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TENSILE AND TRANSVERSE TESTING OF GRAY CAST IRON

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ABSTRACT

In this report, the types and causes of defects in transverse test bars are discussed. The quality of the bars was improved at the Naval Research Laboratory by using a chromium plated steel pattern, fine grained sand, horizontal ramming of the mold, and horizontal pouring followed immediately by setting the casting in the vertical position. A rapid, accurate, and inexpensive transverse testing technique was developed using an extensometer dial anchored to the testing machine ram with the dial pin in contact with a rigid reference bar. Problems encountered in judging the strength of a casting are described in a study of the effect of the size and location of tensile specimens.

PROBLEM STATUS

This report concludes the work on this problem, and unless the Laboratory is otherwise advised by the Bureau, the problem will be closed one month from the mailing date of this report.

AUTHORIZATION

NRL Problem No. M55-02.

TENSILE AND TRANSVERSE TESTING OF GRAY CAST IRON

INTRODUCTION

Test bar specifications have always been a subject of interest among foundrymen. This report describes the common defects found in commercial transverse test bars and the techniques developed at the Naval Research Laboratory for improving the casting and testing of such bars. The tensile strength as affected by the size of the specimen and its location in a casting was also studied.

The objective of the work was to reveal the common defects occurring in transverse test bars made by commercial foundries and to develop improved techniques for making and testing the bars.

KNOWN FACTS AND THEORETICAL CONSIDERATIONS

Since test bars and physical testing present problems common to most metal casting industries, considerable work has been done on this subject. Many of the investigations have been published and some of the more important aspects of these studies closely related to the subject of this work serve well as an introductory background.

Cast iron is a "section sensitive" material whose physical properties are greatly influenced by cooling rate. An example of the effect of section size may be seen in Figure 1, reproduced from a paper by Henry C. Winte,[1] in which it is seen that tensile strength and Brinell hardness decrease with increasing size of test bar.

Rother and Mazurie[2] related the tensile strengths of bars of various diameters in the following manner:

Soft Iron	Tensile Strength of 1-1/2″ bar is 82% of 1″ bar.
	Tensile Strength of 2″ bar is 72% of 1″ bar.
	Tensile Strength of 2-1/2″ bar is 62% of 1″ bar.
	Tensile Strength of 3″ bar is 55% of 1″ bar.
Machinery Iron	Tensile Strength of 1-1/2″ bar is 90% of 1″ bar.
	Tensile Strength of 2″ bar is 84% of 1″ bar.
	Tensile Strength of 2-1/2″ bar is 76% of 1″ bar.
	Tensile Strength of 3″ bar is 75% of 1″ bar.

[1] H. C. Winte, Am. Foundryman, 10: 68-75 (Oct. 1946)

[2] W. H. Rother and V. Mazurie, Trans. Am. Foundrymen's Assoc., 34: 746-765 (1926)

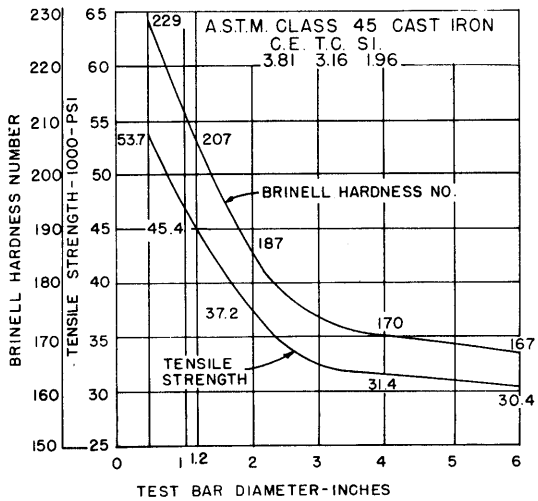

Fig. 1 - Effect of Section Size on Brinell Hardness and Tensile Strength of a Gray Cast Iron

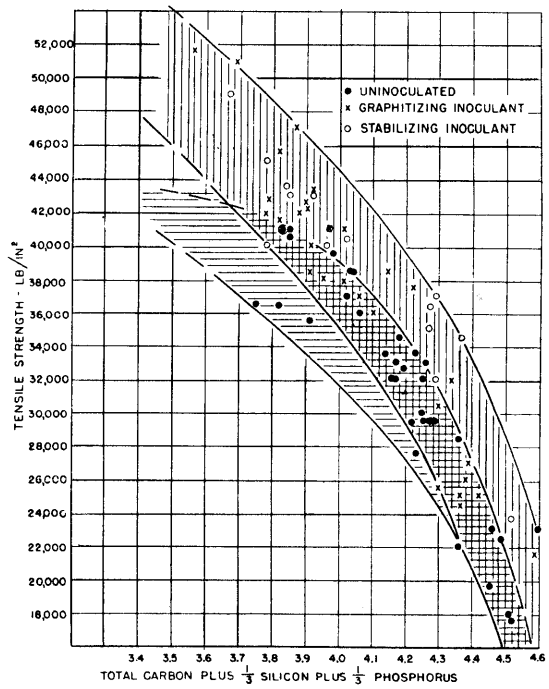

Fig. 2 - Relation Between Tensile Strength and Equivalent Carbon of Cast Iron

An investigation of transverse or arbitration test bars made at the Bureau of Standards by Krynitsky and Saeger[3] showed that vertically cast bars, particularly those which were bottom-poured, were much more uniform in diameter than bars cast in horizontal or inclined molds. Phillips,[4] comparing horizontal and vertical pouring of pairs of transverse test bars, found 60 percent of the horizontally cast bars were stronger than the vertically cast ones. None of the horizontal bars were defective, while 8 percent of the vertical bars were. The Institute of British Foundrymen[5] recommended that arbitration bars be poured in oil or dry sand with a distance between individual bars in the same mold equal to at least 1-1/2 times the diameter of the bar.

The physical testing of the arbitration bar has presented many problems in technique and in interpretation of results. The Bureau of Standards[6] devised a technique in which the deflection was measured with a micrometer telescope. MacKenzie and Donoho[7] examined the effect of the length of the transverse span on modulus of rupture and modulus of elasticity and found that with decreasing span, the modulus of rupture increases whereas the modulus of elasticity decreases.

Gray iron does not follow Hooke's law, according to which stress is proportional to strain. The stress-strain curve obtained in transverse testing is not a straight line but a curve with a different value for the modulus of elasticity at each load level. This deviation from a straight-line relation is caused by plastic flow, which takes place almost entirely

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[3] A. I. Krynitsky and C. M. Saeger, Jr., Nat. Bur. Standards J. Research, 16: 367-384 (1936)

[4] Garnet P. Phillips, Trans. Am. Foundrymen's Assoc., 42: 485-507 (1934)

[5] Inst. Brit. Foundrymen, Sub-Comm. T.S. 4 Technical Council, Foundry Trade J., 76: 175-76 (1945)

[6] A. I. Krynitsky and C.M.Saeger, Jr., Nat. Bur. Standards J. Research, 22: 191-207 (1939)

[7] J.T.MacKenzie and C.K.Donoho, Proc. Am. Soc. Testing Materials, 37, Part 2, 71-87 (1937)

in the first loading cycle. For example, if an arbitration bar is alternately loaded to a stress below its breaking point, and then unloaded, the strain produced after the first loading is essentially elastic. If the load at any time exceeds the previous maximum, however, there will be a plastic deformation for that increment.

