REPORT ON

THE ELEVATED-TEMPERATURE PROPERTIES OF SELECTED SUPERALLOYS

Issued Under the Auspices of

THE DATA AND PUBLICATIONS PANEL

of

THE ASTM-ASME-MPC JOINT COMMITTEE ON

EFFECT OF TEMPERATURE ON THE PROPERTIES OF METALS

and

THE DEFENSE METALS INFORMATION CENTER

Prepared by

D. P. Moon, R. C. Simon, and R. J. Favor

BATTELLE MEMORIAL INSTITUTE

Columbus Laboratories

ASTM Data Series DS 7-S1

(Supplement to Publication DS 7, formerly STP 160)

REPORT ON

THE ELEVATED-TEMPERATURE PROPERTIES OF SELECTED SUPERALLOYS

Issued Under the Auspices of

THE DATA AND PUBLICATIONS PANEL
of
THE ASTM-ASME-MPC JOINT COMMITTEE ON
EFFECT OF TEMPERATURE ON THE PROPERTIES OF METALS
and
THE DEFENSE METALS INFORMATION CENTER

Prepared by
D. P. Moon, R. C. Simon, and R. J. Favor
BATTELLE MEMORIAL INSTITUTE
Columbus Laboratories

ASTM Data Series DS 7-S1
(Supplement to Publication DS 7, formerly STP 160)

Published by the
AMERICAN SOCIETY FOR TESTING AND MATERIALS
1916 Race Street, Philadelphia, Pa. 19103

DEDICATION

The Data and Publications Panel wishes to dedicate this publication to Mr. Howard C. Cross, long-time secretary of the ASTM-ASME-MPC Joint Committee on Effect of Temperature on the Properties of Metals, in recognition of his service to the Panel and the Joint Committee and of his accomplishments in the field of high-temperature alloys.

Printed in Alpha, New Jersey

July, 1968

SUPPLEMENTAL REPORT ON THE ELEVATED-TEMPERATURE PROPERTIES OF SELECTED SUPERALLOYS

Issued Under the Auspices of
The Data and Publications Panel of
The ASTM-ASME-MPC Joint Committee on
Effect of Temperature on the Properties of Metals
and
The Defense Metals Information Center

Prepared by D. P. Moon, R. C. Simon, and R. J. Favor[1]

This compilation is a summary of the elevated-temperature mechanical-property data (with a very limited amount of low-temperature data) for 21 selected, commercially produced super-strength alloys. The effects of temperature on the tensile and creep-rupture properties of these alloys are presented in 196 figures. In addition, all primary data, together with chemical composition, heat treatment, and other pertinent information, are tabulated by lot.

These data were collected through the combined efforts of the Data and Publications Panel of the ASTM-ASME-MPC Joint Committee on Effect of Temperature on the Properties of Metals and the Defense Metals Information Center. This compilation is a supplement to ASTM Data Series Publication DS 7 (formerly STP 160); it does not replace it.

Since ASTM STP 160 was published in 1954, new data have become available for several of the alloys covered in the original publication. More important, perhaps, many new super-strength alloys have been developed that have supplemented or even supplanted the alloys formerly used. As a consequence, a combined effort was conducted by the Data and Publications Panel of the ASTM-ASME-MPC Joint Committee on Effect of Temperature on the Properties of Metals and the Defense Metals Information Center (DMIC) to collect, analyze, and present available data on the mechanical properties of selected super-strength alloys, as affected by temperature. For this purpose, a number of new, commercially produced alloys, as well as five alloys previously covered, were selected for inclusion in this compilation. For purpose of reference, the following listed alloys are covered (as indicated by an "X" beneath the publication) either by Data Series

[1]Information Operations Division, Battelle Memorial Institute, Columbus Laboratories

Publications DS 7 (formerly STP 160) or by this supplement (DS 7-S1):

Alloy	DS 7	DS 7-S1
16-25-6	X	
19-9DL	X	
Haynes Alloy No. 21	X	
Discaloy 24	X	
Refractaloy 26	X	
X-40 (Haynes Alloy No. 31)	X	X
Rene 41		X
WI-52		X
IN-100		X
N-155	X	
MAR-M200		X
GMR 235D		X
M-252	X	X
A-286	X	X
MAR-M302		X
U-500		X
S-590	X	
L-605 (Haynes Alloy No. 25)	X	X
Alloy 625		X
U-700		X
Alloy 713C		X
Alloy 718		X
Alloy X-750 (Inconel "X")	X	X
S-816	X	
Alloy 901		X
D-979		X
Hastelloy X		X
TD-Nickel		X
Waspaloy		X

Both the Data and Publications Panel and DMIC have continuing programs to collect property data of metals. Data included in this supplement were obtained from the following sources[1]:

ABEX Corporation
Aeronca Manufacturing Corp.
Allegheny Ludlum Steel Corp.
Allison Div., General Motors Corp.
Allvac Metals Company
Cannon-Muskegon Corp.
The Carpenter Steel Company
Convair Division, General Dynamics Corp.
Crucible Steel Company
E. I. du Pont de Nemours and Company, Inc.
Elliott Company
General Electric Company
The International Nickel Company, Inc.
Jet Propulsion Laboratory, Cal. Inst. of Tech.
Latrobe Steel Company
LTV Vought Div., Ling-Temco-Vought, Inc.
Lycoming Division, Avco Corp.
McDonnell Douglas Corp.
Marquardt Corporation
Metcut Research Associates, Inc.
NASA, Langley Research Center
NASA, Marshall Space Flight Center
New England Metals Laboratory, Inc.
North American Rockwell Corp.
Pratt & Whitney Aircraft Div., United Aircraft
Southern Research Institute
Standard Pressed Steel Company
TRW Metals Division, TRW Inc.
Union Carbide Corp., Materials Systems Div.
United States Steel Corp.
University of Michigan
Wright Aeronautical Div., Curtis-Wright Corp.

