SERIAL NO. **SSC-90**

Eighth

PROGRESS REPORT

(Project SR-110)

on

EFFECTS OF ALUMINUM ADDITIONS AND VARIATIONS IN FINISHING TEMPERATURE ON PROPERTIES OF HOT-ROLLED EXPERIMENTAL OPEN-HEARTH STEELS

by

R. H. FRAZIER, F. W. BOULGER and C. H. LORIG
Battelle Memorial Institute

Transmitted through

**NATIONAL RESEARCH COUNCIL'S
COMMITTEE ON SHIP STEEL**

Advisory to

SHIP STRUCTURE COMMITTEE

Division of Engineering and Industrial Research
National Academy of Sciences - National Research Council
Washington, D. C.

July 15, 1955

SERIAL NO. **SSC-90**
BuShips Project NS-011-078

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SECRETARY
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July 15, 1955

Dear Sir:

As part of its research program related to the improvement of hull structures of ships, the Ship Structure Committee is sponsoring an investigation of the influence of deoxidation and composition on properties of semikilled steel ship plate at the Battelle Memorial Institute. Herewith is a copy of the Eighth Progress Report, SSC-90, of the investigation entitled "Effects of Aluminum Additions and Variations in Finishing Temperature on Properties of Hot-Rolled Experimental Open-Hearth Steels" by R. H. Frazier, F. W. Boulger and C. H. Lorig.

The project is being conducted with the advisory assistance of the Committee on Ship Steel of the National Academy of Sciences-National Research Council.

Any questions, comments, criticism or other matters pertaining to the report should be addressed to the Secretary, Ship Structure Committee.

This report is being distributed to those individuals and agencies associated with and interested in the work of the Ship Structure Committee.

Yours sincerely,

K. K. Cowart

K. K. COWART
Rear Admiral, U. S. Coast Guard
Chairman, Ship Structure Committee

EIGHTH
Progress Report
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R. H. Frazier
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under

Department of the Navy
Bureau of Ships NObs-53239
BuShips Project No. NS-011-078

for

SHIP STRUCTURE COMMITTEE

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EFFECTS OF ALUMINUM ADDITIONS AND VARIATIONS IN FINISHING TEMPERATURE ON PROPERTIES OF HOT-ROLLED EXPERIMENTAL OPEN-HEARTH STEELS

INTRODUCTION

Small amounts of aluminum are sometimes added to semikilled steel in order to control the evolution of gas during freezing and the final structure of the ingot. Aluminum additions large enough to suppress all gas evolution produce killed steels which are characterized by their tendency to shrink on solidification and to form pipe cavities. Even with devices such as hot-tops which reduce piping, killed steel ingots give lower yields of usable product than do semikilled ingots. Furthermore, the capacity of the United States to produce the more expensive killed steel is considerably below the tonnage of ship plate that would be required in an emergency.

The experimental work described in this report was done principally on semikilled steels which could be manufactured in sufficient quantity for ship plate in the event of an emergency. The steels used were provided by three commercial producers of ship plate.

The principal objective of the present investigation was to determine the influence of small amounts of aluminum on the properties of hot-rolled open-hearth steels. A previous study(1) showed that aluminum additions lowered the Charpy and tear test transition temperatures of hot-rolled laboratory steels. Since adequate quantities of the open-hearth steels were available, it was also desirable to study the influence of finishing temperatures on these steels. This work was done on a laboratory rolling mill.

MATERIALS

Each of three steel companies furnished eight 3/4-in. and eight 1 3/4-in. thick plates for the investigation. One plate of each thickness was taken from each ingot made for the program. Two types of steel, one containing, nominally, 0.25% carbon and 0.45% manganese, the other containing 0.21% carbon and 0.75% manganese, were studied. These compositions are typical of steels currently supplied under specifications set by the American Bureau of Shipping for Classes A and B steels. The silicon contents of all steels were within the normal range for semikilled steels. Each company furnishing the steels added various amounts of aluminum to the molds to produce four ingots from each steel grade with different aluminum contents. The acid-soluble aluminum content of the steels containing the largest aluminum addition was intended to be approximately 0.020 per cent. Normally, an addition to give this amount of aluminum would be made to the ladle instead of to the ingot in the mold. Because of this variation from normal practice, all of the steels must be classed as being of experimental rather than of commercial quality.