Although many of the applications for cast iron do not place the material in tension, its quality is often judged by its tensile strength. Because tensile testing is relatively expensive, considerable effort has been expended in attempting to relate that property with chemical analysis, Brinell hardness, or transverse strength. For example, Barlow and Lorig[8] prepared a number of charts, such as the one shown in Figure 2, which correlated tensile strength with carbon equivalent (carbon plus 1/3 silicon plus 1/3 phosphorus). These properties are roughly related by a broad band of values. They also found that the ratio of tensile strength to Brinell hardness varied with carbon equivalent.

Recently, MacKenzie plotted the tensile strength versus the Brinell hardness of 1,553 test specimens.[9] Figure 3 is a graphic reproduction of his data. As the tensile and hardness values increase, the relation tends to spread over a wider area. The author developed the following general relation from the average values:

$$\text{Tensile Strength} = (1.82)(\text{B.H.N.})^{1.85}$$

(for Brinell impressions ranging from 3.2 to 5.8 mm.)

On the theory that the properties of cast iron are dependent to an important degree upon graphite, Herzig[10] plotted the percent graphitic carbon versus the elastic modulus, as shown in Figure 4. The solid line represents the average relation between graphitic carbon and elastic modulus obtained from 180 transverse bend tests. The shaded area represents a ± 10 percent error band which includes 70 percent of the results.

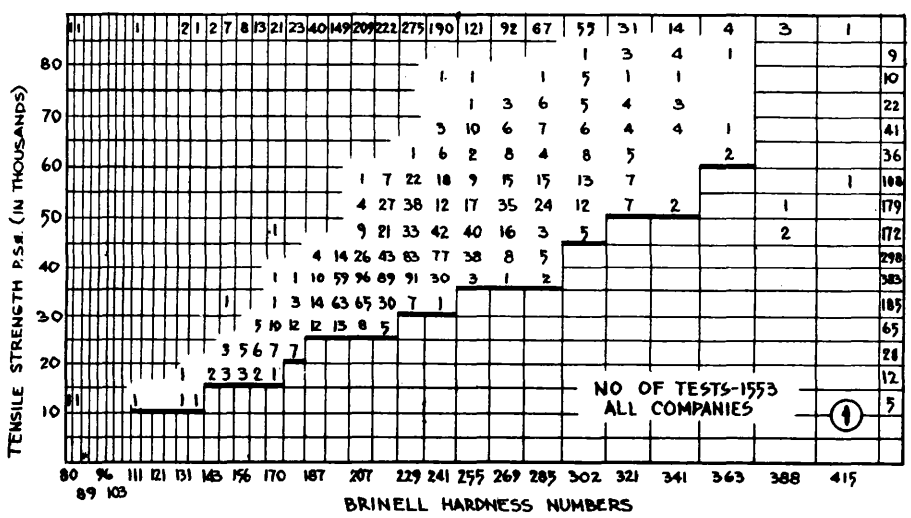

Fig. 3 - Relation Between Brinell Hardness and Tensile Strength of Cast Iron

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[8] T. E. Barlow and C. H. Lorig, Trans. Am. Foundrymen's Assoc. 54: 545-552 (1946)

[9] J. T. MacKenzie, Foundry, 74: 86-93 (Oct. 1946)

[10] A. J. Herzig, Am. Foundryman, 9: 134-135 (April 1946)

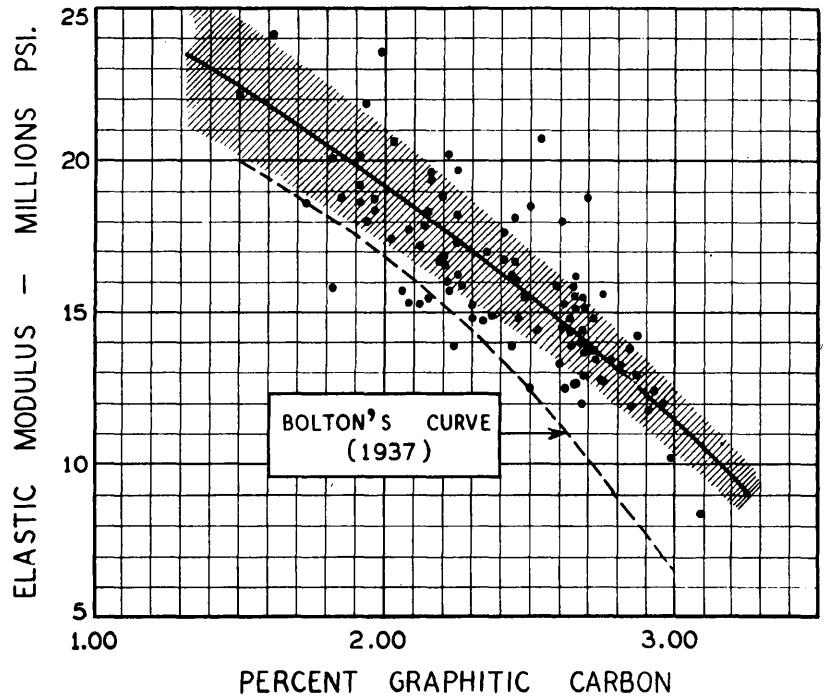

Fig. 4 - Effect of Graphite on the Modulus of Elasticity of Gray Cast Iron

DESCRIPTION AND DISCUSSION OF EXPERIMENTS

Inspection and Testing of Arbitration Bars Made by Commercial Foundries

Twenty-nine standard arbitration bars were obtained from thirteen representative commercial foundries through the cooperative efforts of the Gray Iron Founders' Society. These bars were approximately 1.2 inches in diameter by 21 inches long.

After sand blasting, the surface of these bars was inspected and photographed. Figure 5 shows the surface condition. Pertinent information on the pouring and molding techniques, and surface condition, are listed in Table I (see page 7). Table II (see page 7) contains the chemical analyses.

The majority of these arbitration bars have surface defects which might materially reduce the physical properties if tested in the "as cast" condition. Bars that are rammed in the horizontal position, so that one half is in the cope and the other half in the drag, always have an undesirable fin running the length of the bar along the parting line. This fin may be seen in bars numbered 9 and 23.

Considerable evidence of metal penetration into the sand is apparent in the vertically poured molds. This defect is usually the greatest at the bottom of the bars and gradually diminishes toward the top, probably as a result of the static pressure developed by the tall column of metal (see bars 13 and 25). The walls of the vertically poured molds are subject to severe erosion by the impinging stream of falling metal and this action often results in the trapping of sand at the metal surface as i bar 23. Defects in the patterns are usually transferred to the mold walls and give the type of surface visible on the bars 5 and 23.

