80
11/29

MASTER

BNWL-137

AEC
RESEARCH
and
DEVELOPMENT
REPORT

**A HIGH-TEMPERATURE CREEP MACHINE
FOR IN-CELL OPERATION**

**D. H. NYMAN, M. R. KEEGAN,
and J. A. WILLIAMS**

SEPTEMBER, 1965

RELEASED FOR ANNOUNCEMENT
IN NUCLEAR SCIENCE ABSTRACTS

RICHLAND, WASHINGTON

PACIFIC NORTHWEST LABORATORY operated by BATTELLE MEMORIAL INSTITUTE

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

PACIFIC NORTHWEST LABORATORY
RICHLAND, WASHINGTON
operated by
BATTELLE MEMORIAL INSTITUTE
for the

UNITED STATES ATOMIC ENERGY COMMISSION UNDER CONTRACT AT(45-1)-1830

PRINTED BY/ FOR THE U. S. ATOMIC ENERGY COMMISSION

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

BNWL-137

UC-25, Metals, Ceramics,
and Materials

A HIGH TEMPERATURE CREEP MACHINE FOR IN-CELL OPERATION

By

D. H. Nyman, M. R. Keegan,
and J. A. Williams*

Metallurgy Research Section
Reactor and Materials Technology Department

* Reactor and Fuels Branch, U. S. Atomic Energy Commission,
Richland Operations Office

September, 1965

RELEASED FOR ANNOUNCEMENT

IN NUCLEAR SCIENCE ABSTRACTS

FIRST UNRESTRICTED
DISTRIBUTION MADE

NOV 23 '65

PACIFIC NORTHWEST LABORATORY
RICHLAND, WASHINGTON

33 34 304

Printed in USA. Price \$1.00. Available from the Clearinghouse for Federal
Scientific and Technical Information, National Bureau of Standards
U. S. Department of Commerce, Springfield, Virginia

TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	1
SUMMARY	1
DESCRIPTION	1
EVALUATION	4
ACKNOWLEDGEMENTS.	6
REFERENCES	6

A HIGH TEMPERATURE CREEP MACHINE FOR IN-CELL OPERATION

INTRODUCTION

This report describes a machine developed for measuring high temperature creep of irradiated and unirradiated reactor structural materials. The machine can measure creep properties to 1300 °C in air, inert gas, or vacuum.

Currently, creep properties of structural materials are being measured during irradiation with instrumented creep capsules. Neutron flux effects are determined by comparing creep data measured in-reactor with data for unirradiated control specimens. There is both fundamental and practical interest in determining what differences or similarities exist in creep behavior measured both during and after irradiation. Some post-irradiation tests might exhibit transient effects similar to those observed in-reactor during reactor shutdowns when a neutron flux is absent. In other situations a simple correlation might be found which would permit obtaining data for design purposes by postirradiation testing rather than by the more expensive and difficult in-reactor method. The creep apparatus described in this report is adaptable to such postirradiation testing in a hot cell.

SUMMARY

A high temperature creep machine capable of conducting creep and stress-rupture tests to 1300 °C by remote operation was developed.

Evaluation tests demonstrated that the apparatus meets the requirements of ASTM Recommended Practice E 139-58T.

DESCRIPTION

Design of the high temperature, remotely operated creep apparatus was based on the following criteria:

- The apparatus must operate within the limits set by the ASTM Recommended Practice for conducting creep-rupture tests (E 139-58T).⁽¹⁾ These limits call for a load accuracy of $\pm 1\%$ over the load range and a temperature control of ± 5.5 °C along the gage length for temperatures over 982 °C.
- The apparatus must be light, compact, and operable by remote handling techniques.
- The apparatus must operate at high temperatures (1300 °C) to allow evaluation of the creep behavior of temperature-resistant materials.

