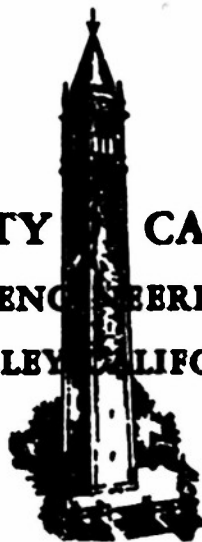


AD No. 16714
ASTIA FILE COPY

UNIVERSITY OF CALIFORNIA
INSTITUTE OF ENGINEERING RESEARCH
BERKELEY, CALIFORNIA



THE CORRELATION OF HIGH TEMPERATURE

RUPTURE DATA FOR NIOBIUM

Twenty Eighth Technical Report

By

Raymond L. Orr and Douglas W. Bainbridge

22, N7-onr-295, Task Order II,
SERIES NO. NR-031-048
ISSUE NO. 28
DATE July 1, 1953

THE CORRELATION OF HIGH TEMPERATURE
RUPTURE DATA FOR NIOBIUM

By

Raymond L. Orr⁽¹⁾ and Douglas W. Bainbridge⁽¹⁾

Twenty Eighth Technical Report, Series 22, Issue 28
N7-onr-295, Task Order II, NR-031-048

July 1, 1953

(1) Research Engineer, Institute of Engineering Research, University
of California, Berkeley, California

ABSTRACT

Stress-rupture data for niobium were obtained at 1144°K under four stress conditions between 18,000 and 25,000 psi. These data correlated well with existing rupture data for the same material at 1255°K by means of the relation $t_r e^{-\Delta H_r/RT} = f(\sigma)$, where σ is the stress, T is the absolute temperature, R is the gas constant, and ΔH_r is the experimental activation energy for rupture. ΔH_r was found to be equal to 75,000 calories per mole for niobium.

THE CORRELATION OF HIGH TEMPERATURE RUPTURE DATA FOR NIOBIUM

It has recently been shown⁽¹⁾ that stress-rupture data for metals at elevated temperatures are correlatable by means of the equation

$$\theta_r = f(\sigma) \quad (1)$$

where σ = the applied stress

θ_r = temperature-compensated time at rupture

$= t_r e^{-\Delta H_r / RT}$ for a constant temperature test

t_r = time to rupture

T = temperature of test in absolute degrees

R = gas constant in calories per degree per mole

and ΔH_r = experimental activation energy for rupture in calories per mole.

For a given metal, ΔH_r was found to be a constant equal to the activation energies for high temperature creep and self-diffusion.

The rupture properties of relatively pure niobium in an atmosphere of helium under three stresses at 1255°K have been determined by Grassi, Bainbridge and Harman⁽²⁾. Since the same material and apparatus used by those investigators were readily available, it was decided to extend their measurements to include data at some other temperature in order to permit evaluation of the activation energy for rupture of niobium through application of Equation 1.

Rupture data for 99.8 percent niobium have therefore been obtained under four stresses at 1144°K using the same material and equipment described previously by Grassi, Bainbridge and Harman^(2,3). The test specimens, fabricated from 0.125 inch diameter wire with reduced sections 0.08 inch in diameter and 0.5 inch long, were annealed in a helium

atmosphere at 1255°K for two hours prior to testing. The tests were conducted in a protective atmosphere of high purity helium at 3 psig in a sealed chamber heated by a vertical glo-tube furnace, the temperature of which was measured and controlled by means of a chromel-alumel thermocouple. The load was applied to the interior of the chamber through the use of a sylphon bellows.

These data together with the data at 1255°K reported by Grassi, Bainbridge and Harman⁽²⁾ are presented in Table I. The nominal stress listed is the initial stress for each test.

TABLE I
Stress-Rupture Properties of Niobium

Temperature	Nominal Stress psi	Rupture Time Hours
1255°K	19,200	7.6
	16,900	23.9
	14,500	82.0
1144°K	25,000	3.6
	22,500	27.5
	20,000	79.3
	18,000	242.7

Analysis of these data by means of Equation 1 resulted in the good correlation shown in Figure 1, yielding 75,000 calories per mole as the activation energy, ΔH_r , for the rupture of niobium. It is believed that this value should approximate the value of the activation energy for the high temperature creep and self-diffusion of niobium.

