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REPORT TITLE **EFFECT OF S8DR CHROMIUM DIFFUSION TREATMENT ON THE CREEP
RUPTURE PROPERTIES OF PROCESSED HASTELLOY-N TUBING**

AUTHOR

G. G. Allaria

NAA-SR-MEMO 12495

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TECHNICAL DATA RECORD		PAGE 1 OF 10	
AUTHOR	DEPT & GROUP NO	DATE 6-3-67	
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TITLE Effect of S8DR Chromium Diffusion Treatment on the Creep-Rupture Properties of Processed Hastelloy N Tubing		S/A NO 35411	TWR
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STATEMENT OF PROBLEM			
The reference S8DR process, for fabricating Hastelloy N fuel cladding, has been modified by the addition of a chromium diffusion treatment.			
Determine the effect of this process modification on the 1400°F biaxial creep-rupture properties of processed Hastelloy N tubing.			
ABSTRACT			
Creep-rupture testing at 1400°F, with a hoop stress of 10,800 psi, in a hydrogen internal/vacuum external environment was performed on chromium diffusion treated and on non-diffusion treated samples of Hastelloy N. The average diametral creep rate of the diffusion treated samples is slightly less than half the creep rate of the non-diffusion treated samples. Rupture life and rupture ductility comparisons were not made, since all of the non-diffusion treated samples failed prematurely in the blind end weld.			

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I. INTRODUCTION

Process development personnel have been seeking means of improving the (after thermal exposure) adhesion of the S8DR ceramic coating to chromized Hastelloy N tubing. This effort has led to the incorporation of an elevated temperature chromium diffusion treatment prior to the application of the ceramic coating. The details of this chromium diffusion treatment (classified) may be found in references 1 and 2.

This report describes the results of tests performed to ascertain the influence of the additional thermal treatment on the 1400°F creep-rupture properties of S8DR tubing. The effect(s) of the chromium diffusion treatment on short term tensile properties of S8DR processed Hastelloy N tubing is detailed in reference 3.

II. EXPERIMENTAL

A. SAMPLE PREPARATION

The samples used in the test program were shortened (9" long) SNAP 8 type cladding tubes (0.560" O.D.), fitted with pressure probes in the blended closure end caps. The samples were fabricated from two different heats of Hastelloy N tubing having different nominal wall thicknesses. Chemical compositions and wall thicknesses are listed in Table I. All samples were made and inspected in accordance with the applicable S8DR process specifications.

Prior to testing, the samples were submitted to Tool and Gage Inspection for diametral measurements. Two measurements, 90° apart, were taken at 1/2 inch increments along the entire length of the tubes. The sample serial number, impression stamped on the blind end cap, served as the 0° reference mark for the measurements. A P&W Electrolimit Supermicrometer was used for these measurements. An identical procedure, using the same reference marks, was used to obtain the diametral creep deformation of the samples. These measurements are the basis for the conclusions reached during this investigation.

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B. TEST DESCRIPTION

The equipment used for the test program is described and illustrated in Reference 4 under "Vacuum Creep Testing".

All creep testing was performed at 1400°F isothermal conditions. Hydrogen pressures of 600 and 400 psi were applied to the nominal 0.015" and 0.010" wall thickness samples, respectively, to produce a nominal hoop stress of 10,800 psi in all samples. The samples were removed from test for diametral creep measurements after 250, 500, 750, 1252, and 2038 hours on test, or at the time the samples ruptured. After being placed back on test, pressure was not applied (and time was not recorded) until 1400°F isothermal conditions were re-established.

In the determination of the average diametral strains, supermicrometer measurements taken at the sample ends (and at points 1/2" from the ends) were excluded. This method compensates for the effect of end restraint on the ductility measurements.

A limited amount of post-test metallography was performed to determine the nature of the ruptures.

III. RESULTS AND DISCUSSION

The results of the investigation are presented in Tables II and III and Figures 1 and 2.

As can be seen from Figures 1 and 2, the average diametral creep rates (average diametral elongation/rupture life) reported in Tables II and III are very good estimates of the secondary or minimum diametral creep rates of the samples. This implies that the primary and tertiary stages of creep contributed little to the total diametral deformation of the samples. Therefore, for the test conditions investigated, a stress-rupture test would provide the same information as a creep-rupture test at a savings in time and cost. This fact should be considered in future biaxial creep-rupture test programs. However, the relationship probably does not apply to uniaxially loaded samples, since tertiary creep would be expected to be greater than in the biaxial case.

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The chromium diffusion treatment has a definite effect on the creep rate of S8DR processed Hastelloy N cladding. The treatment reduces the creep rate to less than one-half that of non-diffusion treated material stressed at the same level, as shown in Table III.

A valid comparison of the rupture lives and rupture ductilities (between the diffusion treated and non-diffusion treated samples) cannot be made due to the prevalence of premature failures in the blind end or closure end of the samples. Metallographic examination of these ruptures failed to reveal any metallurgical abnormalities in the samples. All fractures were of an intergranular nature, typical of the stress-rupture mode of failure in Hastelloy N. However, from a stress consideration, the isothermal test conditions along the complete length of the samples undoubtedly aided or accentuated the premature ruptures at these locations.