The 1 3/4-in. plates were rolled to 3/4-in. plates in the laboratory using finishing temperatures of 1650, 1850, and 2050 F.

Full-thickness strip tensile specimens were used to determine the tensile properties. The notched bar properties were established using the Navy tear test and the keyhole notch Charpy test.

The three steel companies who supplied the experimental plates were major steel plate producers. Each had certain standard practices of steelmaking and rolling which were followed in producing the experimental plates. The melting and rolling data for each heat are summarized in Tables 1 and 2. The reported furnace and ladle additions were made to give the desired steel compositions. Company "V" also made an addition of ferro-silicon to the top of the ingot containing no aluminum to control mold action. Company "Z" found it necessary to add three ounces of aluminum per ton of steel to control the mold action in ingots of low-aluminum-containing steel.

The plates were rolled from various sized ingots, as indicated in the tables. During their rolling, therefore, the plates received different rolling reductions which might have some influence on their properties. Company "Z" reported that some cross rolling was done on their plates. The reported finishing temperature of plates from Company "W" was about 250 F lower than the average reported for plates from Company "V".

The chemical analyses furnished by the steel companies are shown in Tables 3 and 4. Two companies reported small variations in composition between the 3/4-in. plates and the 1 3/4-in. plates,

TABLE 1. OPEN-HEARTH AND ROLLING DATA FOR THREE EXPERIMENTAL TYPE A STEELS (0.25% C, 0.45% Mn)

Steel Company:	W	V	Z
Heat:	64C623	8504	65M439
Furnace Additions:	Not reported	None	None
Ladle Additions:			
80% FeMn	2.25 lb/ton	10.9 lb/net ton	12.82 lb/ton
50% FeSi	4.5 "	3.4 "	2.99 "
Coke	None	1.4 "	None
Coal	None	None	0.85 lb/ton
Mold Additions:			
84% FeSi	None	0.4 lb*	None
Aluminum †	Various	Various	Various
Mold Size:			
Plain Top	26" x 50" x 84"	--	Not reported
Hot Top	31" x 50" x 66"	--	Ditto
For 3/4" Plate	--	22 1/2" x 34"	"
For 1 3/4" Plate	--	22 1/2" x 24 1/2"	"
Cross Rolling:	Not reported	None	Some**
Finishing Temp for 3/4" Plates:	1700-1750 F	1850-1990 F	1850-1890 F

Footnotes:

*An addition of 0.4 lb. of 84% ferro-silicon was made to the top of the ingot containing no aluminum.

**The ingots were rolled straightaway to slabs 60 in. wide by 8 in. thick. To produce the 3/4-in. plates, the slabs were cross rolled 112% to a width of 127 in. before final rolling. To produce the 1 3/4-in. plates, the slabs were cross rolled 28.4% to a width of 77 in.

†See Table 3 for aluminum additions.

TABLE 2. OPEN-HEARTH AND ROLLING DATA FOR THREE EXPERIMENTAL TYPE B STEELS (0.21% C, 0.75% Mn)

Steel Company:	W	V	Z
Heat:	67C658	6354	73M393
Furnace Additions:			
80% FeMn	Not reported	None	16.5 lb/ton
20% Spiegleisen	Ditto	6.3 lb/net ton	None
15% FeSi	"	None	12.8 lb/ton
Ladle Additions:			
80% FeMn	9.1 lb/ton	16.9 lb/net ton	6.16 lb/ton
50% FeSi	4.0 lb/ton	3.0 lb/net ton	0.62 lb/ton
Coke	None	0.4 lb/net ton	None
Mold Additions:			
84% FeSi	None	0.5 lb*	None
Aluminum†	Various	Various	Various
Mold Size:			
Plain Top	26" x 50" x 80"	--	--
Hot Top	31" x 50" x 65"	--	--
For 3/4" Plate	--	22 1/2" x 34"	--
For 1 3/4" Plate	--	22 1/2" x 24 1/2"	--
Cross Rolling:	Not reported	None	Some**
Finishing Temp for 3/4" Plates:	1700-1800 F	1980-2000 F	1810-1830 F

Footnotes:

*An addition of 0.5 lb. of 84% ferro-silicon was made to the top of the ingot containing no aluminum.

**The ingots were rolled straightaway to slabs 60 in. wide by 8 in. thick. To produce the 3/4-in. plate, the slabs were cross rolled 112% to a width of 127 in. before final rolling. To produce the 1 3/4-in. plates, the slabs were cross rolled 28.4% to a width of 77 in.

