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# MECHANICAL PROPERTIES OF INOR-8 CAST METAL

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METALS AND CERAMICS DIVISION

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## ABSTRACT

Tensile and stress-rupture data for INOR-8 castings are presented. It is shown that the high-temperature strength of castings is sufficient to allow present Molten-Salt Reactor Experiment stresses for wrought metal to be used. At lower temperatures, however, the tensile strength limits the maximum stress to low values. The effect of defects in castings is illustrated.

## INTRODUCTION

Since several components in the Molten-Salt Reactor Experiment (MSRE) fuel circulation system will be fabricated by casting, it is desirable to know the limiting strength of INOR-8 cast metal. This report summarizes available mechanical property data on this material. Portions of the information provided here were obtained by the Haynes-Stellite Company and are reported in the literature.[1] They are included here for completeness.

## PROGRAM

Tensile tests were performed on four heats of sand-cast metal and one heat of investment-cast metal. The chemical analyses provided by the vendor are given in Table 1. The analyses for the investment-cast heat are not known.

Rod specimens were machined from cast blanks and annealed at 2150°F for 1 hr/in. of thickness. Both 0.505 and 0.250-in.-diam bars were used. All tensile tests were performed in air at an extension rate of 0.05 in./min.

Stress-rupture tests were performed on the investment-cast heat. The specimens were similar to those used in the tensile testing program.

[1] Developmental Data on Hastelloy Alloy N, Haynes-Stellite Company brochure (May 1959).

Table 1. Chemical Analyses for INOR-8 Castings

| Heat No. | Cr | Fe | C | Si | Co | Ni | Mn | Mo | Cu | P | S |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Specified | 6–8 | 5 max | 0.02–0.12 | 1.0 max | 0.2 max | bal | 1.0 max | 15–18 | 0.35 max | 0.15 max | 0.2 max |
| 7707 | a | a | 0.02 | 0.021 | a | a | a | a | a | a | a |
| 8860 | 7.2 | 4.0 | 0.07 | 0.27 | 0.20 | bal | 0.38 | 16.2 | 0.01 | 0.001 | 0.01 |
| 8861 | 7.4 | 4.0 | 0.07 | 0.12 | 0.17 | bal | 0.4 | 16.1 | 0.01 | 0.001 | 0.01 |
| 9615 | a | a | a | a | a | a | a | a | a | a | a |

[a]Within specification but not reported.

During the machining of the bars from heats Nos. 8860 and 8861, it was seen that there were flaws in the specimens. Radiography was then performed on eight bars from these heats prior to testing.

RESULTS

Tensile data are shown in Figs. 1 through 4. The tensile strength for sand-cast metal, shown in Fig. 1, exhibits a wide variation from one specimen to another, especially at the low temperatures. Inspection of radiographs and rupture surfaces revealed gross defects in at least nine specimens. Most of the scatter in the tensile strength can, therefore, be attributed to defects. The tensile strength for sound cast metal is about 60% of that for wrought metal.