Figure 1 shows the apparatus developed to meet these criteria. The unit consists of a loading system, an extensometer system, and a furnace. Most creep test machines utilize a lever-operated, dead-weight loading system which is simple and economical but also bulky and difficult to operate with light-weight manipulators. A pressure-operated loading system was used in the present design, since such a system requires very little

FIGURE 1
High Temperature
Creep-Rupture Apparatus

2

space and the pressure control equipment can be located outside of the cell. The pressure control system is outlined in Figure 2. The desired force is created in the load train by applying a differential pressure across a bellows. The force is calibrated against the differential pressure and is transmitted by a push rod to the sample. Loads of up to 1200 lb can be applied with an accuracy of $\pm 1\%$. The hydraulic fluid in the pressure accumulator reduces shock to the loading system when the specimen breaks.

Slotted specimen grips (Figure 3) were incorporated so specimens could be inserted and removed by manipulators. Button-head specimens with a 0.160 in. diam and a 1 in. gage length are used.

An in-cell creep test machine must have an accurate and compact extensometer system. Measuring the movement

FIGURE 2
Pressure Control System

FIGURE 3
Specimen Grips

of the load-bearing rods is not a sufficiently accurate measure of strain. Rather, the extensometers sensors must measure changes in specimen length directly. Accordingly, a specimen-end-point-displacement extensometer that is independent of the specimen grip system was designed. The elongation is measured by a dial gage, which has a sensitivity of 5×10^{-5} in. and an accuracy of 1×10^{-4} in. For remote operation the dial gage may be supplemented with a strain gage arrangement. To withstand the high temperatures encountered, the entire loading and extensometer systems are constructed of molybdenum and molybdenum alloy TZM. The high temperature furnace consists of a high current, low voltage heating element made from a 1/8 in. diam molybdenum rod, approximately 8 ft long, coiled on a 2 in. ID, high-purity, recrystallized-alumina tube.

FIGURE 4
Temperature Control System

With a 40 V, 300 A, motor-generator set with water-cooled leads as a power supply, a temperature of 1300 °C can be attained. The specimen temperature is monitored by three, platinum-sheathed, Pt-Pt-13 Rh thermocouples placed along the gage length of the specimen. The middle thermocouple also serves as the controlling thermocouple.

Figure 4 outlines the temperature control system. With proper adjustment of the heater coil spacings, the temperature gradient along the gage length of the specimen can be controlled within ± 5 °C at 1150 °C throughout the duration of the test. For testing at higher temperatures, a tantalum or tungsten heater can be used. For testing at temperatures below 900 °C, current requirements can be reduced by using a nichrome heater.

Since many metals and alloys react with air at high temperatures, the entire system is enclosed in a cold-wall vacuum chamber that can be back-filled with an inert gas. An Inconel X-750 loading and extensometer system is used for testing

oxidation-resistant alloys in air to 900 °C.

Figure 5 shows two creep systems in place ready for testing, and Figure 6 shows the associated temperature and pressure control panels. When a new specimen is installed, the vacuum chamber and heating element are first lowered together, to expose both the grips and the previously tested specimen. The upper and lower extensometer rods are then retracted from the specimen heads and the specimen is removed. The grips are brought together so the new specimen can be inserted and seated in the grips. The extensometer rods are then allowed to make contact with the specimen heads. When the vacuum chamber and heater are raised back into place and the vacuum seal is made, the system is ready for another test.

EVALUATION

Evaluation tests were carried out on the apparatus to determine the structural stability of the load train and the repeatability and eccentricity of the load transmitted to the specimen. Since the push rods have a large ratio of length to radius, buckling of the rods could occur under a large load. A Zircaloy-2 specimen containing 40% cold work was inserted into the specimen holders and a load applied at room temperature. The machine showed no apparent effects of structural instability at loads up to 1200 lb (specimen stress of 60,000 psi).

In another test, the ability of the machine to repeat a given specimen stress was determined after the

FIGURE 5
High Temperature Creep Machines

FIGURE 6
Control Panels
for High Temperature Creep Machines

specimen had been removed and then reinserted in the grips. A 40% cold-worked Zircaloy-2 specimen with a bonded strain gage was employed. Specimen strain was recorded for increments of 50 psig on the bellows in the range 0 to 250 psig (0 to 25,000 psi stress on the specimen). Repeated runs were made, and the specimen was removed from the grips and replaced in its original orientation after each run. Repeatability in the load was within $\pm 1\%$ over the load range investigated.