†See Table 3 for aluminum additions.

TABLE 3. CHEMICAL COMPOSITION OF EXPERIMENTAL OPEN-HEARTH STEELS COMMERCIALLY ROLLED TO 3/4-IN. THICK PLATES

Steel Co.	Steel	Composition, per cent C	Mn	P	S	Si	Aluminum Acid Sol.	Aluminum Acid Insol.	Aluminum Added, lb/ton of steel
					Type A Steel				
W	W-1	0.23	0.52	0.013	0.037	0.09	<0.003	<0.003	0
W	W-2	0.23	0.52	0.011	0.037	0.10	<0.003	<0.003	1/4
W	W-3	0.23	0.52	0.012	0.041	0.09	<0.003	<0.003	1/2
W	W-4	0.23	0.52	0.013	0.039	0.10	0.020	<0.003	1
					Type B Steel				
W	W-5	0.23	0.78	0.012	0.025	0.09	<0.003	<0.003	0
W	W-6	0.22	0.80	0.013	0.026	0.08	<0.003	0.006	1/4
W	W-7	0.20	0.80	0.012	0.025	0.08	<0.003	0.008	1/2
W	W-8	0.21	0.78	0.013	0.026	0.08	0.029	0.008	1
					Type A Steel				
Z	Z-5	0.27	0.50	0.017	0.041	0.06	<0.003	<0.003	3/16
Z	Z-6	0.27	0.51	0.017	0.042	0.06	<0.003	<0.003	3/8
Z	Z-7	0.27	0.49	0.017	0.042	0.06	0.006	<0.003	3/4
Z	Z-8	0.27	0.50	0.018	0.042	0.06	0.043	<0.003	1-1/2
					Type B Steel				
Z	Z-1	0.19	0.67	0.012	0.028	0.04	<0.003	<0.003	3/16
Z	Z-2	0.19	0.68	0.013	0.028	0.04	<0.003	0.003	3/8
Z	Z-3	0.18	0.68	0.012	0.027	0.04	0.003	<0.003	3/4
Z	Z-4	0.19	0.68	0.013	0.027	0.04	0.027	<0.003	1-1/2
					Type A Steel				
V	V-1	0.26	0.45	0.008	0.032	0.09	<0.003	<0.003	0*
V	V-2	0.27	0.45	0.009	0.032	0.07	<0.003	<0.003	0.09
V	V-3	0.28	0.46	0.009	0.032	0.09	0.005	0.011	0.54
V	V-4	0.29	0.45	0.009	0.032	0.07	0.018	0.009	0.84
					Type B Steel				
V	V-5	0.21	0.67	0.012	0.033	0.07	<0.003	0.005	0*
V	V-6	0.19	0.67	0.011	0.032	0.07	0.004	0.006	0.09
V	V-7	0.22	0.67	0.012	0.033	0.07	0.006	0.012	0.54
V	V-8	0.19	0.66	0.011	0.033	0.08	0.017	0.008	0.84

*An addition of 0.4 lb. of 84% ferro-silicon was made to the top of the ingot.