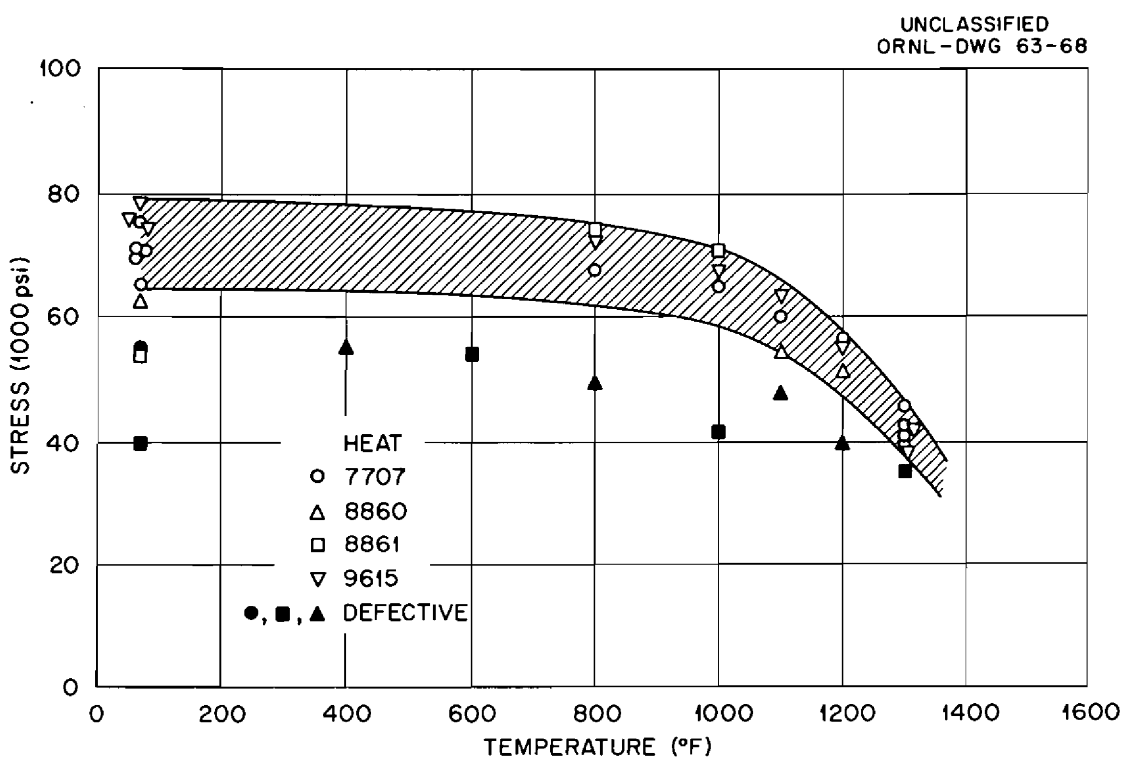


Fig. 1. Ultimate Tensile Strength of Sand-Cast INOR-8.

