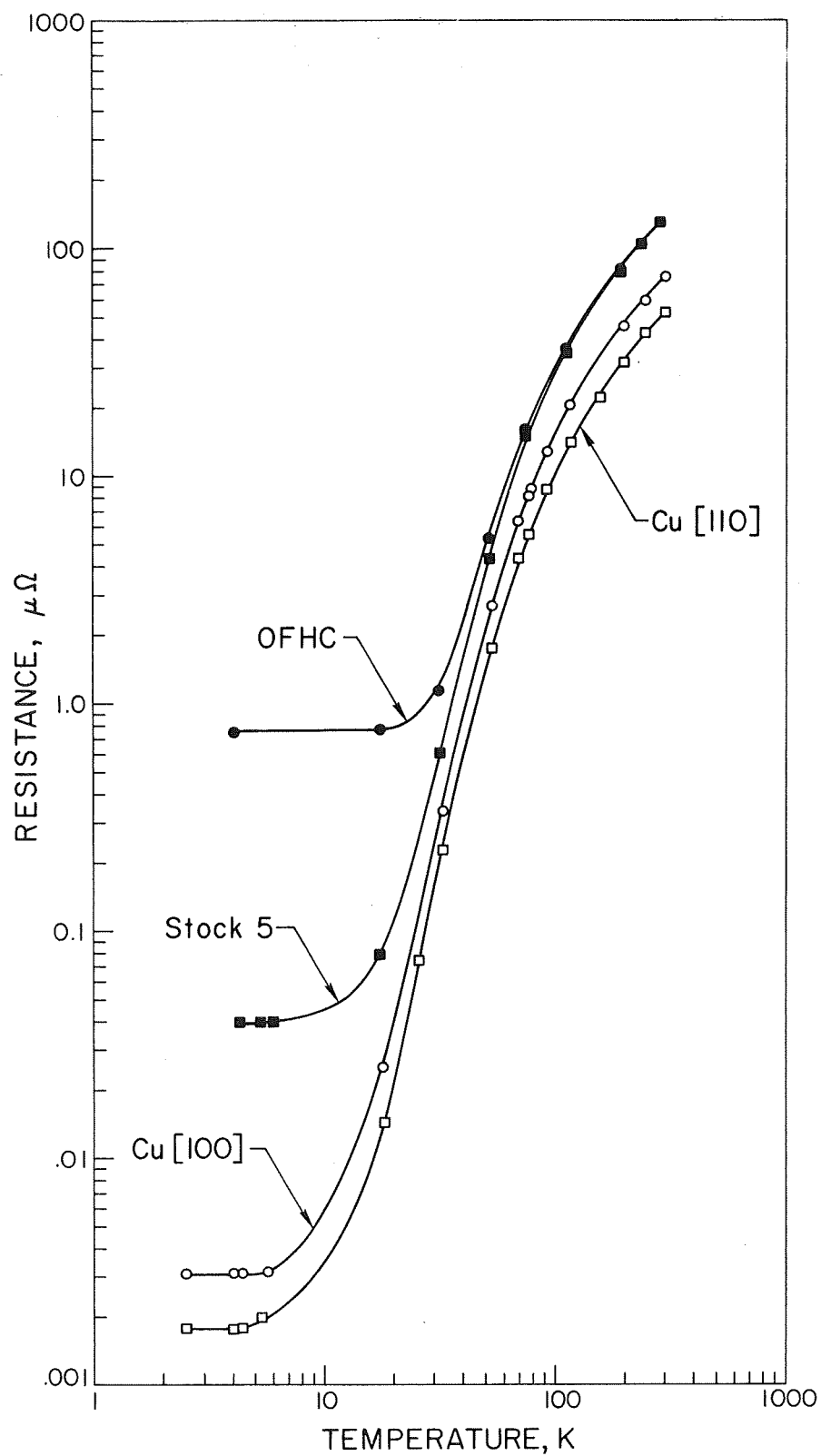


Figure 2.2.1. Resistance of Pure Copper as a Function of Temperature.

3. Consultation and Advisory Services

3.0 General Comments

Consultation and advisory services have continued in two NASA program areas: Centaur (funded separately) and NERVA.

3.1 Centaur Program - R. W. Arnett and R. O. Voth.

3.1.1 Stratification and Pressurization

Work is continuing on the preparation of a final report and the prediction of pressure rise by use of the computer program for a coast phase condition.

3.1.2 Test Assistance

No work has been done in this area during the reporting period due to delays in the test program at the Plumbrook facility.

3.2 NERVA Program - A. F. Schmidt, R. D. McCarty, H. M. Roder, R. V. Smith, R. L. Powell, J. G. Hust.

A significant amount of time has been spent on the low temperature NERVA turbine and the question of hydrogen properties used in its design. Closely spaced tables from the TAB Code programs were turned out for the temperature and pressure ranges of interest, and an error analysis of H and S was accomplished showing that the nominal 1 percent error of the TAB Code may affect the turbine design. On November 19, Smith and Roder visited AGC and discussed the turbine problem, heat transfer problems, and the problem of errors. At a later date it appeared that the functions used by NBS to generate values for the grid of the TAB Codes would be useful to Aerojet; McCarty spent December 29-30 in Sacramento assuring compatibility of the generating functions with the Aerojet IBM computer.

On October 23-24, Powell and Hust attended the Radiation Effects Meeting at Westinghouse Astronuclear Laboratory. Several action items resulting from that meeting are described in Section 2 of this report.

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