TABLE I

Industry Arbitration Bars

No.	Pouring Position	Sand	Surface Finish
1	Vertical	Dry Sand	Rough surface due to coarse sand.
3	Vertical	Oil Sand Core with Silica Wash.	Bar undersize due to wash, and covered with globules of metal as if wash contained air bubbles. Surface smooth.
5	Vertical	Dry Sand Mold (Core).	Roughness or penetration. End of pattern burred.
7	Horizontal	Green Sand.	Smooth. Shows effect of fine sand.
9	Horizontal	Green Sand.	Smooth. Shows effect of fine sand.
11	Vertical	Black Sand - Coat of Blacking - Oven Dried.	Smooth.
13	Vertical	Dry Sand Mold.	Rough. Penetration due to soft ramming.
15	Vertical	Green Sand.	Smooth.
17	Horizontal	Green Sand.	Smooth, with a few droplets of penetrated metal.
19	Vertical	Oil Sand Core.	Rough - Slight penetration.
21	Vertical	Oil Sand Core.	Veins and slight roughness.
23	Vertical	Dry Sand Core - Washed.	Horizontal fin-pattern defects visible - some dirt.
25	Vertical		Very rough - soft ramming.
27	Vertical	Dry Sand with Wash.	Slightly rough. Wash not very effective.
29	Horizontal	Core Mold.	Good surface for a core.

TABLE II

Chemical Analyses of Arbitration Bars

(percent)

Bar Number	C	Si	Mn	S	P	Ni	Mo	Cr
1	3.29	1.79	0.65	0.10	0.15			
3	3.07	2.20	.84	.111	.088	1.38		0.65
5	3.17	1.77	.70	.078	.082	1.65	0.69	.10
7	3.43	3.00	.65	.091	.492			
9	3.43	3.00	.65	.091	.492			
11	3.57	1.65	.30	.097	.556			
13	3.72	2.14	.89	.057	.096		.35	.43 (.05-V, .19-Ti)
15	3.18	1.48	1.23	.079	.056			
17	3.36	2.25	0.67	.113	.204			
19	3.39	2.20	.82	.131	.124	0.37	.32	.24
21	3.39	2.20	.82	.131	.124	0.37	.32	.24
23	3.52	2.66	.66	.106	.316			
25	3.52	2.27	.83	.097	.140			
27	3.26	2.08	.90	.072	.37			
29	3.14	1.69	.43	.075	.114			

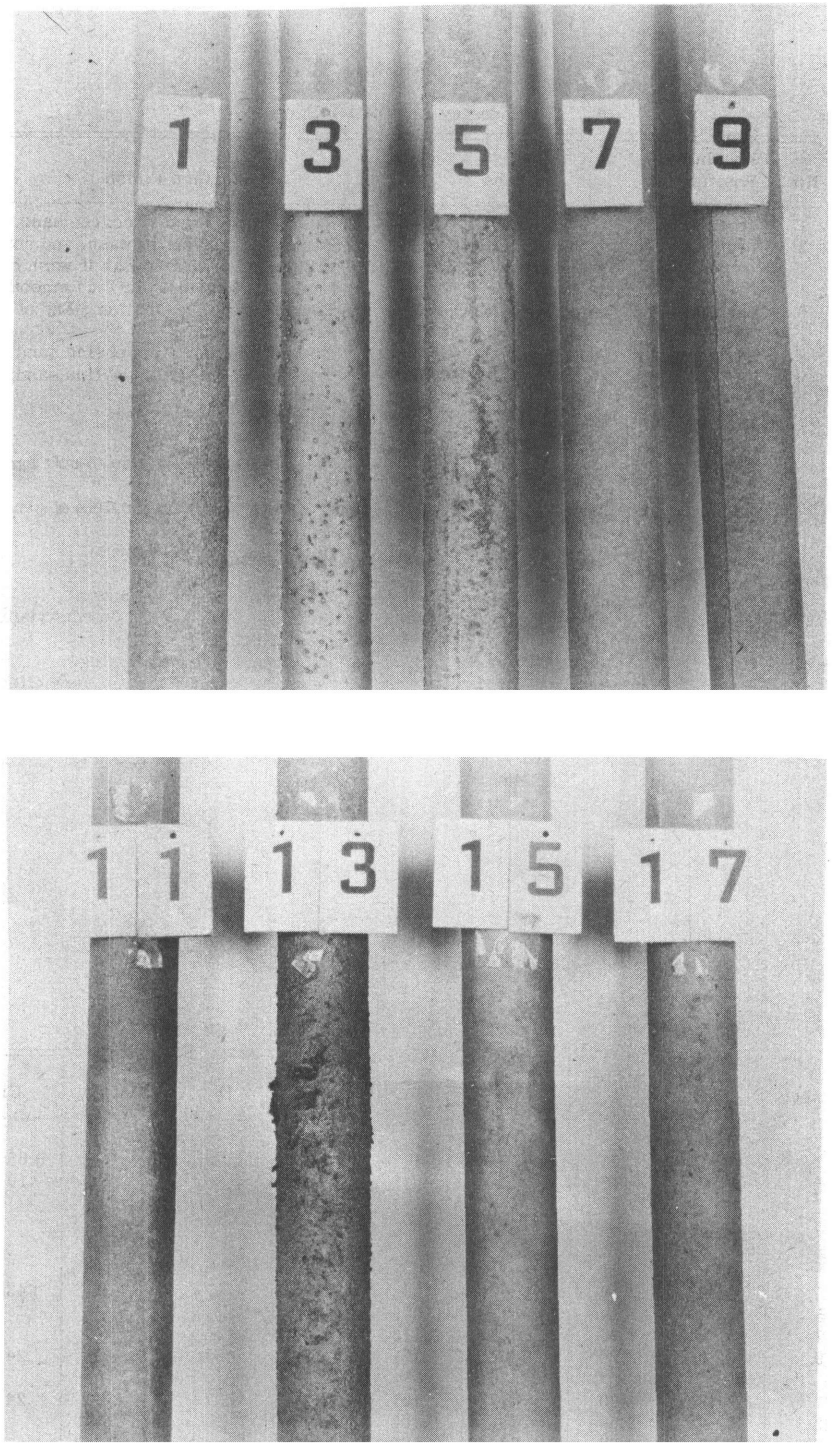

Fig. 5 - Surface Conditions of Industry Arbitration Bars Numbers 1, 3, 5, 7, 9, 11, 13, 15, and 17

