MASTER

WESTINGHOUSE ASTRONUCLEAR LABORATORY

Engineering Mechanics Section

TEST REPORT

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Subject: 1.5% Boron - Stainless Steel

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Serial: 10:50:73-1T

BRITTLE TESTS 1.5% BORON - STAINLESS STEEL STEEL

Abstract

Borated steel of the form and quality to be used in the KIWI B-5 shield capsules was tested to verify its reported brittleness. The material behavior was classified as being definitely ductile at both room and liquid nitrogen temperatures. The material supplied had been used for criticality studies in a test reactor, i.e., subjected to very low neutron densities and "clean" enough to be handled by hand.

Introduction

Two series of tests were conducted to determine the reported brittleness of 1.5% Boron - stainless steel, its resistance to thermal and mechanical shock and the effect of temperature on its flexibility. Of the two series of tests, one was conducted using specimens known to have material defects (cracks, inclusions, etc.) while the other used comparatively perfect specimens of the material. All of the material supplied had been used previous to testing for criticality studies in a reactor.

The borated steel is used in pellet form in the shield capsules of the KIWI B-5 shield.

Discussion

A cylindrical specimen of 1.5% boron - stainless steel (9/16" dia. x 1-3/16" long) was soaked in liquid N_2 and then subjected to impact. The cooled specimen was held in a vise and then struck severely with a hammer. Transverse, as well as longitudinal, blows were imparted with a hammer. Several impacts were then administered via the point of the cold chisel. Figure 1 is a photograph of this specimen showing the results of these blows as well as the imprints of the jaws of the vise. Obviously, the material is not brittle under these circumstances.

Nine specimens similar in dimensions to the one described above were subjected to a thermal shock test. The specimens were numbered, divided into three groups and measured. Group I (#10, 11, 12) was heated to 1200°F in a furnace and then immersed in a liquid N_2 bath. Group II (#20, 21, 22) was heated to 1400°F and Group III (#30, 31, 32) to 1600°F before being put into the liquid N_2 bath. Microscopic (3X) examination revealed no cracks either before or after the thermal shock. Both ends and the lateral surface of the cylinders were examined. Measurements of the length and diameter of each specimen were made with a 4 place micrometer before and after the shock test. There were no apparent changes in these dimensions. This data appears in Figure 2.

Five small blocks of this material were subjected to a similar thermal shock. However, these specimens were known to contain either cracks or other imperfections by previous photomicrographic studies. The thermal shock consisted of heating the specimens to 1600°F and then immersing them in liquid N_2.

When this did not produce any visible change in the appearance of the specimens they were each given at least one solid blow with a 4 oz. ball peen hammer. Neither the thermal nor the mechanical shock succeeded in causing the test pieces to fracture. The specimens were returned to Quality Assurance for more photomicrographic studies.

In the final test two specimens were machined from each of three test coupons provided. These coupons were reportedly free of defects and marked 26A, 26B and 28A respectively. One specimen from each coupon was subjected to a flexure test at room temperature and the other after being chilled at liquid N_2 temperature for 30 minutes. The specimens which were approximately 1-3/4" x 3/4" x 1/8" were simply supported and loaded in the center with a loading tool having a 1/4" radius head. A sketch of the loading scheme is included in in Figure 3 along with a tabulation of the data. Besides the ultimate loads, the modulus of rupture is included in the data for, although it is not definitive of a true ultimate strength, the values obtained are of use in giving an index of the ultimate strength and in making possible a comparison of materials or testing variables.

A Southwark-Emery UTM was used for the loading and the rate of loading was very nearly the same for all six specimens. Figures 4, 5 and 6 are photographs of the test coupons and each of the specimens after being fractured.

Results

The 1.5% boron - stainless steel as supplied for this series of tests was capable of withstanding temperatures to 1600°F followed by immediate immersion in liquid N_2. Mechanical shocks imparted by hammer and chissel could not produce fracture. Presence of cracks or other material defects did not affect the thermal or mechanical shock test results.

Using the modulus of rupture as a point of comparison, the material does not display embrittlement at lowered temperatures.

