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TENSILE PROPERTIES AND SWELLING OF 20%-COLD-WORKED
TYPE 316 STAINLESS STEEL IRRADIATED IN HFIR*R. L. Klueh and M. L. Grossbeck
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ABSTRACT: Immersion density and elevated-temperature tensile properties were determined on 20%-cold-worked type 316 stainless steel irradiated in the HFIR at approximately 285, 370, 470, 560, and 620°C to fluences of 1.8 to 6.2×10^{26} neutrons/m² (>0.1 MeV), which resulted in displacement damage levels of 16 to 54 dpa and helium concentrations of 900 to 3300 at. ppm. Tensile tests were done at temperatures near the estimated irradiation temperatures. Swelling increased with increasing irradiation temperature to a maximum of 2.1% at 620°C. Irradiation at the lowest temperatures (285 and 370°C) increased the strength. At the higher irradiation temperatures, the strength decreased during irradiation. Ductility generally reflected the strength behavior: an increase in strength resulted in a decrease in ductility. When the present data are compared with previously published data, there is good agreement with one exception. Previous experiments showed a large decrease in ductility when irradiated at 600°C and tested at 575°C that was not observed in the present tests. There was also good agreement between HFIR-irradiated steel and literature data for EBR-II-irradiated steel.

KEY WORDS: STAINLESS STEEL, COLD WORK, NEUTRON IRRADIATION, SWELLING,
HELIUM, TENSILE PROPERTIES, DUCTILITY, ELEVATED TEMPERATURE

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Introduction

The first wall of a fusion reactor will be subjected to high-energy neutron irradiation, which will result in atom displacement damage and the production of helium in transmutation reactions. Because the helium production rate will be much higher than in fission reactors, the properties determined on materials irradiated in fission reactors may not be directly applicable to fusion reactors. However, for nickel-containing alloys irradiated in a mixed-spectrum fission reactor such as HFIR, transmutation of ^{58}Ni by thermal neutrons can give helium generation rates approximating those projected for fusion reactor service. At the same time, the fast neutrons produce displacement damage at relevant rates. Previous studies conducted on an experimental heat of type 316 stainless steel have shown that the helium generated during HFIR irradiation has a significant effect on the swelling, microstructural response, strength, and ductility of 20%-cold-worked type 316 stainless steel [1,2].

The primary goal of this experiment was to expand the mechanical property and swelling data base on irradiated 20%-cold-worked type 316 stainless steel. The previous irradiation experiments provided an initial, lower fluence data base for an understanding of the behavior of the material [1] and also provided high-fluence data [2]. However, the previous work was on specimens from an experimental heat of steel. In the present experiment, the MFE reference heat of type 316 stainless steel (heat X15893) was used. Sufficient overlap with previous irradiation conditions should enable a correlation to be made between the irradiation response of the two heats of steel.

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Experimental Procedure

The chemical composition of the MFE reference heat (X15893), which was supplied by the vendor, is

<u>Element</u>	<u>wt %</u>	<u>Element</u>	<u>wt %</u>
Cr	17.28	Nb	<0.05
Mn	1.70	Ta	<0.05
Ni	12.44	Ti	<0.05
Mo	2.10	B	0.0004
Co	0.3	C	0.061
Cu	0.3	S	0.018
Si	0.67	P	0.037

Before specimen fabrication the barstock was annealed 1 h at 1150°C, then swaged to obtain the proper diameter prior to the final cold work. The rod was annealed 1 h at 1050°C and swaged to a 20% reduction of area to obtain the cold-worked material from which the specimens were machined. Cylindrical specimens with a 2-mm-diam by 18.3-mm-long reduced section were machined from the 20%-cold-worked rod.

The specimens in the HFIR-CTR irradiation experiments were contained in a 0.62-m-long aluminum tube that was surrounded by a shroud to provide a high coolant velocity. Eleven specimens were arranged along the capsule axis with each specimen surrounded by an aluminum holder. Each holder was sized to maintain the specimen gage section at the specified temperature. The temperature was determined by the thickness of a helium-filled gap between the specimen and holder, which provided resistance to the radial flow of heat produced in the specimen by nuclear heating. The details on the design of this holder have been published [3].