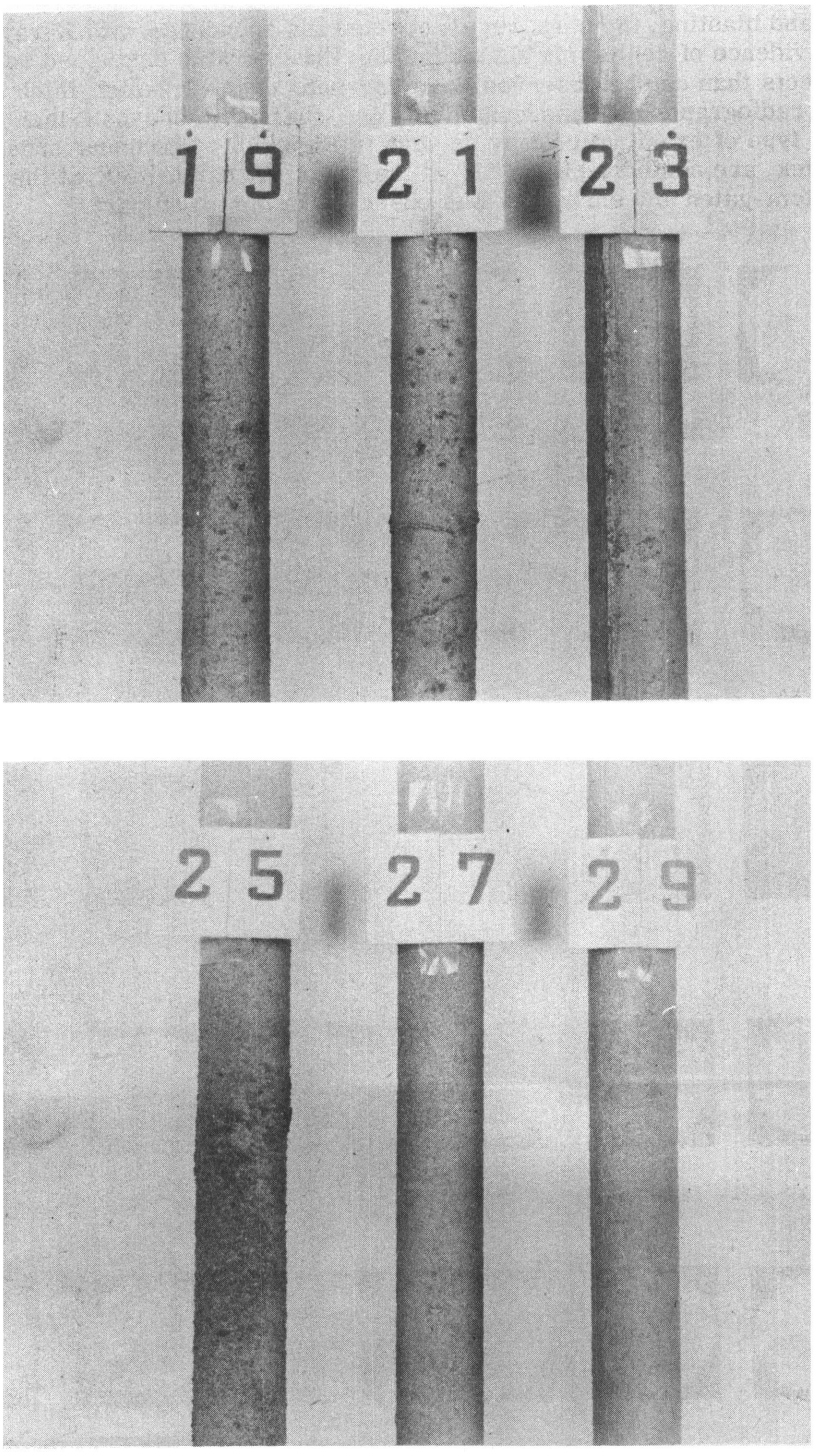

Fig. 5 - Surface Conditions of Industry Arbitration Bars Numbers 19, 21, 23, 25, 27, and 29

After sand blasting, the bars were inspected for soundness with X-rays. There was very little evidence of centerline shrinkage, but considerable entrapped sand was revealed. Smaller defects than can be observed in radiographs of the 1.2-inch-thick section can be revealed by radiographs of transverse discs one-quarter to one-half-inch thick. The results of this type of examination may be seen in Figure 6. The transverse slices, one-half-inch thick, are numbered from "1" at the top of the bar to "30" at the bottom. This bar was bottom-gated and shrinkage was observed in the lower part.

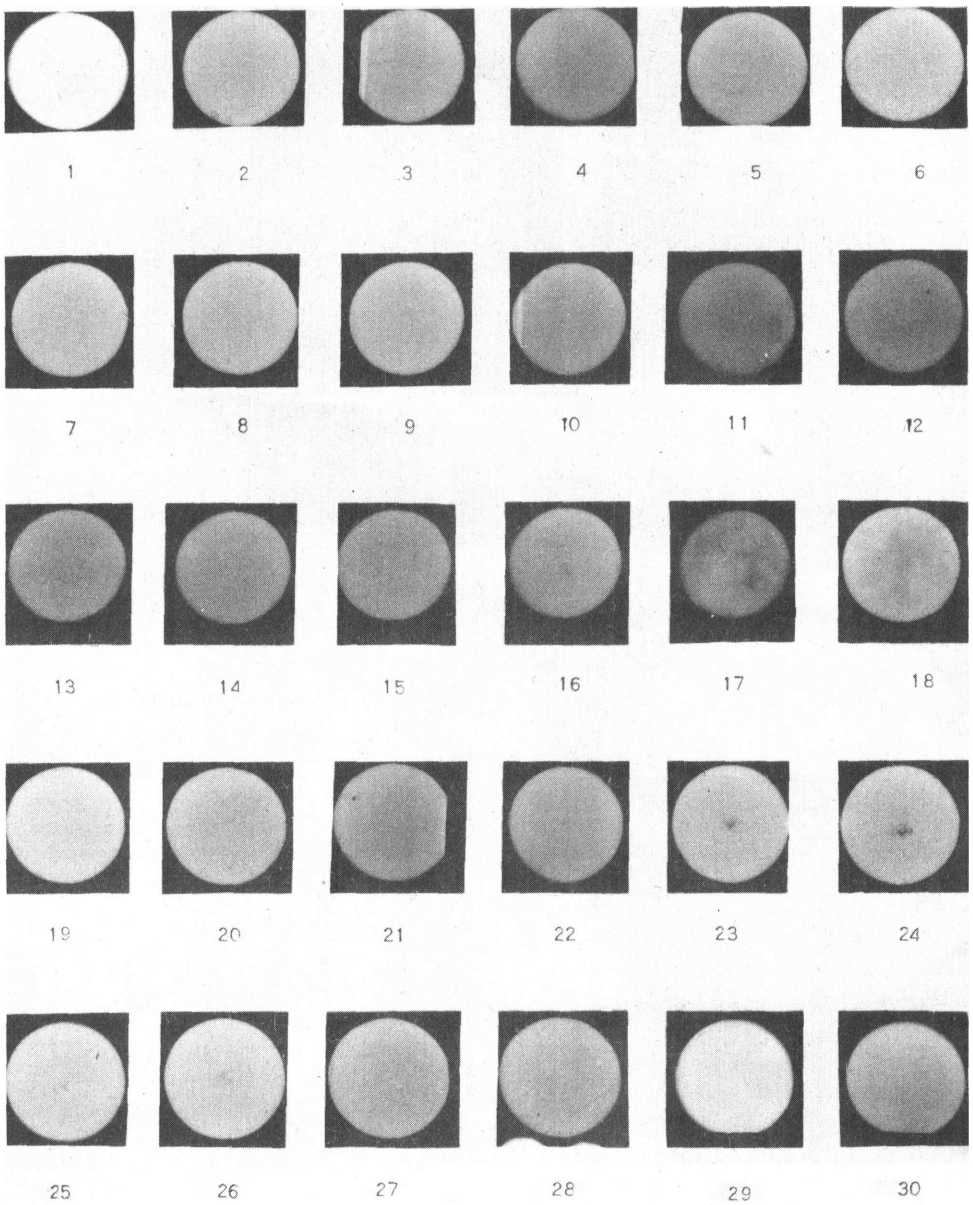

Fig. 6 - Radiographs of One-Half-Inch-Thick Transverse Slices of an Arbitration Bar - Numbered Consecutively from Top (1) to Bottom (30) of Bar