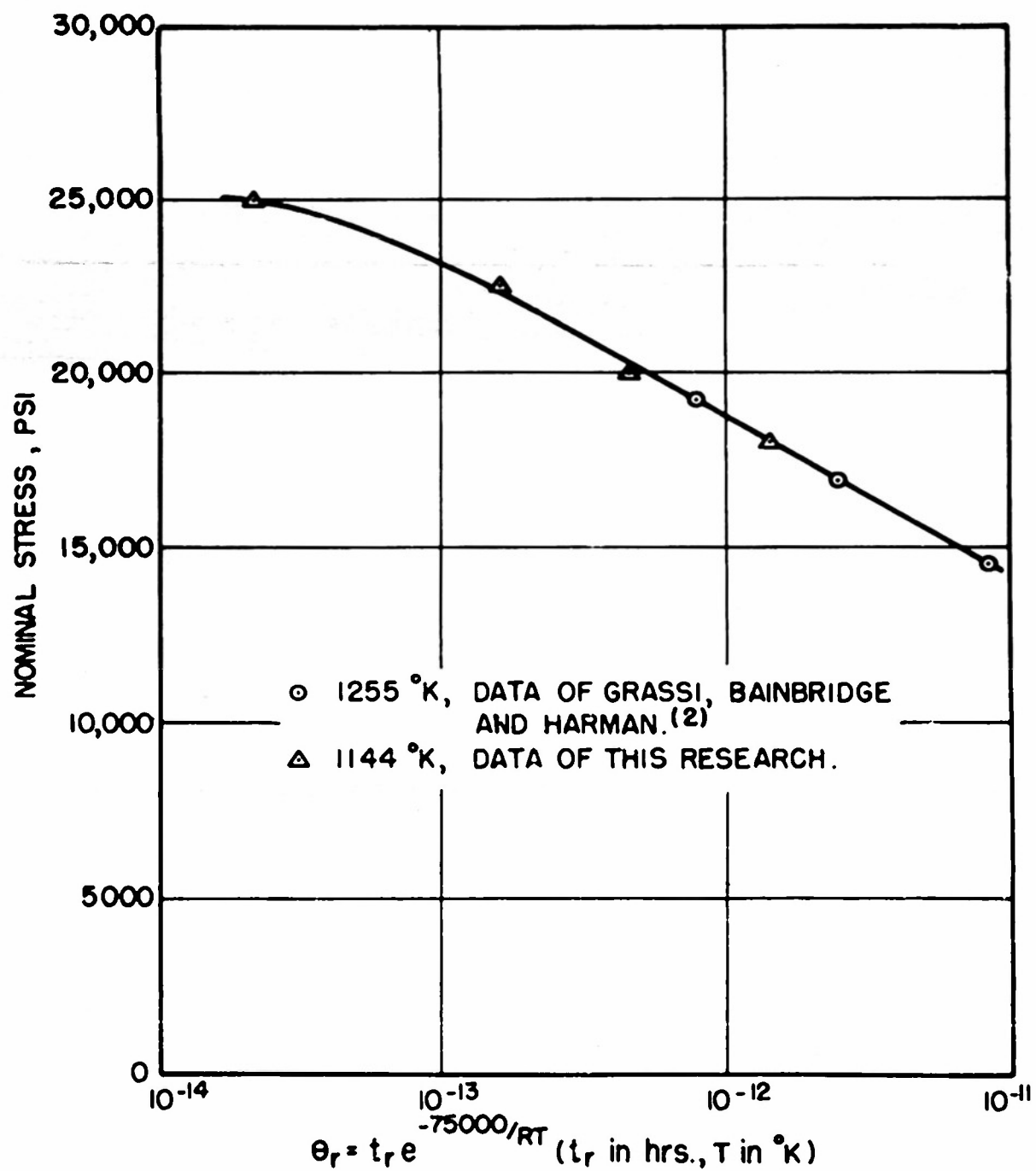


FIG. 1 CORRELATION OF STRESS-RUPTURE DATA FOR 99.8 % NIOBIUM BY MEANS OF THE RELATION $\theta_r = f(\sigma)$.

ACKNOWLEDGMENTS

This investigation was sponsored by the Office of Naval Research. The authors wish to thank the ONR staff for its continued interest and support during this investigation. They also wish to thank Professor R. C. Grassi for his permission to use the ^{125}K data included in this report. The material used was supplied by the Oak Ridge National Laboratories.