The experiment was irradiated in a HFIR peripheral target position with a peak thermal neutron flux of 2.5×10^{19} neutrons/(m²·s) and fast flux of 1.3×10^{19} neutrons/(m²·s) (>0.1 MeV). Irradiation temperatures were calculated to be approximately 285, 370, 470, 560, and 620°C. As discussed later, there is some question about the actual temperatures of the specimens. The displacement damage and helium production were calculated by the procedures described by Gabriel, Bishop, and Wiffen [4].

This irradiation experiment consisted of three capsules, HFIR-CTR-26 through -28. Two capsules were irradiated for 15 cycles and one capsule for 25 cycles. For the 15-cycle capsules, the fluence ranged from approximately 1.8 to 3.7×10^{26} neutrons/m² to give damage levels that ranged from 16 to 32 dpa with helium concentrations from about 900 to 2000 at. ppm. The 25-cycle capsule was irradiated to fluences between approximately 3.0 to 6.2×10^{26} neutrons/m² to give 27 to 52 dpa and 1670 to 3300 at. ppm He.

Immersion density measurements in Fluorinert-42^{*} were made to determine any swelling produced by the irradiation. Tensile tests were conducted in a vacuum chamber on a 44-kN capacity Instron universal testing machine using a nominal strain rate of 4.6×10^{-5} /s (0.85 μm/s crosshead speed). Test temperatures were selected to be close to the calculated irradiation temperatures; tests were at 300, 350, 450, 575, and 600°C. Several tests at the approximate radiation temperature plus 80 to 115°C were also conducted.

Results and Discussion

The results of the immersion density measurements showed measurable swelling (Table I). In Fig. 1, the swelling data are shown as a function

*Flourinert is a trade name of the 3M Company.

of temperature. Two scatter bands have been sketched to indicate two sets of data. The lower band is for the data where the displacement damage ranged from 16 to 32 dpa with helium concentrations of 900 to 2000 at. ppm. The upper band is for high-dose data, where the displacement damage ranged from 37 to 54 dpa and helium content from 2300 to 3300 at. ppm. Also shown in Fig. 1 is a curve determined by Maziasz and Grossbeck for specimens taken from a different heat of steel (the D0 heat) irradiated in HFIR [5]. The fluence range for those irradiations was slightly higher (42–61 dpa, 3000–4200 at. ppm He) than for the upper end of the fluence range of the present study (37–54 dpa, 2300–3300 at. ppm He), although there is an overlap of the data. The Maziasz and Grossbeck swelling values were calculated from cavity-volume fraction measurements determined from transmission electron microscopy studies.

As the fluences and helium concentrations for the two experiments became comparable, the immersion density values began to approach the cavity-volume fraction values. It might be possible to fit the higher fluence data points with a curve that has the general shape of the cavity volume data. However, because of the scatter in the data, only the bands are shown.

Tensile test results also are tabulated in Table I. In Fig. 2 the 0.2%-offset yield stress is plotted against displacement damage (and fluence) for the test temperatures of 350, 450, and 575°C (for specimens irradiated at 370, 470, and 560°C, respectively). A similar plot is given in Fig. 3 for the ultimate tensile strength. Because of the scatter, bands have been drawn to indicate the trends. The total elongation shows still more scatter — especially at the lowest temperatures — and only the data points are presented (Fig. 4). The data points for zero fluence are for

unaged controls. No thermally aged controls were tested, and for this discussion, the thermal aging data of Fish et al. [7] and Fahr [8] will be used. Such a comparison requires some interpolation and extrapolation, since Fahr aged for 4000 h at 450, 550, and 650°C and Fish et al. aged for times up to 12,000 h at temperatures between 538 and 760°C.

For tensile tests at 350°C on the specimen irradiated at 370°C, the yield stress and ultimate tensile strength are relatively constant with fluence between ~15 and 43 dpa. Because relatively little change in strength due to thermal aging is expected at this temperature and that change would result in a slight strength decrease [8], we concluded that there was a slight amount of irradiation hardening. Only two specimens were irradiated at 285°C and tested at 300°C (Table I), and these specimens also hardened during irradiation.