Conclusions

The 1.5% boron - stainless steel tested was not brittle under any of the test circumstances. Extremely low temperatures (-320°F) did not affect its flexibility but appeared to enhance it.

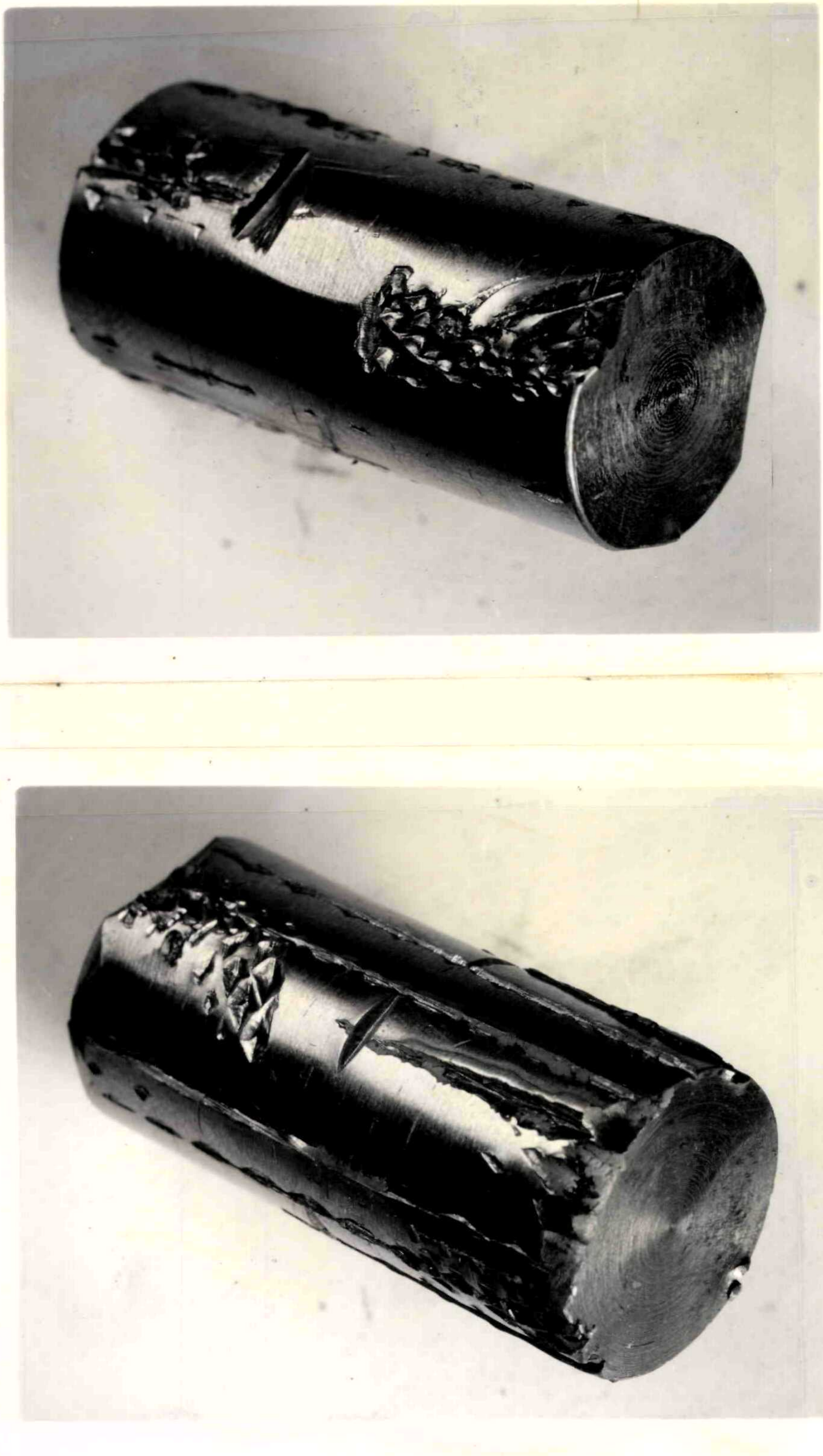

Figure 1

Two Views of the 1.5% Boron - Stainless Steel Cylinder Cooled in Liquid N_2 and Subjected to Impact with a Hammer and Chisel.