In addition appreciation is expressed to Professor J. E. Dorn and to Mr. O. D. Sherby for their interest in and contributions to this study.

REFERENCES

1. Raymond L. Orr, Oleg D. Sherby and John E. Dorn "Correlations of Rupture Data for Metals at Elevated Temperatures", Institute of Engineering Research Report, University of California, Berkeley, Series No. 22, Issue No. 27, July 1, 1953.
2. R. C. Grassi, D. W. Bainbridge and J. W. Harman, "Final Report on Metallurgical Investigation of Materials Subjected to Liquid Lead-Bismuth Alloy Environment", Institute of Engineering Research Report, University of California, Berkeley, Series No. 15, Issue No. 7, July 31, 1952.
3. R. C. Grassi, D. W. Bainbridge and J. W. Harman, "Metallurgical Investigation of Materials Subjected to Liquid Lead-Bismuth Alloy Environment", Institute of Engineering Research Report, University of California, Berkeley, Series No. 15, Issue No. 6, December 1951.

DISTRIBUTION LIST

Report No.

Chief of Naval Research, Dept. of Navy, Washington, Attn: Code 423	1-2
Chief of Naval Research, Dept. of Navy, Washington, Attn: Code 421	3
ONR Branch Office, New York	4
ONR Branch Office, Chicago.	5
ONR Branch, Pasadena.	6
ONR Branch, San Francisco	7
ONR Contract Administrator, Wash., Attn: Mr. R. F. Lynch	8
Director, Naval Research Lab., Wash., Attn: Tech. Inf. Officer	9-17
Director, Naval Research Lab., Wash., Attn: Dr. G. I. Irwin, Code 510.	18
Director, Naval Research Lab., Wash., Attn: Code 3500, Metallurgy Div.	19
Director, Naval Research Lab., Wash., Attn: Code 2020, Tech. Lib.	20
Director, Materials Lab. N.Y. Naval Shipyard, Attn: Code 907	21
Asst. Naval Attache for Research (London), New York	22
Commanding Officer, Naval Air Mat. Ctr., Philadelphia, Aero. Mat. Lab.	23
Commanding Officer, U.S. Naval Ord. Test Sta. Inyokern, Calif.	24
Commanding Officer, U.S. Ord. Lab., White Oaks, Md.	25
Commanding Officer, Nav. Proving Grd., Dahlgren, Va. Attn: Lab. Div.	26
Commanding Officer and Director, David Taylor Model Basin, Wash.	27
Superintendent, Naval Gun Factory, Wash., Attn: Eng. Res. & Eval. Div., 720	28
Bureau of Aeronautics, Dept. of Navy, Wash., Dr. N.E. Promisel, AE-41	29-31
Bureau of Aeronautics, Dept. of Navy, Wash., Attn: Tech. Lib.	32
Bureau of Ordnance, Dept. of Navy, Wash., Attn: ReX.	33-35
Bureau of Ordnance, Dept. of Navy, Wash., Attn: Tech. Lib. Ad3	36
Bureau of Ordnance, Chief, Dept. of Navy, Wash., Attn: Re3a.	37
Bureau of Ships, Dept. of Navy, Wash., Attn: Code 343.	38-40
Bureau of Ships, Dept. of Navy, Wash., Attn: Code 337L, Tech. Lib.	41
Bureau of Yards & Docks, Dept. of Navy, Wash., Res. & Stands. Div.	42
U.S. Naval Academy, Post Graduate School, Monterey, Calif., Metall. Dept.	43
U.S. Naval Engineering Expt. Station, Annapolis, Attn: Metals Lab.	44
Chief of Staff, U.S. Army, Wash., Attn: Div. of Res. & Development	45
Office of Chief of Engineers, Dept. of Army, Wash., Res. & Develop. Bd.	46
Office of Chief of Ordnance, Dept. of the Army, Wash., Attn: ORDTB	47-49
Commanding Officer, Watertown Arsenal, Mass., Attn: Lab. Div.	50
Commanding General, Wright Air Develop. Ctr., Dayton, Mat. Lab (WCRT)	51-52
Wright Air Develop. Ctr., Dayton, Attn: Metall. Grp. (WCRRL)	53
U.S. Air Forces, Washington, Attn: Res. & Develop. Div.	54
Frankford Arsenal, Philadelphia, Attn: Dr. Harold Markus	55
Office of Ordnance Research, Duke University, Durham, N.C., Dr. A.G. Guy.	56
U.S.A.E.C. Div. of Research, Wash., Attn: Metall. Branch	57
U.S.A.E.C. Div. of Research, Wash., Attn: Dr. D. W. Lillie	58
U.S.A.E.C. Washington, Attn: B.M. Fry.	59-60
U.S.A.E.C. Mound Lab., Miamisburg, Ohio, Attn: Dr. J. J. Burbage	61
U.S.A.E.C. N.Y. Operations Office, N.Y., Attn: Div. of Tech. Inf.	62
U.S.A.E.C. Library Branch, Oak Ridge, Tenn.	63
Argonne National Lab., Chicago, Attn: Dr. Hoylande D. Young.	64
Brookhaven National Lab., Upton, N.Y., Attn: Res. Library.	65
Carbide & Carbon Chem. Div., Oak Ridge, Central Files (K-25).	66
Carbide & Carbon Chem. Div., Oak Ridge, Central Files & Inf. Off. (Y-12).	67
General Electric Co., Richland, Washington, Attn: Miss M.G. Freidank	68
Knolls Atomic Power Lab., Schenectady, Attn: Document Librarian.	69