TABLE 4. CHEMICAL COMPOSITION OF EXPERIMENTAL OPEN-HEARTH STEELS ROLLED FROM 1 3/4- TO 3/4-IN. PLATES IN LABORATORY

Steel Co.	Steel	Composition, per cent C	Mn	P	S	Si	Aluminum Added, lb/ ton of steel
				Type A Steel			
W	W-1	0.23	0.52	0.013	0.037	0.09	0
W	W-2	0.23	0.52	0.011	0.037	0.10	1/4
W	W-3	0.23	0.52	0.012	0.041	0.09	1/2
W	W-4	0.23	0.52	0.013	0.039	0.10	1
				Type B Steel			
W	W-5	0.23	0.78	0.012	0.025	0.09	0
W	W-6	0.22	0.80	0.013	0.026	0.08	1/4
W	W-7	0.20	0.80	0.012	0.025	0.08	1/2
W	W-8	0.21	0.78	0.013	0.026	0.08	1
				Type A Steel			
Z	Z-5	0.30	0.51	0.019	0.051	0.06	3/16
Z	Z-6	0.29	0.52	0.018	0.046	0.06	3/8
Z	Z-7	0.29	0.51	0.017	0.050	0.06	3/4
Z	Z-8	0.29	0.50	0.018	0.048	0.06	1-1/2
				Type B Steel			
Z	Z-1	0.21	0.70	0.013	0.030	0.04	3/16
Z	Z-2	0.21	0.71	0.013	0.036	0.04	3/8
Z	Z-3	0.20	0.70	0.012	0.028	0.04	3/4
Z	Z-4	0.20	0.68	0.013	0.027	0.04	1-1/2
				Type A Steel			
V	V-1	0.27	0.48	0.007	0.033	0.08	*
V	V-2	0.26	0.48	0.007	0.034	0.07	0.09
V	V-3	0.27	0.48	0.008	0.034	0.08	0.54
V	V-4	0.27	0.48	0.009	0.031	0.07	0.84
				Type B Steel			
V	V-5	0.19	0.68	0.012	0.034	0.07	*
V	V-6	0.20	0.69	0.010	0.034	0.06	0.09
V	V-7	0.18	0.68	0.011	0.032	0.07	0.54
V	V-8	0.19	0.68	0.011	0.033	0.07	0.84

*An addition of 0.4 lb. of 84% ferro-silicon was made to the top of the ingot.

although they were from the same heat of steel. All aluminum analyses were made at Battelle. The carbon contents varied from 0.23 per cent to 0.30 per cent in Type A steels and from 0.18 per cent to 0.23 per cent in Type B steels. Manganese ranged from 0.45 per cent to 0.52 per cent in Type A steels and from 0.66 per cent to 0.80 per cent in Type B steels. All of the steels had low phosphorus contents, the highest reported value being 0.017 per cent. Sulfur contents were within narrow limits and averaged 0.032 per cent. The silicon contents of all steels were under 0.11 per cent.

Each company used somewhat different aluminum additions to the mold to obtain the several series of four steels having increasing amounts of acid-soluble aluminum. The recovery of acid-soluble aluminum from these mold additions, shown in Fig. 1, was approximately the same as that obtained from similar additions to laboratory induction-furnace-melted steels of the same type.

The 3/4-in. plates produced by the steel plants were tested in the as-received condition. The 1 3/4-in. plates were rolled to 3/4-in. plates at Battelle using a laboratory rolling mill and finishing at either 1650, 1850, or 2050 F. Sections of the 1 3/4-in. plate were heated to 2250 F and rolled to 0.9 in. using reductions of 1/6 in. per pass. After the initial rolling, the plates were placed in a furnace at the desired finishing temperature, held for thirty minutes, and then rolled to 3/4-in. plate