Data included in this compilation fall generally into two categories: (1) quality-control, certification, or acceptance data, usually representing only one or two tests at room temperature and at one elevated temperature as designated by material procurement specifications, and (2) more extensive evaluation data, representing multiple tests over a range of temperatures. Data in the first-mentioned category were generally received as copies of test-report forms; those in the second category were received in various tabulations, on ASTM-ASME-MPC data-reporting forms, and in formal technical reports.

For identification, all data from a single source (whether a packet of loose test-report forms or a single bound report) were assigned a unique "accession number" by the DMIC Technical Data Files. Within each accession, a numerical suffix was assigned to each lot of material. In those cases where more than one heat treatment was employed for samples from the same lot, additional lot suffixes

[1] Individual data sheets may list obsolete designations for parent companies or their divisions.

were assigned to cover each additional heat treatment. Consequently, the accession number plus the lot suffix located in the lower right-hand corner of each product-description table (for example, 12345-67) provides a unique identification for both a material and a set of data.

In addition to data on the effect of temperature on mechanical properties, a brief description of each alloy has been provided, including a listing of major procurement specifications, ranges of chemical composition, typical applications, and information on processing and heat treatment. These descriptions are not intended to be all-inclusive and the reader is directed to producers' literature and knowledgeable metallurgists for more detailed information.

This information, which is placed at the beginning of each alloy section, is supplemented by product-description tables located immediately ahead of primary data from individual lots of material. These describe, to the extent that the information was reported initially, the specific chemical composition, processing history, and heat treatment for each lot.

GENERAL COMMENTS

Alloy Designations. Many of the alloys in this publication are known by a variety of trade names and, unfortunately, no generic system of identifying these alloys has found general acceptance. An attempt has been made in this publication to employ for each alloy its most common designation, whether or not this be proprietary. In the general description at the beginning of each alloy section are listed other designations by which the alloy is known and which might not be readily identified with the designation employed in this publication.

Chemical Composition. An attempt has been made to report the actual chemical composition for each major element. In several instances, only a nominal composition or a reference to a procurement specification was reported in the original source. A notation "N. R." for an individual element indicates that it was not reported in the original source.

Melting Practice. The following abbreviations were used, where appropriate, to save space:

CEVM — consumable-electrode vacuum melted
VIM — vacuum induction melted

Primary Data. An attempt was made to exclude from this publication (1) lots for which the composition, processing, or heat treatment appeared to be non-standard and available documentation was not considered adequate to make the accompanying data useful and (2) data obtained by unconventional testing practice. Other than this, acceptable tensile, creep, stress-rupture, and notched tensile and rupture data were reported, together with appropriate material description.

Data were identified, screened for obvious errors and duplications, then stored on IBM punched cards for subsequent printing and manipulation. Two abbreviations in the computer-printed tables of data require explanation. The term "PC" indicates "per cent" (elongation, etc.). The letter "R" for test duration indicates that the test ruptured at the time indicated. In many of the creep-rupture tests, times for several amounts of total (i.e., plastic) creep strain were reported; each pair of time-strain values appears as a separate line in the computer printout. Minimum creep rates, where available, were stored with the data represented by the longest duration reported for a single test.

In several instances tabular data consisting only of room-temperature tensile tests were deleted during final assembly of this publication although these data may have been used previously in preparing figures illustrating the effect of temperature on tensile properties.

Curve Fitting. Data from combined lots were plotted as a function of temperature and fitted by least-squares regression to a polynomial curve of the form:

$$\text{Property} \equiv a + bT + cT^2 + dT^3.$$

Where data proved to be inadequate or the resulting curve unsatisfactory from a metallurgical standpoint, portions of curves were deleted or redrawn manually. The logarithms of stress-rupture life and of minimum creep rate were regressed against the logarithm of stress, using the same equation. The

creep-rupture regression was employed both for individual lots (to obtain tables of creep-rupture strengths) and for combined lots (plots of stress vs creep rate and rupture time).

The reader is cautioned that all drawn curves are intended only to indicate the trend of the points plotted and *are not considered valid for use in design.*

ACKNOWLEDGMENT

The authors wish to thank the many organizations and their representatives who contributed to this publication through the financial support, data-gathering activities, and technical guidance.

ASTM-ASME-MPC Joint Committee on Effect of Temperature on the Properties of Metals

American Society for Testing and Materials
American Society of Mechanical Engineers
The Metal Properties Council

Defense Metals Information Center

R. J. Runck, Director
E. Dugger, Air Force Materials Laboratory
D. A. Shinn, Air Force Materials Laboratory

Project DP-17 Task Group

E. E. Reynolds, Chairman
J. J. Moran
W. F. Simmons

Data and Publications Panel

J. J. Moran, Chairman
A. J. Belfour
H. C. Cross
R. Curran
R. F. Domagala
R. W. Fenn, Jr.
J. W. Freeman
E. L. Horne
J. J. Kanter
W. E. Leyda
H. Marcus
E. E. Reynolds
E. L. Robinson
M. Semchyshen
J. G. Sessler
W. F. Simmons
G. V. Smith
G. W. Stickley
H. W. Wyatt