TABLE III

Summary of Transverse Bend Tests

Bar (Number)	Diameter at fracture, maximum and minimum (inches)	Corrected breaking load (pounds)	Corrected total deflection (inches)	Pouring position
1	1.284-1.267	2640	0.286	Vertical
3	1.184-1.165	3730	.300	Vertical
5	1.213-1.193	3260	.320	Vertical
7	1.291-1.230	1660	.232	Horizontal
9	1.301-1.251	1620	.244	Horizontal
11	1.193-1.176	2070	.205	Vertical
13	1.232-1.214	2130	.276	Vertical
15	1.212-1.204	3520	.283	Vertical
17	1.289-1.188	2690	.262	Horizontal
19	1.187-1.176	2810	.338	Vertical
21	1.184-1.177	2230	.225	Vertical
23	1.333-1.290	1420	.218	Vertical
25	1.259-1.228	2440	.309	Vertical
27	1.203-1.188	2730	.281	Vertical
29	1.239-1.210	3090	.260	Horizontal

After X-ray examination the arbitration bars were subjected to transverse bend tests, the results of which are summarized in Table III. The maximum and minimum diameters of the bars were measured at the point of fracture with a micrometer caliper. The breaking loads and total deflections were then corrected to the average diameter with the standard correction factors listed in Table II of the A.S.T.M. Standard Specification for Gray Iron Castings, A 48-46.

The tendency for horizontally cast test bars to have an elliptical cross section is apparent in bars 7, 9, and 17 in Figure 5. The difference between the maximum and minimum diameters of these three bars ranged from 0.050 inches to 0.101 inches. The vertical bars had more consistent dimensions, the usual difference in maximum and minimum diameters being 0.010 to 0.020 inches.

From each of the broken bars, four tensile test specimens were cut as shown in Figure 7. A summary of the results is given in Table IV. Column 4 shows for each arbitration bar the maximum percentage of deviation in tensile strength of any one specimen from the average of the four specimens. This deviation varied from a low of 1.2% to a high of 13.3%. The actual differences between the maximum and minimum tensile strengths varied from 900 to 6200 pounds per square inch. Thus, the choice of the location of the test bar may very well make the difference between the acceptance or rejection of a casting.

As shown in Figure 7, the strongest metal was usually found in position D, with C, B, and A successively weaker. Of twelve bars, nine had the strongest metal in position D and

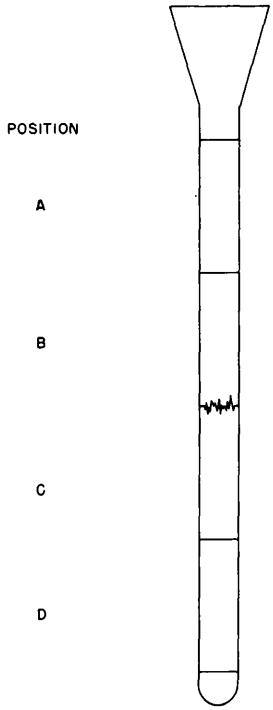

Fig. 7 - Location of Tensile Test Coupons Cut from Arbitration Bars

all twelve had the strongest metal in either C or D. Thus it may be concluded that the lower part of the bar contains the metal with the best tensile properties.

The relation of transverse strength to tensile strength may be seen in the graph of Figure 8. The band of maximum and minimum properties extends over a range of 800 pounds transverse strength and 14,000 psi tensile strength. For example, bars numbered 13 and 21 had approximately the same transverse strengths, but the former had a minimum tensile strength of 25,300 psi whereas the latter had a maximum of 41,200 psi - a difference of 15,900 psi! Similarly bars 19 and 21 had approximately the same tensile strengths, but their transverse properties were 2810 and 2230 pounds, respectively.

A good correlation of properties was obtained from the simplest test, i.e., macro-examination of the fracture. Table V shows three broad fracture classifications - coarse, medium, and fine - correlated with the tensile strength, transverse strength, and equivalent carbon. The range of these properties for each fracture group is quite well defined. This agreement may be partially attributed to the fact that all the specimens were cut from the same size of casting, namely, the 1.2 inch diameter arbitration bar.

Improved Techniques for Making Arbitration Bars

After examining the industry arbitration bars, efforts were directed toward improving the methods used for making the bars. After making a number of bars, it became apparent that the

TABLE IV

Industry Arbitration Bars

Arbitration Bar Number	Average Tensile Strength (psi)	Maximum Tensile Strength (psi)	Minimum Tensile Strength (psi)	Max. Deviation of Col. 3 or 4 from Col. 2 (%)	Difference between Max. and Min. Tensile Strength (psi)
1	42,700	43,200	41,400	3.0	1,800
3	60,700	62,800	59,400	3.5	3,400
5	55,000	56,800	53,100	3.5	3,700
7	19,300	20,200	18,400	4.7	1,800
9	18,100	20,500	16,600	13.3	3,900
*11	29,600	29,700	29,500	--	--
13	26,100	26,900	25,300	3.1	1,600
15	55,300	57,400	51,200	7.4	6,200
17	38,200	39,600	36,600	4.2	3,000
19	42,100	42,600	41,200	2.1	1,400
21	40,800	41,200	40,300	1.2	900
**23	18,400	19,400	17,600	--	--
**25	30,300	31,600	29,500	--	--
27	39,600	40,300	39,200	1.8	1,100
29	49,300	52,500	46,500	6.5	6,000

pattern materials, wood and aluminum, were too soft to resist the rough treatment received in the foundry. As previously mentioned, surface scratches and dents in the pattern are accurately transferred to the mold walls and appear on the finished casting. Steel patterns were next adopted but were susceptible to atmospheric corrosion. This was overcome by chromium plating which gave a pattern having a durable smooth surface with good corrosion resistance. Such a pattern was not damaged after several years' use.