The strengths of the specimens irradiated at 450 and 575°C decreased from the strength of the unirradiated control to values where there is little further change with fluence. Indications are that these changes are due to recovery of the cold-worked structure and are similar to the decrease in strength expected during thermal aging [7,8]. The ductility, as measured by total elongation, displayed considerable data scatter, especially at 350 and 450°C (Fig. 4) (note, however, that such scatter is not unusual for ductility measurements). There was little change in total elongation with fluence at 350 and 450°C; the total elongation always remained above 5% (ranging between 5 and 10%) at 350°C and above 7% (ranging between 7 and 12%) at 450°C. At 575 and 600°C, there was a decrease in ductility with fluence. However, even for a fluence of 48 dpa at 575°C and 54 dpa at 600°C, the ductility remained above 6%. The change in uniform elongation

with increasing fluence generally followed the trend for total elongation (Table I).

These results indicate that irradiation hardening occurs for 20%-cold-worked type 316 stainless steel irradiated at 285 and 370°C and tested at 300 and 350°C, respectively. Such hardening is known to be caused by a combination of dislocation loops formed by the agglomeration of interstitials generated by displacement damage, cavities, network dislocations, and precipitates [9]. For the specimens irradiated at 470, 560, and 620°C and tested at 450, 550, and 600°C, respectively, the softening appears similar to that expected during the thermal aging of irradiated material — namely, recovery and changes in precipitate structure at lower temperatures, recrystallization, and changes in precipitate structure at the higher temperatures. Without thermally aged controls on the same heat as the one that was irradiated, it is not possible to make a direct comparison of irradiated and unirradiated properties. However, Fish et al. [7] found little difference between irradiated and thermally aged 20%-cold-worked type 316 stainless steel irradiated in EBR-II at 538 and 593°C. At 593°C, the irradiated specimens softened somewhat more rapidly than the unirradiated controls [7], indicating that irradiation enhanced diffusion, and thus, enhanced the recovery processes.

The only exception between the observed effect of irradiation and that expected to occur by thermal aging is the decrease in ductility at the highest test temperatures. For a thermally aged material, the decrease in strength is expected to be accompanied by an increase in ductility [8], whereas the opposite occurred for the irradiated steel. This slight loss in ductility with increasing fluence is attributed to helium embrittlement.

Small amounts of helium can cause large decreases in the ductility of type 316 stainless steel, especially at temperatures approaching 700°C. However, it should be noted that although the ductility decreased as a result of irradiation at 560 and 620°C and helium concentrations of ~3000 at. ppm, the material still displayed considerable ductility. This will be discussed further below.

Grossbeck and Maziasz [1] and Bloom and Wiffen [2] tested another heat (D0 heat) of 20%-cold-worked type 316 stainless steel after HFIR irradiation. Grossbeck and Maziasz irradiated specimens to ~15 dpa at the temperatures used in this experiment. When the data scatter was taken into account, the results for the two experiments showed good agreement at 350, 450, and 575°C [1].

The only common test temperatures for the Bloom and Wiffen experiments and those of the present study were 350 and 575°C. Bloom and Wiffen tested some specimens at 350°C that were irradiated to 56 dpa at 385°C and some at 575°C that had been irradiated to 119 dpa at 575 to 605°C [2]. Considering the scatter involved, the strengths of those specimens were not much different from those of the present experiment or from the Grossbeck and Maziasz experiment. The major difference involved the total elongation; the values of Bloom and Wiffen were substantially below those from the other two experiments — especially at 575°C, where Bloom and Wiffen reported values that decreased to 0.5% after only 7 dpa and 0.2% after 119 dpa.

Grossbeck and Maziasz concluded that the difference in ductility behavior in the Bloom and Wiffen experiment and their studies may have arisen from differences in the fabrication procedures used when the specimen material was cold worked. Such a possibility agrees with the observation

that the as-received specimens used by Bloom and Wiffen [2] were stronger and less ductile than those used in the present work and in the work of Grossbeck and Maziasz [1]. However, the explanation is somewhat more complicated, because after <10 dpa the strength of the Bloom and Wiffen specimens fell to values similar to those for the other two studies. Whatever the explanation, the results of Grossbeck and Maziasz and the results of the present experiment show no such large ductility degradation.

The irradiation temperatures given in Table I are those that were calculated for this experiment and for previous ones [1,2]. Test temperatures are those chosen previously [1,2] and were used here so results could be compared with previous tests. There has been some discussion concerning the accuracy of these calculated irradiation temperatures [1,6]. Indications are that the actual temperatures are 50 to 75°C higher than those calculated and reported here. These conclusions are based on a comparison of microstructures of type 316 stainless steel irradiated in the HFIR and the ORR where temperatures were known more accurately. Temperature indicators placed in more recent HFIR experiments also indicated that the temperatures are higher.