Figure 2

Table of Measurements Taken Before and After the Thermal Shock Test

Specimen Number	Length (in.)[1]		Weight (grams)		Diameter #1 (in.)[2]		Diameter #2 (in.)[3]		Diameter #3 (in.)[4]	
	Before	After	Before	After	Before	After	Before	After	Before	After
10	1.2120	1.2120	40.7082	40.7084	.5813	.5813	.5814	.5814	.5814	.5814
11	1.2104	1.2101	40.5835	40.5828	.5815	.5815	.5814	.5814	.5814	.5814
12	1.2083	1.2083	40.6680	40.6680	.5820	.5820	.5820	.5820	.5820	.5820
20	1.2144	1.2146	40.9452	40.9458	.5819	.5818	.5815	.5815	.5817	.5818
21	1.2095	1.2095	40.8375	40.8384	.5819	.5819	.5818	.5820	.5820	.5820
22	1.2100	1.2100	40.6821	40.6826	.5818	.5818	.5816	.5818	.5818	.5819
30	1.2117	1.2117	40.7863	40.7866	.5819	.5820	.5819	.5820	.5820	.5820
31	1.2062	1.2063	40.3268	40.3290	.5802	.5802	.5801	.5801	.5802	.5802
32	1.2079	1.2082	40.5927	40.5938	.5812	.5812	.5812	.5812	.5815	.5815

1. Measurements were made in the center of the faces.
2. Diameter #1 was taken at the numbered end of the pellet.
3. Diameter #2 was taken at the middle of the pellet
4. Diameter #3 was taken at the end opposite the numbered face.

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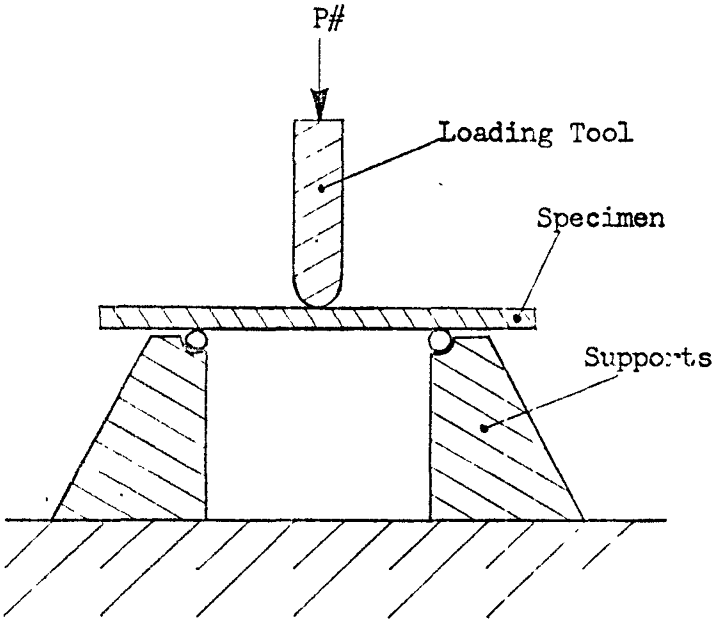

Dimensions

Span length = 1-1/4"

Loading Tool = 1/4" radius

Supports = 1/8" radius

where -

S_u = modules of rupture (psi)

P_u = ultimate load (lbs)

L = span length (in.)

b = width of beam (in.)

h = thickness of beam (in.)