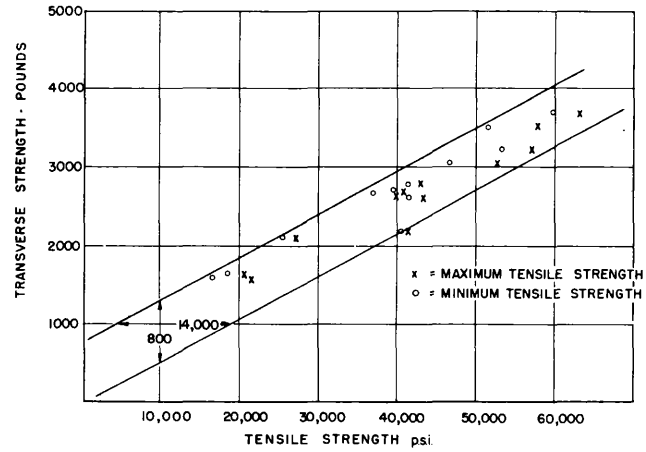

Fig. 8 - Transverse Strength vs Maximum and Minimum Tensile Strength of Each Arbitration Bar

The first bars were molded with a synthetic sand mixture having an AFA grain size fineness of 80. Because of rough surfaces obtained, mold washes were tried. In order to spray or brush the wash on the surface of the mold cavity, it was necessary to use horizontal ramming which had the disadvantage of producing a longitudinal fin running along the bar at the parting line between the cope and the drag. Washes were applied to vertical rammed molds by filling the cavity with a diluted plumbago mold wash. After a short lapse of time the wash was removed through either the bottom or the top of the mold. In either case the thickness of the wash had an undesirable taper from one end of the cavity to the other. Irregularities in wash thickness also resulted from localized variations in the rate of moisture absorption by the mold sand. It was difficult to dry the wash because of the shape of the mold cavity and therefore blowing, scabbing, and rat-tailing commonly resulted.

Surface improvement was then attempted by changing the sand mixture so that it contained 50% New Jersey mulled molding sand (140 g.f.n. with 18% clay and silt), 25% Albany sand, 25% Zanesville sand, and 7% H_2O. This sand burnt onto the surface of the arbitration bar and was very difficult to remove by sand blasting.

The next mixture tried contained 95% New Jersey silica sand with 135 g.f.n., 3% Western Bentonite, 1.5% dextrine, 0.5% corn flour binder, and 6% water. This mixture

TABLE V

Macro-Examination of Industry Arbitration Bars

	Coarse Fracture	Medium Fracture	Fine Fracture
Tensile Strength, psi	18,000 - 26,100	29,600 - 42,700	49,300 - 60,700
Transverse Strength, lbs.	1,420 - 2,130	2,070 - 2,810	3,090 - 3,730
Carbon Equivalent, % C + 1/3 (Si + P)	4.59 - 4.46	4.33 - 3.94	3.83 - 3.74

had adequate permeability, high strength, gave smooth surface, but had poor flowability. Flowability was improved by reducing the bentonite. The resulting mixture had good resistance to erosion and metal penetration. Its composition and physical properties were as follows:

Washed and dried silica sand (135 g.f.n.)	96%
Western bentonite	2%
Dextrine	1.5%
Corn flour binder	0.5%
Moisture	5-6%

The physical properties were:

Green permeability	38 - 48 AFA Units
Green strength	5.5 - 6.0 lbs/sq.in.
Hardness	70 - 78 AFA Units
Flowability	75 - 83%
Dry permeability	52 - 65 AFA Units
Dry strength	180 - 230 lbs/sq.in.

The first difficulty encountered in using this sand was the appearance of bands of metal penetration spaced along the length of the bar. This fault arises in vertical molding when too much sand is added between each ramming, creating a soft strata or band between the layer of sand already rammed and the next layer above it. This defect was minimized by reducing the amounts of sand added between ramming operations.

In molding the pattern in the vertical position the sand must flow normal to the direction of the force applied by the ramming mechanism. This disadvantage was overcome by placing the pattern in a horizontal position, so that the sand could be rammed uniformly hard against the entire surface.

In order to avoid the formation of an undesirable fin of metal along the parting line the special rigging practice shown in Figure 9 was devised. The hole in the end of the flask permits the pattern to be drawn out when ramming is completed. The pattern is placed on a follow board and the drag rammed. After the bottom plate has been clamped in position, the drag is rolled over and the follow board removed. A core print is bedded

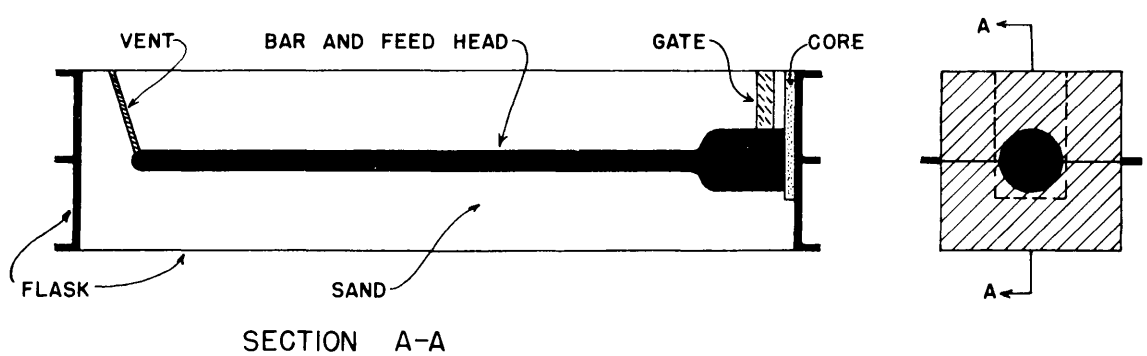

Fig. 9 - NRL Method of Molding Arbitration Bar

into the drag between the hole in the flask and the riser end of the pattern. This print extends to the top of the cope and is removed when ramming is completed. The sand at the joint is roughened so that subsequent ramming of the cope will eliminate all evidence of a parting line. A downgate is cut near the end of the riser. The pattern is then drawn out the end of the flask and a slab core inserted to seal off the hole. Another plate is clamped to the top of the cope. If vertical pouring is preferred, the slab core may be omitted. To avoid the formation of an elliptical cross section in horizontally poured molds, they are set up in a vertical position as soon as pouring is completed.

A series of tests proved that this procedure yielded bars with better physical properties than did vertical casting. In each test, one bar was poured in the vertical position and one in the horizontal followed immediately by raising to the vertical. The order of pouring in each set was alternated. The results of six sets poured from different heats are summarized in Table VI. In all but one instance, the vertical cast bars have less strength and ductility.

Several advantages of horizontal pouring followed by raising to the vertical position are: (1) by pouring the mold in a horizontal position, the long drop of the metal stream and attendant turbulence and erosion are eliminated, (2) by tilting the casting into a vertical position for solidification, the efficiency of the riser is increased by taking advantage of static pressure and directional solidification, (3) lifting to the vertical position eliminates the tendency for an elliptical cross section to develop during solidification, and (4) the short lapse of time before the mold is placed in the vertical position permits some metal skin to form on the mold surface, thus reducing penetration defects.

TABLE VI

Effect of Pouring Position on Physical Properties of Two-inch Diameter Arbitration Bars

Bar Number	Pouring Position	Transverse Strength (lb.)	Transverse Deflection (in.)
1	Vertical	10,200	0.356
2	Horizontal*	11,200	0.368
3	Vertical	9,900	0.295
4	Horizontal	9,800	0.277
5	Vertical	7,100	0.286
6	Horizontal	8,200	0.403
7	Vertical	7,250	0.324
8	Horizontal	7,400	0.349
9	Vertical	4,600	0.144
10	Horizontal	5,420	0.178
11	Vertical	4,620	0.159
12	Horizontal	4,920	0.179

*All bars marked "Horizontal" were poured in the horizontal position and set up vertically as soon as pouring ceased.