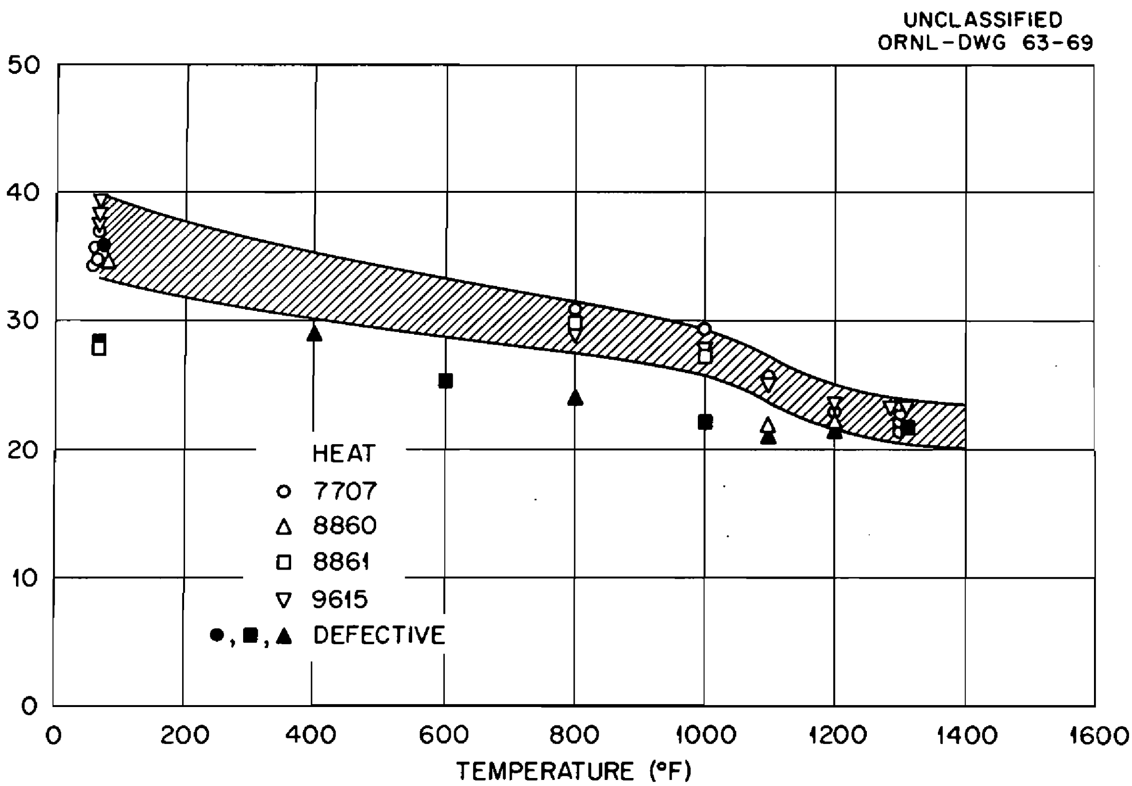


Fig. 2. Yield Strength of Sand-Cast INOR-8.

The 0.2% offset yield strength for sand-cast metal is shown in Fig. 2. Here again the defective castings exhibit less strength than the sound castings. The yield strength for cast metal is about 80% of that for wrought metal.

The tensile elongation for sand castings is shown in Fig. 3. The elongation improves with increasing temperature up to 800°F and diminishes above this temperature. Most of the sound castings have elongations better than 20% at all temperatures. The elongation is particularly sensitive to the quality of the casting and defective castings exhibit ductilities well below those for sound metal. It was noticed that failures in defective castings occurred at shrinkage cracks and large inclusions. These flaws comprised anywhere from 10 to 40% of the cross-sectional area of the specimen. No failures in high porosity regions were observed.

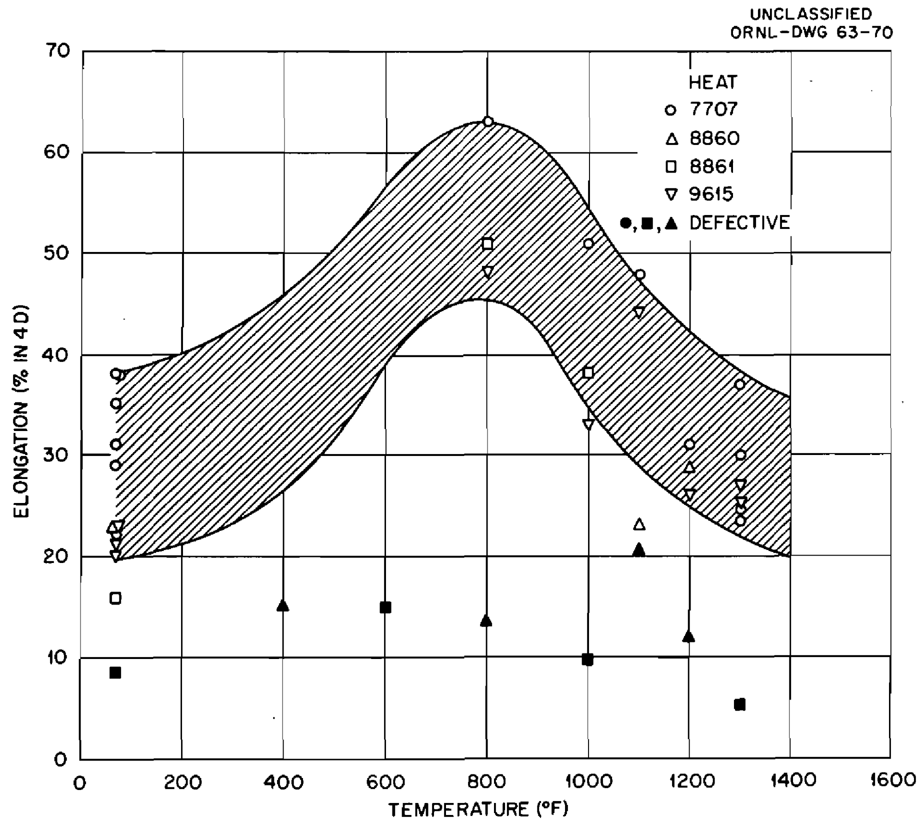


Fig. 3. Elongation of Sand-Cast INOR-8.