Modulus of Rupture

$$S_u = \frac{3 P_u L}{2 b h^2}$$

Specimen	Temp. (°F)	Width (b)	Thickness (h)	Load (P)	Mod. Rupture (S_u)
28A-1	72	.757	.1265	1140	1.758×10^5
2	-320	.765	.1265	1368	2.095×10^5
26A-3	72	.768	.1280	1286	1.915×10^5
4	-320	.789	.1300	1466	2.060×10^5
26B-5	72	.784	.1275	1200	1.762×10^5
6	-320	.784	.1290	1270	1.830×10^5

Figure 3

Loading Scheme and Table

of Data for Flexure Test

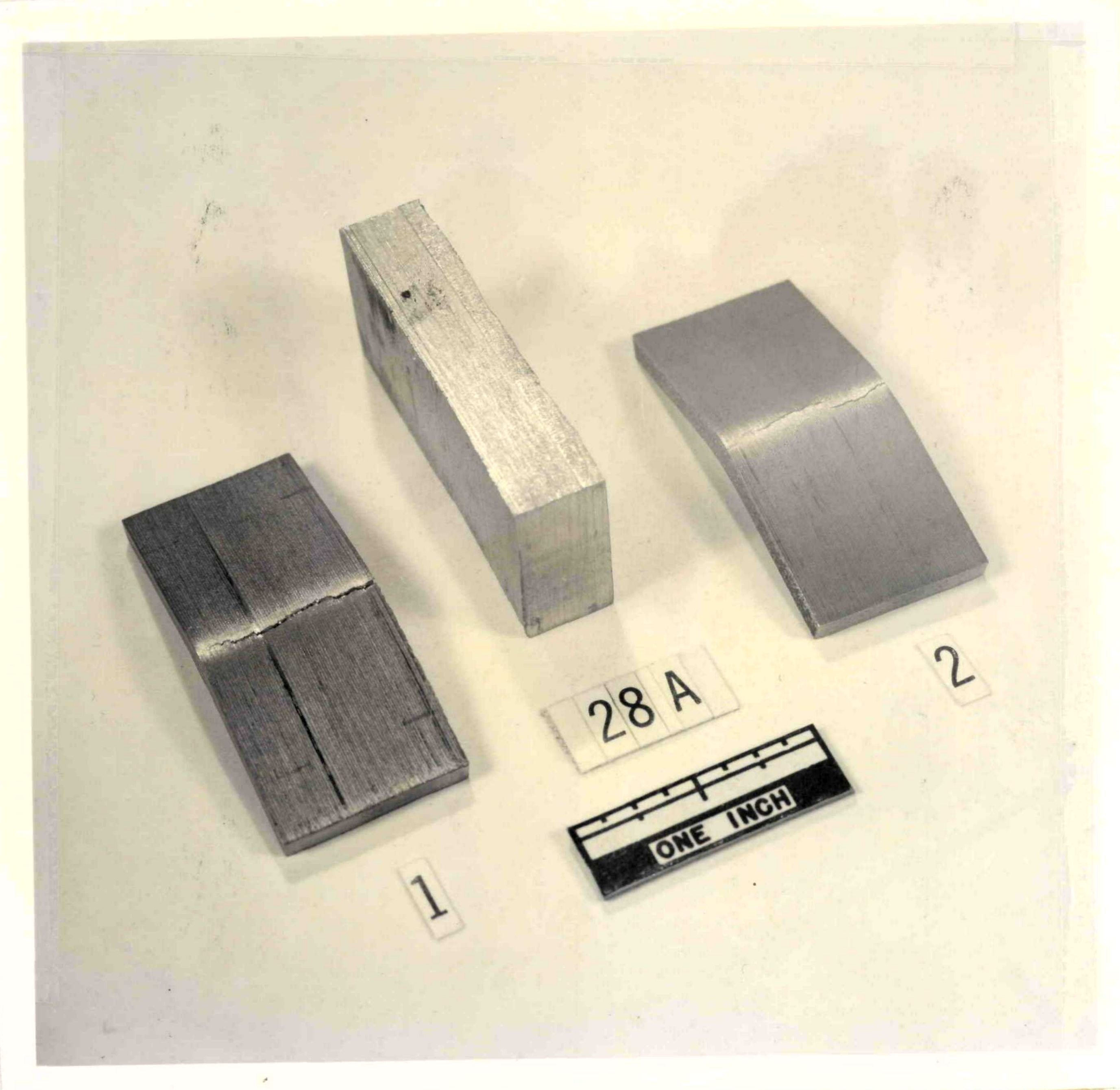

Figure 4

Photograph of Flexure Test Specimens and Coupon of 1.5% Boron - Stainless Steel From Which They Were Taken