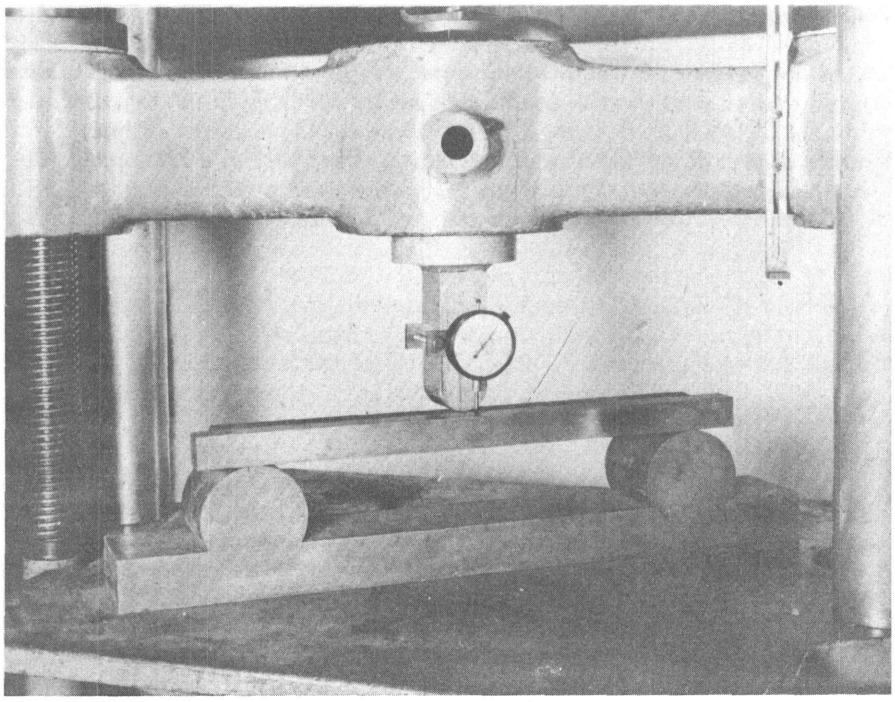

Fig. 10 - Front View of NRL Method for Transverse Testing of Arbitration Bars

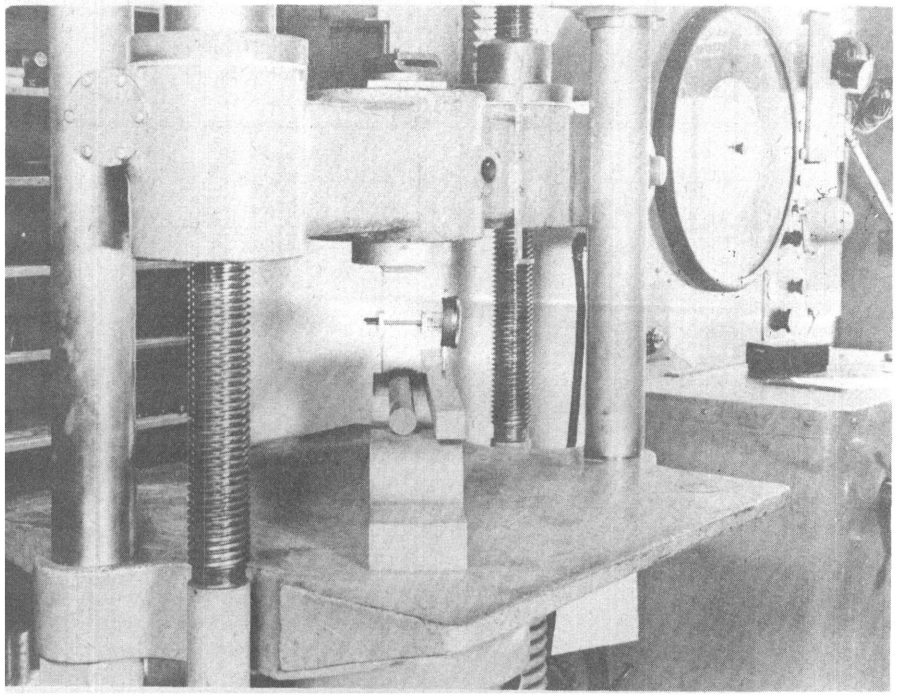

Fig. 11 - Side View of NRL Method for Transverse Testing of Arbitration Bars

Transverse Testing

Because of the great variety of techniques employed for measuring the deflection of arbitration bars during transverse loading, efforts were made to improve the accuracy of this measurement as well as to simplify the procedure. Figures 10 and 11 show two views of the equipment devised at the Naval Research Laboratory. A 1.2-inch arbitration bar is shown in position for the transverse bend test. The testing jig consists of a mild steel bar stock base 2 inches thick, 4 inches wide, and 28 inches long, with seatings machined out for placement of the bar supports 18 inches between centers. The two supports are made of similar steel, 4 inches in diameter and 4 inches long. A steel reference bar, measuring 1 inch by 1 inch by 22 inches is placed parallel to the arbitration bar. A Federal Extensometer dial, calibrated in units of .001 inches, is anchored to the testing machine ram with a clamp so positioned that the dial pin is in contact with the reference bar before the ram contacts the arbitration bar. An initial load of 50 pounds is applied to take up slack in the system, and the dial is set at zero. The loading is then commenced with deflection read directly on the dial at appropriate loads. As the bar nears the breaking point the dial is watched continuously in order to observe the maximum deflection obtained at the moment of fracture. The data can be corrected for average diameter of bar at fracture, as recommended by A.S.T.M. Specification A 48-46, and then be used to construct a stress-strain curve similar to the one shown in Figure 12. (An attempt to measure the indentation of the testing machine ram on the arbitration bar yielded values from 0.001 to 0.004 inches at a load of 1600 pounds, a small amount as compared with the total deflection of 0.2 to 0.3 inches.)

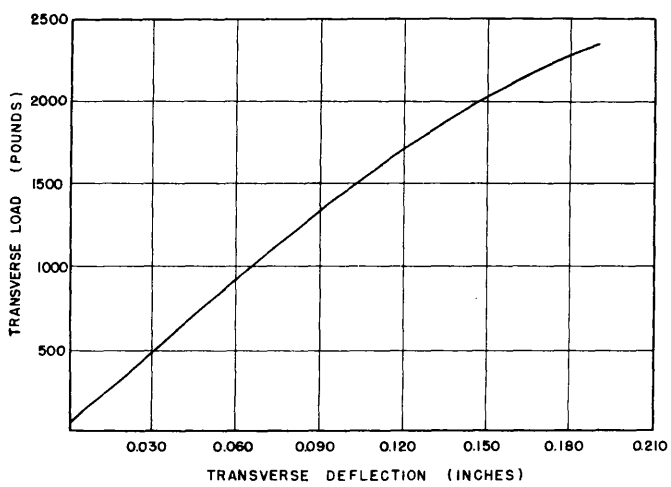

Fig. 12 - Stress - Strain Curve Constructed from Transverse Test Data

Of interest was the observation that gray cast iron will creep at room temperature when subjected to transverse loads. Figures 13 and 14 show the increase in transverse deflection occurring with time under a constant load of 1600 pounds. Since creep is plastic flow, the increase in strain with time remains as permanent set. In the overall time consumed for the transverse tests in this report, the effect of creep was negligible.