To determine the effect of such a temperature difference on the tensile results, specimens irradiated at the calculated temperatures of 370, 470, and 560°C were tested at 450, 550, and 675°C, respectively (instead of the 350, 450, and 575°C temperatures used for the majority of the specimens.) The results of these tests are given in Table I. For the 370°C-irradiated specimen tested at 450°C and the 470°C specimen tested at 550°C, there was essentially no difference in properties from similarly irradiated specimens tested at 350 and 450°C, respectively. The only major difference occurred

for the specimen irradiated at a calculated temperature of 560°C and tested at 675°C instead of 575°C. In this case there was a slight decrease in yield stress and a considerably greater decrease in ultimate tensile strength. Despite the modest decrease in strength properties, however, there was a large decrease in ductility. The total elongation decreased from 9.9 to 1.1%; a similar large decrease in uniform elongation was noted.

The large decrease in ductility for the specimen tested at 675°C is due to elevated-temperature helium embrittlement and is independent of the irradiation temperature. To show this, a specimen irradiated at 470°C to 26 dpa (1530 at. ppm He) was tested at 675°C. The total elongation decreased from about 10% when a similar specimen was tested at 450°C to 1.7% when tested at 675°C. This 1.7% is similar to the value for the specimen with 1980 at. ppm He irradiated at 560°C and tested at 657°C (Table I).

These results indicate that even if the calculated irradiation temperatures are 50 to 75°C below actual temperatures [1,6], there is little difference in tensile properties for specimens irradiated at temperatures up to about 500°C and tested at the corrected temperatures. However, as discussed below, this upper temperature may be as high as 560°C.

A large degradation of ductility can occur when specimens are tested at 675°C, regardless of the irradiation temperature. The lower temperature bound for such a large degradation has not been determined, and it will probably depend on helium concentration. For the helium concentrations achieved in this experiment (~3000 at. ppm), it must be above 600°C. That conclusion follows from the 600°C tests for specimens irradiated at a calculated irradiation temperature of 620°C (which means it could have been as high as 695°C). Although the 600°C test of the specimen irradiated at that

temperature to 54 dpa (3300 at. ppm He) had a slightly lower total elongation than the specimen irradiated to 32 dpa (2000 at. ppm He), it still had 8% total elongation. Thus, even if this degradation in ductility at 600°C was due to this large helium concentration, it was of relatively minor consequence.* These results at 600°C are the basis for the above statement that even if the calculated irradiation temperature of 560°C is off by 50 to 75°C, no large effect on properties is expected.

It is of interest to compare the results obtained in the present investigation with those obtained after irradiation in EBR-II, where very little helium is generated. For this comparison, the yield stress and ultimate tensile strength after irradiation to ~26 dpa in HFIR and EBR-II are plotted in Fig. 5. The EBR-II data are from Fish et al. [7], who determined the tensile properties on specimens taken from tubing of one heat (N-lot) of 20%-cold-worked type 316 stainless steel irradiated in EBR-II to fluences up to $\sim 8 \times 10^{26}$ neutrons/m² ($E > 0.1$ MeV) over the temperature range 371 to 616°C. Below ~500°C, irradiation caused hardening. At a given temperature, the yield stress and ultimate tensile strength increased with fluence up to some saturation level, after which they remained constant with further increase in fluence. Above ~500°C, the strength decreased from the unirradiated value to some saturation strength that decreased for increasing temperature [7]. Figures 2 and 3 show that the data obtained in the present experiment show a somewhat similar behavior: There is an increase in strength to a saturation level at 300°C and a decrease to saturation at 450 and 550°C.

*Note that this conclusion applies to tests at strain rates greater than 4×10^{-5} /s. Lower strain rates will probably result in ductility losses at lower temperature.