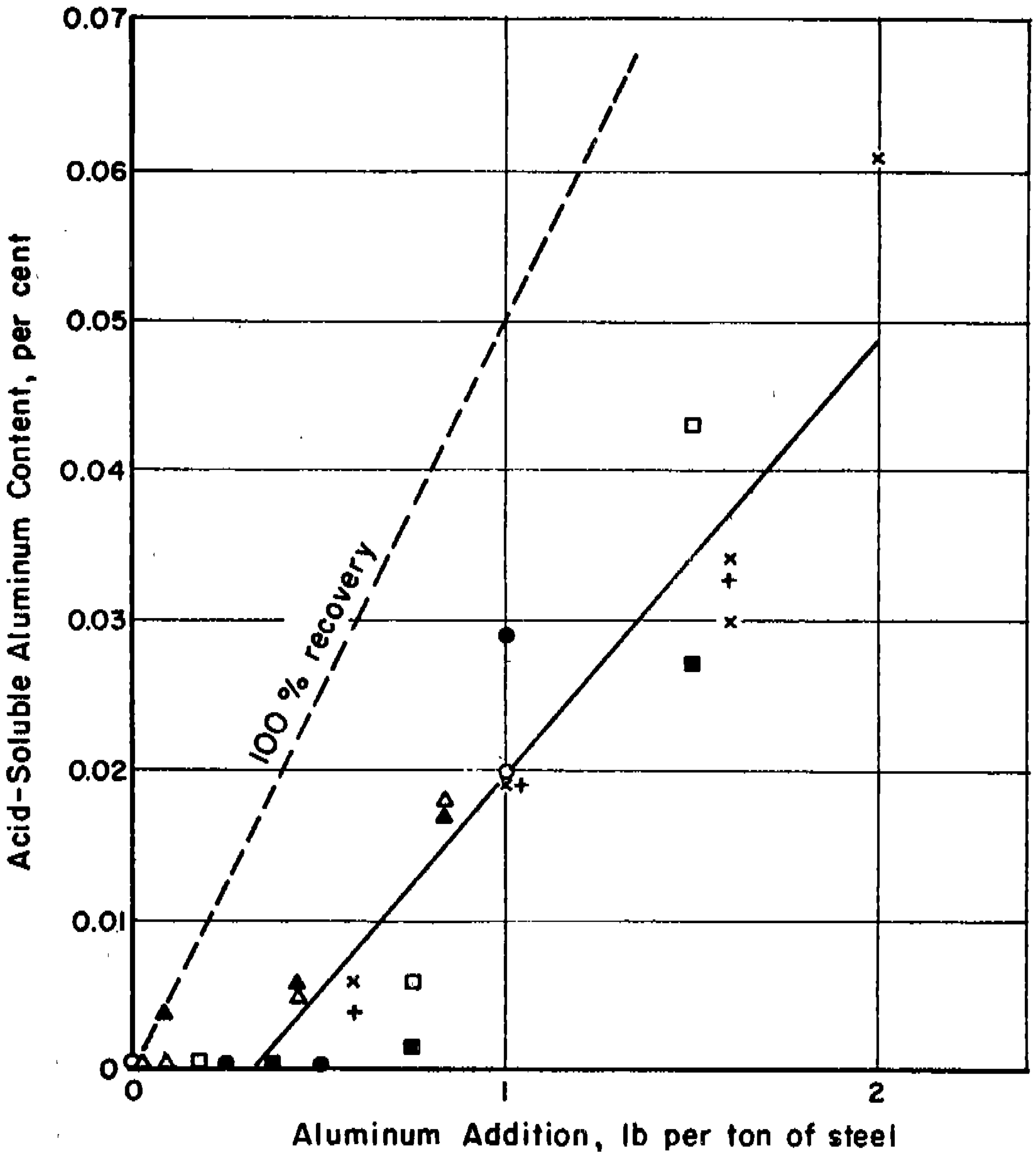

FIGURE I. RECOVERY OF ACID-SOLUBLE ALUMINUM FROM VARIOUS ALUMINUM ADDITIONS

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in a single pass. The plates were placed on edge, separated from each other by a brick, and allowed to cool in air. Test specimens were then cut from these plates.

TENSILE PROPERTIES

Duplicate full-thickness strip tensile tests were made from each commercially rolled 3/4-in. plate. Test data for each specimen are recorded in Table A-1 of the Appendix. The average tensile strengths, shown in Table 5, vary from 59,700 to 70,900 psi. Only two groups of steels, Z-1 to Z-4 and V-5 to V-8, had tensile strengths of less than 60,000 psi. These steels were expected to have the lowest tensile strengths of all the steels tested, since they had the lowest carbon and manganese contents. The steels with the lowest strengths also had the highest elongation values.

The tensile properties given in Table 6 were reported by Company "W" for their 3/4-in. plates. The difference in the average tensile strength of the eight plates, as determined by the company and in this investigation, was only 325 psi, with the maximum difference for any individual steel being 3750 psi. Similarly, the difference in average yield-strength values was only 480 psi, with the maximum difference for any individual steel being 4800 psi.