In addition to load repeatability, bending moments on the specimen during load application were measured. A bending moment can be caused by an uneven stress distribution across the specimen due to misalignment of the push rods. The Zircaloy-2 specimen with the bonded strain gage

5 was rotated 180° with respect to the central axis of the pull rods during repeated runs of the above series of load application. The strain across the specimen diameter varied about 10% at an applied stress of 25,000 psi, which is within the 15% variation allowed by ASTM E 139-58T. Since both the load tests and heater calibrations complied with the desired criteria, a creep test in vacuum was performed on Hastelloy X at 1150°C and 500 psi. The resulting curve of strain versus time is shown in Figure 7. From the Larson-Miller parameter⁽²⁾ and through extrapolation of lower temperature data (732 to 982°C) taken by other investigators⁽³⁾ to the test conditions described above, a rupture life of about 130 hr is predicted. The experimental rupture life of 115 hr compares favorably with the predicted value.

FIGURE 7

Creep Test of Hastelloy X
at 1150°C , 500 psi Stress

ACKNOWLEDGEMENTS

The authors wish to acknowledge the help of N. E. Harding and G. L. Hood in assembling and testing the creep apparatus.

REFERENCES

1. Recommended Practice for Conducting Creep and Time-for-Rupture Tension Test of Materials, ASTM E 139-58T
2. F. R. Larson and J. Miller. "A Time-Temperature Relationship for Rupture and Creep Stresses," Trans. ASME, vol. 74, p. 765. 1952.
3. M. J. Donachie and R. G. Shepheard. Materials Research and Standards, p. 495. September, 1965.

ONSITE DISTRIBUTIONCopy NumberPacific Northwest Laboratory

1	F. W. Albaugh
2	R. C. Aungst
3	J. A. Ayres
4	A. L. Bement
5	W. A. Burns
6	S. H. Bush
7	J. J. Cadwell
8	J. W. Carter
9	T. T. Claudson
10	L. J. Defferding
11	D. R. de Halas
12	R. F. Dickerson
13	R. L. Dillon
14	S. L. Fawcett
15	N. E. Harding
16	R. G. Hoagland
17	G. L. Hood
18	J. E. Irvin
19	J. H. Johnson
20	D. C. Kaulitz
21-25	M. R. Keegan
26	R. S. Kemper
27	H. E. Kissinger
28	G. A. Last
29	R. D. Leggett
30	I. S. Levy
31	J. E. Minor
32-41	D. H. Nyman
42	D. P. O'Keefe
43	R. E. Olson
44	H. M. Parker
45	F. A. Smidt, Jr.
46	R. Teats
47	F. W. Van Wormer
48	K. R. Wheeler
49	R. G. Wheeler
50	O. J. Wick
51	R. D. Widrig
52-56	J. A. Williams
57	H. H. Yoshikawa

58	Technical Publications, 700 Area
59-60	Technical Publications, 300 Area
61-66	Technical Information Files

Richland Operations Office

67	J. M. Musser
68	R. K. Sharp
69	Technical Information Library

OFFSITE DISTRIBUTION (SPECIAL)No. of Copies

1	Argonne National Laboratory Attn: A. D. Rossin
1	Battelle Memorial Institute Attn: F. R. Shober
1	Brookhaven National Laboratory Attn: D. H. Gurinsky
1	General Atomic Division Attn: T. A. Trozera
1	Materials Research Laboratory Chicago Attn: E. J. Ripling
2	Naval Research Laboratory Attn: J. W. Hawthorne L. E. Steele
3	General Electric Company Nuclear Materials & Propulsion Oper Attn: F. E. Kingsbury J. Moteff J. R. Smith
2	Oak Ridge National Laboratory Attn: R. G. Berggren M. S. Wechsler
1	Phillips Petroleum Company Idaho Falls, Idaho Attn: W. C. Francis
2	AEC, Washington Division of Reactor Development and Technology Attn: W. L. R. Rice J. M. Simmons