The rupture life of the four diffusion treated samples with main body ruptures ranged from 1108 to 2173 hours, with an average of 1585 hours. A comparison of these values with the interpolated 10,800 psi rupture life range of about 700 to 1700 hours for non-diffusion treated samples tested in air and pressurized with argon, indicates that the chromium diffusion treated material is as good as, if not better, than the non-diffusion treated material.

The test program has shown that, for the conditions investigated, the chromium diffusion treatment does not degrade the biaxial creep-rupture properties of processed Hastelloy N tubing. In fact, it improves these properties by reducing the creep rate and thereby increasing the rupture life.

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REFERENCES

1. NAA-SR-MEMO-12470, CRD, "Process Flow Sheets - S8DR Cup Plugs," C. A. Martin.
2. NAA-SR-MEMO-12475, CRD, "Process Flow Sheets - S8DR Cladding Tube Fabrication," D. T. McClelland, K. Langrod, and C. A. Martin.
3. NAA-SR-MEMO-12229, CRD, (to be published), "Short Term Tensile Testing of the S8DR Fuel Cladding," T. H. Christensen and W. F. Dennison.
4. NAA-SR-11316, CRD, "Effects of Processing and Operating Parameters on the Creep Properties of SNAP Reactor Fuel Element Cladding," G. E. Culley and J. T. Berling.

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CHEMICAL COMPOSITIONS

<u>Element</u>	<u>Heat #5911</u>	<u>Heat #281-4-0143</u>
Cr	6.15	7.00
Mo	16.6	16.88
Fe	.39	.28
Ni	Bal.	Bal.
W	.01	.01
C	.07	.05
Si	.01	.28
Co	.08	.01
Mn	.12	.50
P	.002	.002
S	.002	.009
Al	{ .13	.20
Ti		.04
B	.0005	.003
Cu	<.001	.03
O ₂	.0036	.0006
H ₂	.0006	.0004
N ₂	.0017	.0025
Nominal Wall Thickness	0.015"	0.010"

TABLE II
HASTELLOY N CLADDING CREEP TEST - 10,800 PSI, 1400°F
HYDROGEN INTERNAL - VACUUM EXTERNAL

Heat Number	Sample Number	Sample Condition	Rupture Life (hrs)	Average Diametral Elongation (%)	Maximum Diametral Elongation (%)	Average Diametral Creep Rate (%/hr)	Location of Rupture
281-4-0143	4608	Diffusion Treated	1524	3.11	3.55	2.04×10^{-3}	Tube Main Body
281-4-0143	4564	Diffusion Treated	1534	2.61	3.09	1.70×10^{-3}	Tube Main Body
281-4-0143	4576	Diffusion Treated	2173	2.61	3.01	1.20×10^{-3}	Tube Main Body
5911	6069	Diffusion Treated	745	1.73	1.96	2.32×10^{-3}	Blind End Weld
5911	6060	Diffusion Treated	878.5	1.99	2.28	2.26×10^{-3}	Closure End
5911	6064	Diffusion Treated	1108	2.45	2.87	2.21×10^{-3}	Tube Main Body
5911	6037	Not Diffusion Treated	492.5	2.13	2.42	4.32×10^{-3}	Blind End Weld
5911	6041	Not Diffusion Treated	568.5	2.88	3.84	5.07×10^{-3}	Blind End Weld
5911	6036	Not Diffusion Treated	663	4.48	5.06	6.76×10^{-3}	Blind End Weld
281-4-0143*	5047	Not Diffusion Treated	412	1.76	2.06	4.27×10^{-3}	Closure End
281-4-0143*	5051	Not Diffusion Treated	295	.93	1.12	3.14×10^{-3}	Closure End
Y8437**	----	Not Diffusion Treated	----	----	----	$4.5 \text{ to } 5.6 \times 10^{-3}$	----

*Previously unreported biaxial stress rupture data obtained on $4\frac{1}{2}$ " long samples

**Average diametral creep rate interpolated from appropriate data in Reference 4

TABLE III
1400°F CREEP RATE COMPARISON
(10,800 PSI)

<u>Heat Number</u>	<u>Sample Condition</u>	<u>Average Diametral Creep Rate (%/hr)</u>	Ratio: <u>Diffused</u> <u>Not Diffused</u>
281-4-0143	Not Diffusion Treated	3.70×10^{-3}	} 0.45
281-4-0143	Diffusion Treated	1.65×10^{-3}	
5911	Not Diffusion Treated	5.38×10^{-3}	} 0.42
5911	Diffusion Treated	2.26×10^{-3}	

1400°F BIAXIAL CREEP DATA FOR HEAT # 281-4-0143

FIGURE 1

1400°F BIAXIAL CREEP DATA FOR HEAT # 5911

FIGURE 2