TABLE 5. TENSILE PROPERTIES OF HOT-ROLLED EXPERIMENTAL OPEN-HEARTH STEELS CONTAINING VARIOUS AMOUNTS OF ALUMINUM

Steel	Composition, per cent			Tensile Strength, psi	Yield Point, psi		Elong in 8", %
	C	Mn	Al		Upper	Lower	
W-1	0.23	0.52	<0.003	65,650	34,850	34,100	29.5
W-2	0.23	0.52	<0.003	65,900	33,550	33,050	28.0
W-3	0.23	0.52	<0.003	65,750	36,600	34,400	28.0
W-4	0.23	0.52	0.020	65,600	36,900	34,000	29.0
W-5	0.23	0.78	<0.003	70,900	37,100	36,650	28.0
W-6	0.22	0.80	<0.003	70,550	39,100	36,750	27.5
W-7	0.20	0.80	<0.003	67,650	35,950	34,950	29.0
W-8	0.21	0.78	0.029	67,600	36,400	35,450	28.5
Z-5	0.27	0.50	<0.003	64,450	34,000	33,100	28.5
Z-6	0.27	0.51	<0.003	65,250	34,150	33,100	29.0
Z-7	0.27	0.49	0.006	65,750	35,400	33,250	29.0
Z-8	0.27	0.50	0.043	66,000	34,700	33,700	29.0
Z-1	0.19	0.67	<0.003	61,050	34,650	33,200	30.0
Z-2	0.19	0.68	<0.003	61,450	33,900	32,800	30.5
Z-3	0.18	0.68	0.003	59,700	33,450	32,400	32.0
Z-4	0.19	0.68	0.027	59,750	33,400	32,400	32.0
V-1	0.26	0.45	<0.003	63,950	34,050	33,050	29.0
V-2	0.27	0.45	<0.003	64,050	34,000	32,500	30.5
V-3	0.28	0.46	0.005	65,000	37,800	34,750	30.0
V-4	0.29	0.45	0.018	64,700	34,900	32,450	28.0
V-5	0.21	0.67	<0.003	60,050	33,050	31,350	32.0
V-6	0.19	0.67	0.004	60,000	34,300	32,550	31.5
V-7	0.22	0.67	0.006	62,800	35,400	32,850	27.5
V-8	0.19	0.66	0.017	61,650	33,150	32,250	30.0

TABLE 6. TENSILE PROPERTIES OF EXPERIMENTAL OPEN-HEARTH STEELS DETERMINED BY STEEL COMPANY "W"

Steel	Composition, per cent C	Mn	Al	Tensile Strength, psi	Yield Strength, psi	Elong., in 8" %
W-1	0.23	0.52	<0.003	66,400	36,200	27
W-2	0.23	0.52	<0.003	65,800	32,800	28
W-3	0.23	0.52	<0.003	67,600	41,400	27
W-4	0.23	0.52	0.020	66,200	39,200	30
W-5	0.23	0.78	<0.003	68,400	36,500	29
W-6	0.22	0.80	<0.003	66,800	35,900	28
W-7	0.20	0.80	<0.003	67,000	35,000	26
W-8	0.21	0.78	0.029	68,800	37,300	28

FERRITE GRAIN SIZE

The ferrite grain size of each plate was determined by a counting method which had been described in an earlier publication[2]. Photomicrographs taken on both longitudinal and transverse cross sections of the plates were used to obtain the average grain count given in Table 7. Variations in aluminum content did not significantly affect the ferrite grain size of the hot-rolled plates from a given series finish-rolled at the same temperature. This observation was also noted in a study[1] using laboratory induction-melted steels. Finishing temperature, on the other hand, did influence the ferrite grain size of plates rerolled in the laboratory, as shown in Fig. 2. A decrease of 400 F in finishing temperature reduced the ferrite grain size on the average almost one ASTM (American Society for Testing Materials) grain-size number. Hodge and others[3] found that a reduction in ferrite grain size corresponding to one ASTM number lowers the keyhole Charpy transition 30 F. Accordingly, lowering the finishing temperature from 2050 F to 1650 F, as was done in the present study, would be expected to lower the Charpy transition temperature almost 30 F. As discussed later, the actual change in transition temperature was 25 F over this range in finishing temperature.