DISTRIBUTION LIST

Report No.

Los Alamos Scientific Lab., Los Alamos, New Mexico, Attn: Document Custodian	70
North American Aviation, Downey, Calif. Attn: Dr. T. A. Coultas	71
Oak Ridge Nat. Lab., Oak Ridge, Attn: Dr. J. H. Frye, Jr.	72
Oak Ridge Nat. Lab., Oak Ridge, Attn: Central Files	73
Sandia Corporation, Albuquerque, New Mexico, Attn: Mr. Dale M. Evans. . . .	74
University of California, Berkeley, Radiation Lab., Attn: Dr. R.K. Wakerling	75
University of California, Berkeley, Radiation Lab., Attn: Mr. R.P. Wallace .	76
Westinghouse Elec. Co. Atomic Power Div. Pittsburgh, Attn: Librarian. . . .	77
National Advisory Committee for Aeronautics, Washington.	78
National Bureau of Standards, Wash., Attn: Phys. Metall. Div.	79
National Bureau of Standards, Wash., Attn: Tech. Lib.	80
National Research Council, Wash., Attn: Dr. Finn Jonassen	81
Research & Development Board, Wash., Attn: Metall. Panel.	82
Australian Embassy, Sci. Res. Liaison Office, Washington	83
Armour Research Foundation, Chicago, Attn: Dr. W. E. Mahin.	84
Battelle Memorial Institute, Columbus, Attn: Dr. H.C. Cross	85
General Electric Co., Schenectady, Attn: Dr. J. H. Holloman	86
University of California, Dept. of Engineering, Berkeley	87-101
Professor W. M. Baldwin, Jr., Case Institute of Technology, Cleveland. . . .	102
Professor P. A. Beck, University of Illinois, Urbana, Ill.	103
Professor D. S. Clark, Calif. Institute of Tech., Pasadena, Calif.	104
Professor M. Cohen, Massachusetts Inst. of Technology, Boston.	105
Professor T. J. Dolan, University of Illinois, Urbana, Ill.	106
Professor Henry Eyring, University of Utah, Salt Lake City, Utah	107
Professor N. J. Grant, Massachusetts Inst. of Technology, Boston	108
Professor C. W. MacGregor, University of Pennsylvania, Phila.	109
Professor E. Machlin, Columbia University, New York City	110
Professor Robert Maddin, Johns Hopkins, Baltimore, Md.	111
Professor R. F. Mehl, Carnegie Institute of Technology, Pittsburgh, Pa. . . .	112
Professor N. M. Newmark, University of Illinois, Urbana, Ill.	113
Professor E. R. Parker, University of California, Berkeley	114
Professor W. Prager, Brown University, Providence, R.I.	115
Professor George Sachs, Syracuse Univ., East Syracuse, N.Y.	116
Professor O. Cutler Shepard, Stanford University, Stanford, Calif.	117
Professor C. S. Smith, University of Chicago, Chicago.	118
Professor F. H. Spedding, Iowa State College, Ames, Iowa	119