As seen in Fig. 5 for a displacement-damage level of ~ 26 dpa, which is above the saturation fluence in EBR-II [7], the yield stress for the HFIR-irradiated steel falls below that of the EBR-II irradiated steel up to $\sim 600^\circ\text{C}$, where similar yield stresses are observed. The ultimate tensile strength values for the HFIR tests fall below those for the EBR-II tests up to 500°C , after which the HFIR data become the stronger. These comparisons do not take into account the discrepancy in HFIR irradiation temperatures. If the calculated HFIR irradiation temperatures are assumed to be 50 to 75°C lower than actual temperatures and such a translation is applied to the data of Fig. 5, the yield stresses for the two data sets would agree quite well up to $\sim 500^\circ\text{C}$, after which the HFIR-irradiated yield stress would become somewhat greater. Such a temperature translation would also result in similar ultimate tensile strength values for the two irradiation conditions up to $\sim 450^\circ\text{C}$, after which the ultimate tensile strength for the HFIR specimens becomes the larger of the two data sets. Total elongations for the two experiments were also comparable. Such comparisons are not straightforward because of differences in specimen geometry.

The data from the present tests have also been compared with those from another heat of steel (FFTF first core heat) irradiated in EBR-II [10]. For that case, reasonable agreement between the two sets of data were also obtained to $\sim 575^\circ\text{C}$.

Summary and Conclusions

Immersion density and elevated-temperature tensile properties were determined on 20%-cold-worked type 316 stainless steel (MFC reference heat) irradiated in HFIR at calculated temperatures of approximately 285, 370, 470,

560, and 620°C. Irradiation was to fluences of 1.8 to 6.2×10^{26} neutrons/m² (>0.1 MeV), which produced damage levels of 16 to 52 dpa and helium concentrations of 900 to 3300 at. ppm. Most of the tensile tests were at temperatures near the irradiation temperatures; these were 300, 350, 450, 550, and 600°C. Three tests were conducted at the test temperature plus 80 to 115°C. The following summarizes the results and conclusions:

1. Measurable swelling was observed; the increase in swelling with fluence and temperature agreed with previous HFIR-irradiated type 316 stainless steel.

2. Irradiation caused an increase in strength (0.2% yield stress and ultimate tensile strength) for specimens irradiated at calculated temperatures of 285 and 370°C; a strength decrease, believed to be associated with thermal recovery of the original cold-worked structure, was observed for specimens irradiated at 470, 560, and 620°C. There was little change in uniform and total elongation for these test conditions. The severe degradation in ductility previously observed on specimens tensile tested at 575°C was not observed.

3. There are indications that the calculated irradiation temperatures were low by 50 to 75°C. For irradiated specimens tested at 80°C above the calculated temperatures of 370 and 470°C, there was little effect of test temperature on strength and ductility. It was concluded that the discrepancy due to calculated temperatures would be minor up to a calculated irradiated temperature of 500°C, and possibly up to 560°C.

4. A large decrease in both strength and ductility was observed for specimens with calculated irradiation temperature of 470 and 560°C tested at 675°C. This loss of ductility was attributed to elevated-temperature helium

embrittlement, which occurs for any helium-containing type 316 stainless steel tested at this temperature, regardless of the irradiation temperature.

5. For specimens tensile tested at 4.6×10^{-5} /s and temperatures up to 600°C, no large ductility degradation due to helium embrittlement was observed, even when the steel contained 3000 at. ppm He.

6. There was little difference in the effect of irradiation on the tensile properties of the 20%-cold-worked type 316 stainless steel irradiated in HFIR and EBR-II, even though the HFIR specimens contained up to 3300 at. ppm He while the EBR-II-irradiated specimens contained less than 50 at. ppm He.

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TABLE I--Swelling behavior and tensile properties of HFIR-irradiated
20%-cold-worked type 316 stainless steel