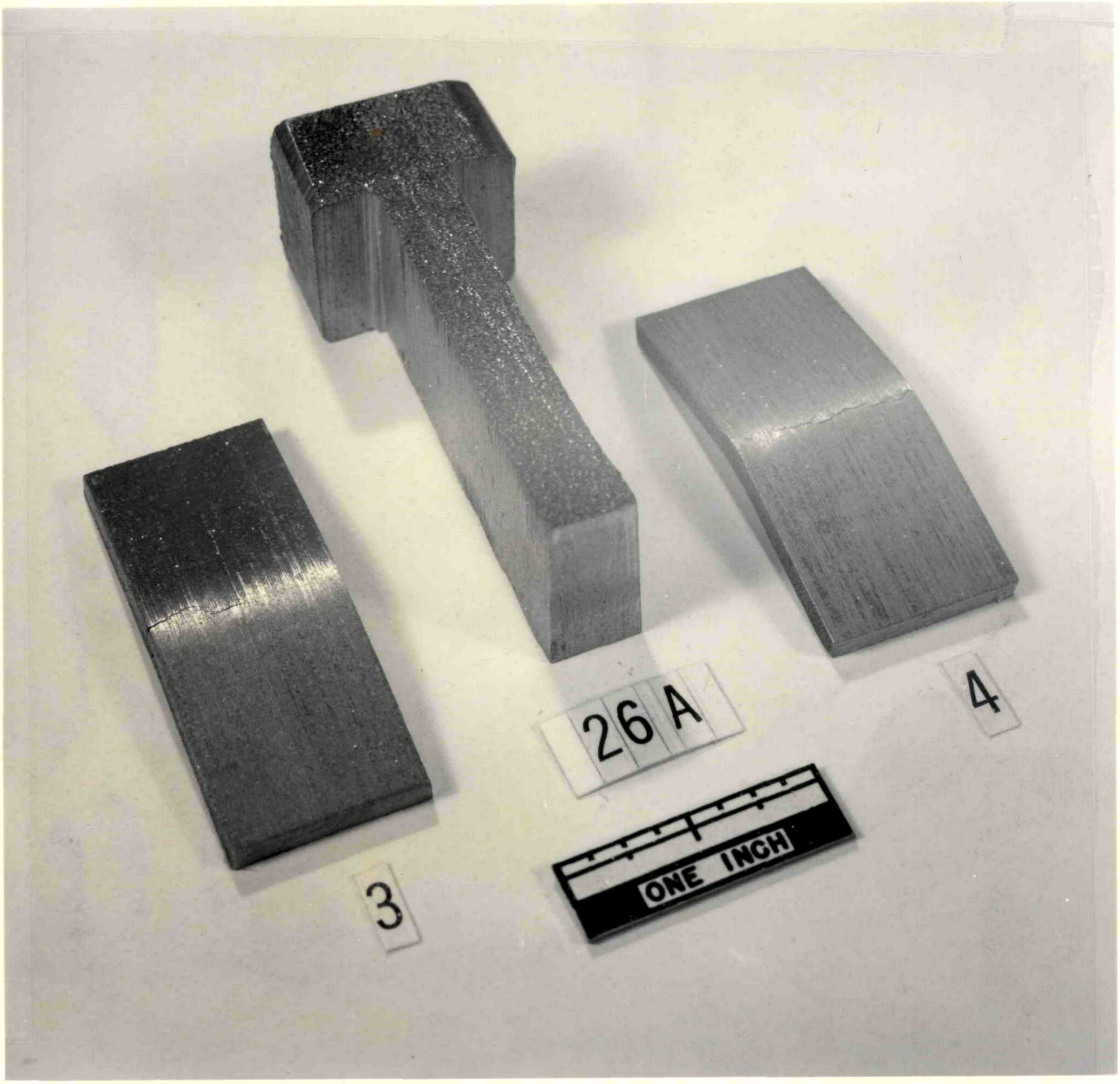

Figure 5

Photograph of Flexure Test Specimens and Coupon of

1.5% Boron - Stainless Steel From Which They Were Taken.