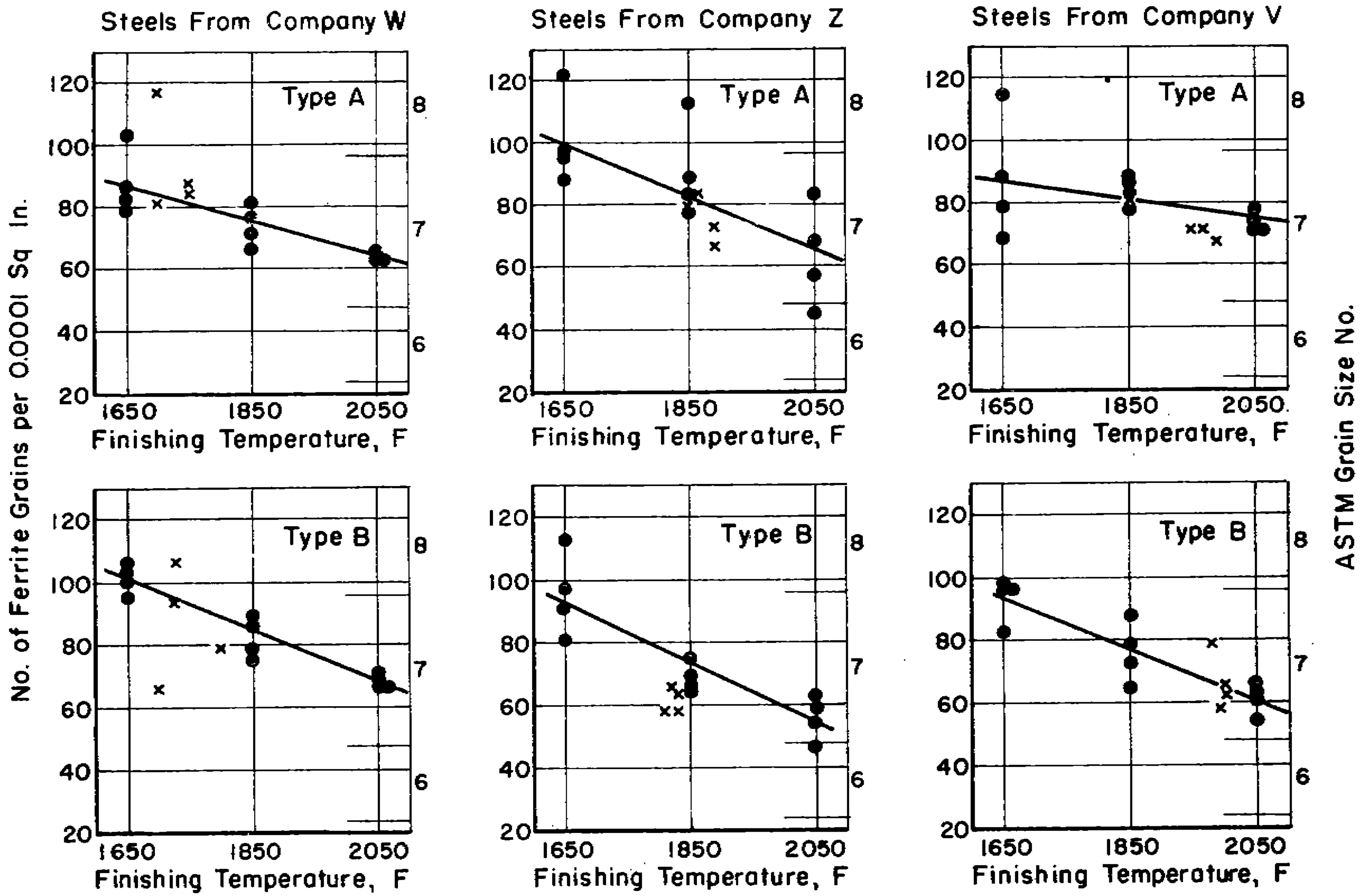
TABLE 7. FERRITE GRAIN SIZE OF 3/4-IN. EXPERIMENTAL OPEN-HEARTH STEEL PLATES

Steel	Composition, %* C	Composition, %* Mn	Composition, %* Al**	Aluminum Added, lb/ton of steel	Commercially Finished Plate: Finishing Temp, F	Commercially Finished Plate: No. of Ferrite Grains Per Square Inch at 100X†	No. of Ferrite Grains Per Square Inch at 100X † of Laboratory-Finished Plate: Finished at 1650 F	Finished at 1850 F	Finished at 2050 F
W-1	0.23	0.52	<0.003	0	1700	116	79	72	66
W-2	0.23	0.52	<0.003	0.25	1750	87	86	81	65
W-3	0.23	0.52	<0.003	0.50	1750	85	83	77	63
W-4	0.23	0.52	0.020	1.00	1700	81	103	67	63
W-5	0.23	0.78	<0.003	0	1700	66	107	86	69
W-6	0.22	0.80	<0.003	0.25	1725	94	103	88	68
W-7	0.20	0.80	<0.003	0.50	1800	79	95	75	68
W-8	0.21	0.78	0.029	1.00	1725	107	101	79	71
Z-5	0.27	0.50	<0.003	0.19	1890	67	121	112	68
Z-6	0.27	0.51	<0.003	0.38	1850	80	88	88	83
Z-7	0.27	0.49	0.006	0.75	1855	83	97	83	45
Z-8	0.27	0.50	0.043	1.50	1890	73	96	77	57
Z-1	0.19	0.67	<0.003	0.19	1820	67	91	75	63
Z-2	0.19	0.68	<0.003	0.38	1810	58	81	69	55
Z-3	0.18	0.68	0.003	0.75	1830	58	98	68	47
Z-4	0.19	0.68	0.027	1.50	1830	65	114	67	59
V-1	0.26	0.45	<0.003	0	1950	72	69	88	71
V-2	0.27	0.45	<0.003	0.09	1965	72	115	86	77
V-3	0.28	0.46	0.005	0.54	1850	80	78	78	74
V-4	0.29	0.45	0.018	0.84	1990	68	88	82	71
V-5	0.21	0.67	<0.003	0	2000	64	97	88	61
V-6	0.19	0.67	0.004	0.09	1980	79	98	79	55
V-7	0.22	0.67	0.006	0.54	2000	65	83	65	66
V-8	0.19	0.66	0.017	0.84	1990	58	97	73	64