The investment castings exhibit about the same strength as sand castings. Data for this material are shown in Fig. 4.

The only available creep data are for investment castings. These data were obtained from short-time stress-rupture tests at temperatures of 1100, 1300, 1500, and 1700°F and are not suitable for establishing design stresses by conventional techniques. The Dorn-Shepard parameter[2] has been used to establish a master curve from which 100,000 rupture-stress values may be obtained. The activation energy, 83,200 cal/mole-°K, for wrought metal[3] was employed. A plot of the Dorn-Shepard against

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[2]J. E. Dorn and L. A. Shepard, What We Need to Know About Creep, ASTM Spec. Tech. Pub. No. 165, p 3 (1954).

[3]R. W. Swindeman, The Mechanical Properties of INOR-8, ORNL-2780, p 58 (1961).

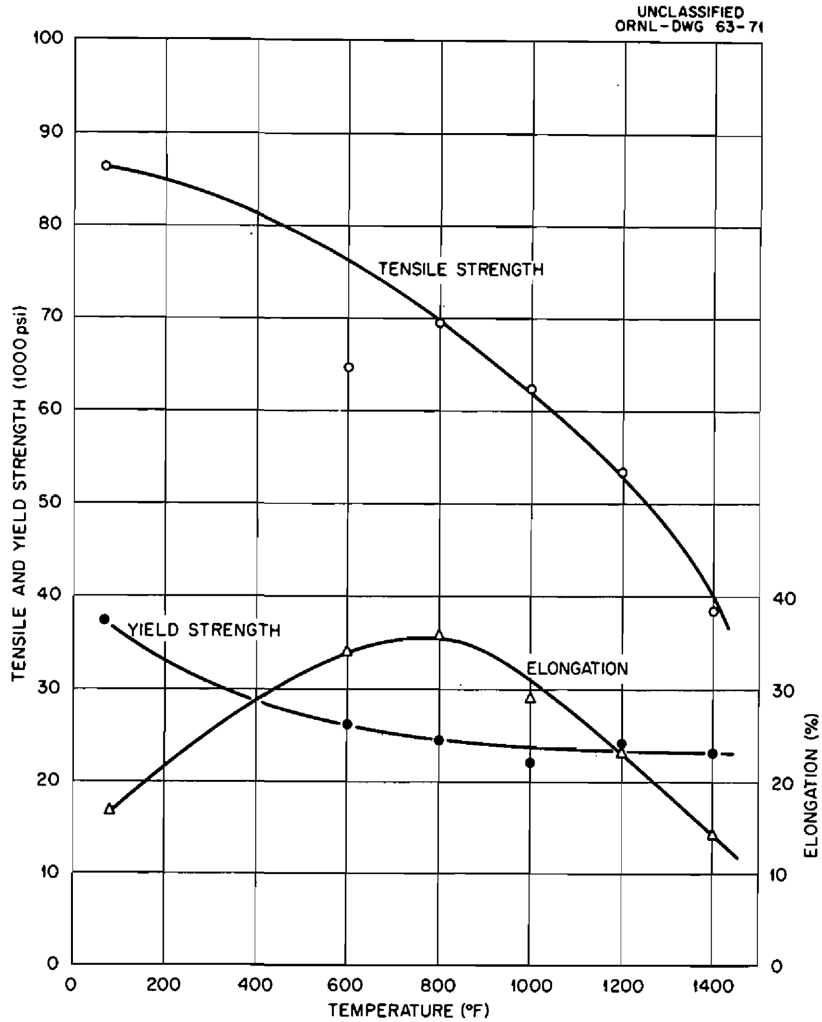


Fig. 4. Tensile Properties vs Temperature for Investment-Cast INOR-8.

stress is shown in Fig. 5. Stress values for 100,000 hr obtained from this curve are presented in Table 2 and compared to present MSRE design stresses. It is apparent that, on the basis of rupture data, the wrought metal stress values may be safely applied as design stresses for castings. This is true for temperatures above 1150°F. Below 1150°F, however, cast metal design stresses must be based on one fourth of the tensile strength since these stresses will be less than those obtained from stress-rupture data. Inasmuch as the minimum specified tensile strength has not been established for castings, stress values at lower temperatures are not suggested.