Test	Temperature, °C Irradiation ^a	Fluence, ^b >0.1 MeV, neutrons/m ² × 10 ²⁶	Displace- ment Damage, dpa	Helium Content, ^c at. ppm	Strength, MPa		Elongation, ^e %		Swelling, ^f %
					Yield ^d	Ultimate	Uniform	Total	
300		0			722	746	1.2	7.9	
300	284	1.8		880	1032	1093	0.7	6.0	0.0
300	284	3.0		1660	851	1064	1.2	5.8	0.0
350		0			589	713	1.7	7.6	
350		0			682	710	1.2	6.7	
350	370	1.8	16	880	901	951	2.1	6.3	0.1
350	370	2.6	22	1270	792	901	5.3	8.8	0.05
350	370	3.1	26	1530	790	888	4.8	7.8	0.3
350	370	3.1	26	1530	794	894	6.6	9.9	0.2
350	370	3.4	29	1730	723	866	8.3	10.4	0.3
350	370	3.7	31	1910	743	876	6.9	8.7	0.2
350	370	3.0	27	1670	940	977	1.5	5.1	0.2
350	370	5.2	43	2660	890	965	5.2	6.9	1.3
350	370	5.2	43	2660	779	869	5.9	8.0	0.8
450	370	3.7	32	1980	750	854	4.1	6.8	0.2
450		0			672	726	5.1	10.4	
450		0			679	725	4.2	8.5	
450	470	1.8	16	880	583	713	6.9	8.9	0.04
450	470	2.6	22	1270	482	625	5.9	7.4	0.3
450	470	2.6	22	1270	519	682	8.6	10.7	0.2
450	470	3.4	29	1730	446	615	7.1	8.2	0.4
450	470	3.7	31	1910	453	626	10.3	12.2	0.5
450	470	3.7	31	1910	444	620	9.9	11.9	0.4
450	470	4.3	37	2260	500	654	6.5	7.7	1.5
450	470	6.2	52	3200	470	635	9.0	10.9	1.1
450	470	6.2	52	3200	470	634	10.2	12.2	1.0
550	470	1.8	16	880	578	683	3.8	4.6	0.2
675	470	3.1	26	1530	422	455	1.2	1.7	0.1
575		0			628	708	6.7	11.8	
575	560	3.1	26	1530	343	539	8.7	9.9	0.3
575	560	3.4	29	1730	323	524	7.4	9.7	0.6
575	560	3.4	29	1730	331	542	7.9	9.5	0.6
575	560	4.3	37	2260	362	535	9.8	11.4	1.0
575	560	5.7	48	2960	344	512	6.1	6.4	5.49
575	560	5.7	48	2960	338	503	7.2	7.9	1.2
675	560	3.7	32	1980	312	355	1.0	1.1	0.8
600		0			620	693	6.4	11.7	
600	620	3.7	32	1980	303	491	8.8	10.0	1.2
600	620	6.2	54	3320	359	543	7.4	8.0	2.1

^aIrradiation temperatures are calculated, ±50°C.

^bCalculated from dosimetry of previous experiments.

^cCalculated from empirical relationship.

^d0.2% offset.

^eBased on an 18.3-mm gage length.

^fImmersion density values.

^gSpecimen holder broke causing increase in temperature.

FIG.1--Swelling as a function of irradiation temperatures for 20%-cold-worked type 316 stainless steel.

FIG.2--The 0.2%-offset yield stress as a function of displacement damage and fluence for irradiated 20%-cold-worked type 316 stainless steel tested at 350, 450, and 575°C. Calculated HFIR irradiation temperatures were near test temperatures.

FIG.3--The ultimate tensile strength as a function of displacement damage and fluence for irradiated 20%-cold-worked type 316 stainless steel tested at 350, 450, and 575°C. Irradiation temperatures were near test temperatures.

FIG.4--Total elongation as a function of displacement damage and fluence for 20%-cold-worked type 316 stainless steel for test temperatures of 350, 450, and 575°C. Irradiation temperatures were near test temperatures.

FIG.5--The 0.2%-yield stress and ultimate tensile strength as a function of test temperature for 20%-cold-worked type 316 stainless steel unirradiated and irradiated to ~26 dpa in HFIR and EBR-II. Irradiation temperatures were near the test temperatures. The EBR-II data were taken from ref. 7.

FIG.1--Swelling as a function of irradiation temperatures for 20%-cold-worked type 316 stainless steel.

FIG.2--The 0.2%-offset yield stress as a function of displacement damage and fluence for irradiated 20%-cold-worked type 316 stainless steel tested at 350, 450, and 575°C. Calculated HFIR irradiation temperatures were near test temperatures.

FIG.3--The ultimate tensile strength as a function of displacement damage and fluence for irradiated 20%-cold-worked type 316 stainless steel tested at 350, 450, and 575°C. Irradiation temperatures were near test temperatures.

FIG.4--Total elongation as a function of displacement damage and fluence for 20%-cold-worked type 316 stainless steel for test temperatures of 350, 450, and 575°C. Irradiation temperatures were near test temperatures.

FIG.5--The 0.2%-yield stress and ultimate tensile strength as a function of test temperature for 20%-cold-worked type 316 stainless steel unirradiated and irradiated to ~26 dpa in HFIR and EBR-II. Irradiation temperatures were near the test temperatures. The EBR-II data were taken from ref. 7.