Effect of Size and Location on Tensile Properties

Since the cooling rate of cast iron is as important a factor as its chemical composition in determining its physical properties, it is practically impossible for any one test bar to represent accurately the properties of the large variety of shapes and sizes of castings common to the foundry industry.

The effect of size and location of tensile test specimens on the tensile strength was investigated by pouring eight blocks (3″ x 3″ x 10″ high) from the same ladle. The metal had a chemical composition of 2.98% C - 1.77% Si - 0.50% Mn - 0.026% S - 0.108% P. These blocks were sectioned longitudinally in such a manner as to provide tensile coupons with the variety of sizes and locations indicated in Figure 15. Tensile specimens were machined from these coupons so that the center of the gauge length of each one was located

three and one half inches from the bottom of the blocks. Standard 0.505 inch tensile specimens were obtained from 13 different locations on the cross section, 0.800-inch specimens from seven locations, and 1.25-inch specimens from three locations. The testing results are also shown in this figure.

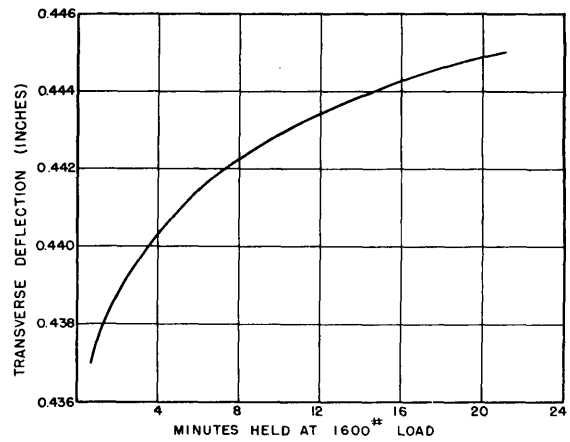

Fig. 13 - Plastic Deformation with Time - Arbitration Bar Held at 1600-Pound Transverse Load for 20 Minutes

When 0.505-inch-diameter specimens were used the tensile strength was found to vary from 34,875 psi at the outer corner to 26,500 psi at the center, whereas the 0.800-inch specimens showed a range from 33,900 psi at the corner to 27,100 psi in the center, and the 1.25-inch specimen from 28,200 psi to 26,800 psi. Thus in the corners the larger specimens have a lower tensile strength than the smaller because the larger specimens include metal which has lower tensile strength, and the larger specimens located at the center tend to have higher tensile strengths because they include higher strength material. A weak core of coarse-grained iron usually exists in the center; the greater the proportion it occupies in a specimen, the lower the tensile values observed.

Although cast iron is noted for its heterogeneity, a part of its cross section may be substantially uniform. For example, with the smaller specimen (0.505″) the tensile strength at the corners varied only from 34,125 psi to 34,875 psi whereas the larger specimens (0.800″) ranged from 30,100 psi to 33,900 psi. Evidently the outer one inch of metal in this casting is relatively uniform, and irregularity increases toward the center. This conclusion was further substantiated by the 0.505-inch specimens located one-half inch off center, the tensile strength of which varied from 28,875 psi to 31,125 psi.

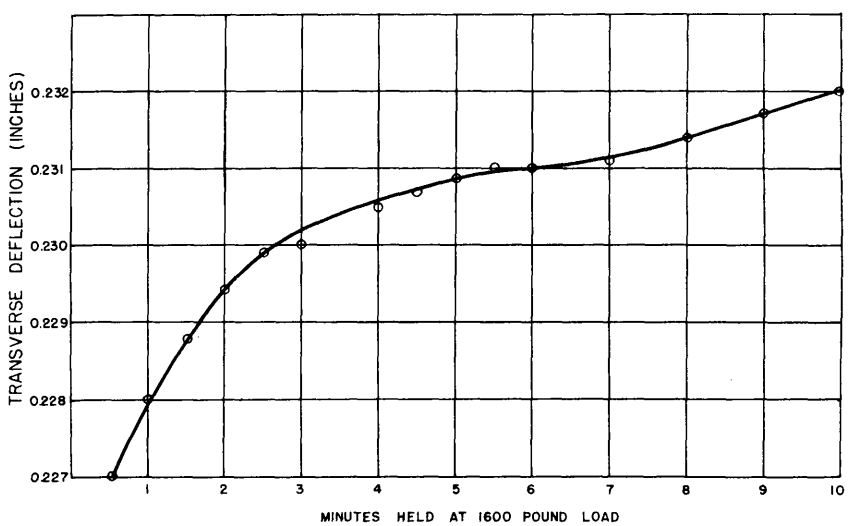

Fig. 14 - Plastic Deformation with Time - Arbitration Bar Held at 1600-Pound Transverse Load for 10 Minutes

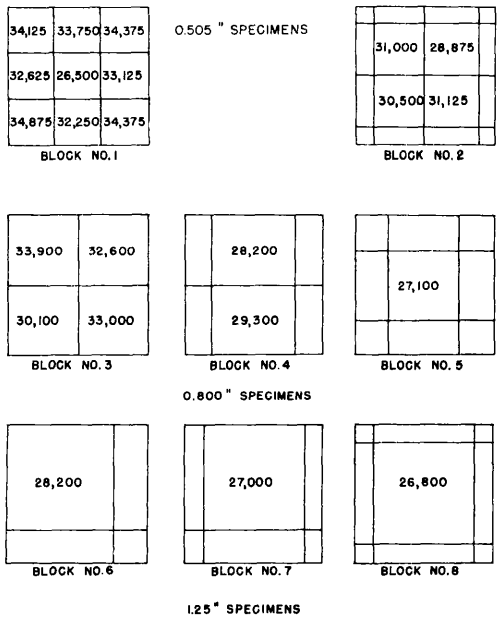

Fig. 15 - Effect of Size and Location of Tensile Specimen on Tensile Strength

CONCLUSIONS

The foundry industry is pouring arbitration bars in a variety of manners some of which lead to elliptical cross sections and to surface defects.

The tensile properties of cast iron vary considerably from one end of an arbitration bar to the other. The strongest metal is located near the bottom of the vertically cast top-poured bars.

The relation between transverse and tensile strength of individual arbitration bars is so inexact as to preclude any accurate prediction of either of these properties when the other is known.

From fracture appearance it is possible to estimate the approximate tensile and transverse strength and equivalent carbon of arbitration bars if the diameter and pouring temperature of the bars are held constant.

The best qualities in arbitration bars are obtained by:

(a) Using a chromium plated steel pattern.
(b) Using a fine grained sand.
(c) Ramming the mold in the horizontal position and drawing the pattern out the end of the flask.
(d) Pouring the bar in a horizontal position and setting it vertical as soon as possible.

A rapid, accurate, and inexpensive transverse testing technique consists of an extensometer dial anchored to the testing machine ram with the dial pin in contact with a rigid reference bar.

The smaller the tensile specimen taken from a casting of given cross section, the higher is the maximum and the lower the minimum observed strength.

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