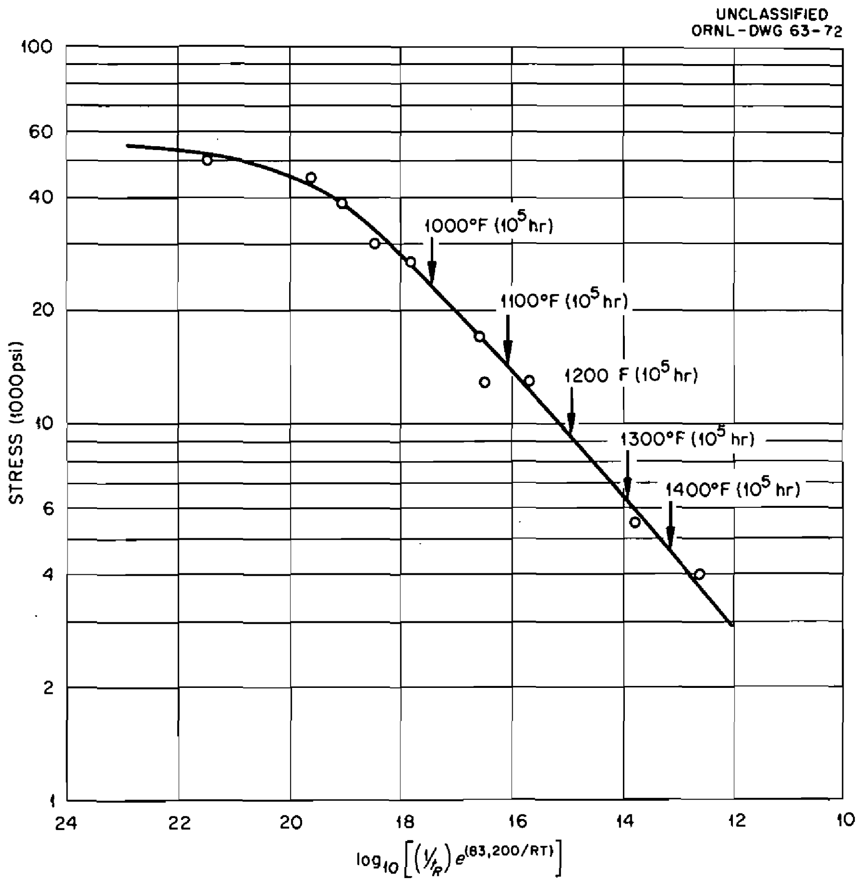


Fig. 5. Dorn-Shepard Parameter for Rupture of Investment-Cast INOR-8.

A creep testing program is now in progress to determine the creep rates and stress-rupture properties of sand castings between 1100 and 1400°F. This program should be completed with six months.

Table 2. Estimated 100,000-hr Rupture Strength for INOR-8 Castings

| Temperature (°F) | Stresses for Cast Metal Predicted from the Dorn-Shepard Parameter (psi) | MSRE Design Stresses for Wrought Metal (psi) |
|---|---|---|
| 1000[a] | 23,300 | 16,000 |
| 1050[a] | 17,850 | 13,250 |
| 1100[a] | 14,000 | 9,600 |
| 1150 | 10,400 | 6,800 |
| 1200 | 9,300 | 4,950 |
| 1250 | 7,450 | 3,600 |
| 1300 | 6,250 | 2,750 |
| 1350 | 5,400 | 2,050 |
| 1400 | 4,650 | 1,600 |

[a]Tensile strength will control the design stress at these temperatures.

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