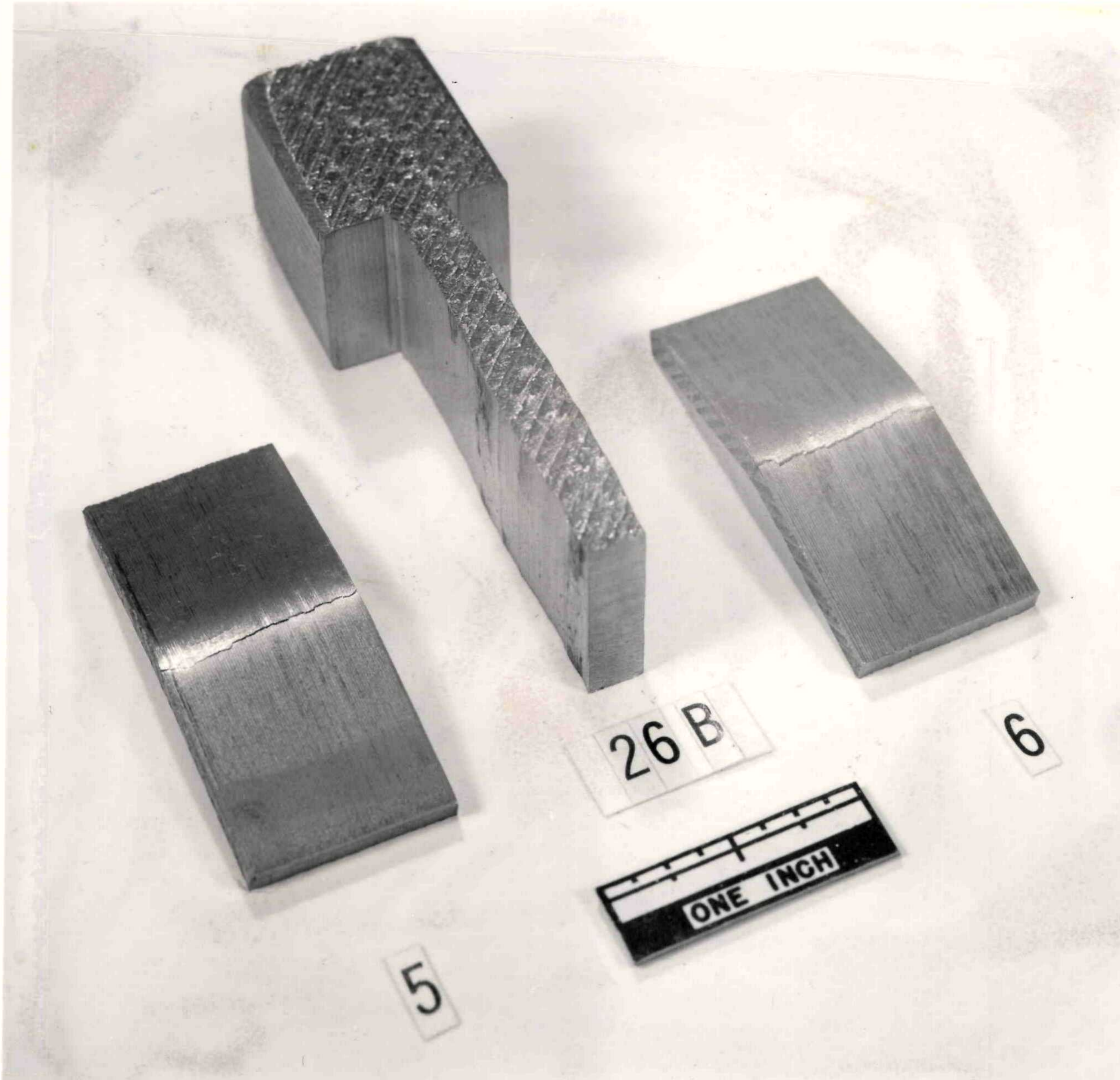

Figure 6

Photograph of Flexure Test Specimens and Coupon of 1.5% Boron - Stainless Steel From Which They Were Taken.