*Composition of the commercially finished 3/4-in. plate

**Acid-soluble aluminum content

†Ferrite grain count is the average of two determinations



Steels finished in commercial mills indicated by x. Solid circles are for steels rerolled from $1\frac{3}{4}$-to $\frac{3}{4}$-inch plate in the laboratory.

FIGURE 2. EFFECT OF FINISHING TEMPERATURE ON THE FERRITE GRAIN SIZE OF OPEN-HEARTH STEELS

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KEYHOLE-NOTCH CHARPY PROPERTIES

The Charpy transition curve for each steel was determined from the average values of four specimens broken at each of several temperatures 10 F apart. The specimens were taken from the center of the plate thickness parallel to the direction of rolling and were notched normal to the plate surface. A bath of ethyl alcohol cooled by dry ice was used to obtain the desired temperature for specimens tested below room temperature. The specimens tested at room temperature or above were heated in a water bath.

The transition temperature used for interpreting the results was defined as the temperature at which the average Charpy value was 12 ft-lb. The 20 ft-lb transition temperature is sometimes used in investigations of this type. However, because the Charpy values of the ductile specimens from some of the steels in the present study were not much higher than 20 ft-lb, which would give them abnormally high transition temperatures, this criterion was not used. Transition temperatures based on other Charpy value criteria can be obtained from the data given in the Appendix.

The test data for each specimen are recorded in Tables A-2 through A-4 in the Appendix. The transition temperatures for each steel rolled at each of four finishing temperatures are shown in Table 8. Variations in acid-soluble aluminum contents up to 0.043 per cent had no consistent effect on the Charpy transition

TABLE 8. SUMMARY OF CHEMICAL COMPOSITIONS AND KEYHOLE CHARPY TRANSITION TEMPERATURES† OF EXPERIMENTAL OPEN-HEARTH STEELS

Steel	Composition, %[1] C	Composition, %[1] Mn	Composition, %[1] Al[2]	Commercially Finished Plate: Finishing Temp, F	Commercially Finished Plate: Keyhole Charpy Transition Temp, F	Keyhole Charpy Transition Temperatures of Laboratory-Finished Plate, F: Finished at 1650 F	Finished at 1850 F	Finished at 2050 F
W-1	0.23	0.52	<0.003	1700	-19	-34	-10	-18
W-2	0.23	0.52	<0.003	1750	-17	-17	-10	-14
W-3	0.23	0.52	<0.003	1750	+2	-33	-38	-25
W-4	0.23	0.52	0.020	1700	-15	-34	-31	-22
W-5	0.23	0.78	<0.003	1700	-8	-50	-23	-13
W-6	0.22	0.80	<0.003	1725	-4	-43	-17	-5
W-7	0.20	0.80	<0.003	1800	-43	-63	-49	-37
W-8	0.21	0.78	0.029	1725	-37	-62	-40	-40
Z-5	0.27	0.50	<0.003	1890	-1	-14	-10	+8
Z-6	0.27	0.51	<0.003	1850	+2	-16	-7	+9
Z-7	0.27	0.49	0.006	1855	+9	-2	+12	+21
Z-8	0.27	0.50	0.043	1890	0	-14	-10	+18
Z-1	0.19	0.67	<0.003	1820	-18	-37	-30	-12
Z-2	0.19	0.68	<0.003	1810	-10	-31	-16	-4
Z-3	0.18	0.68	0.003	1830	-16	-38	-21	-4
Z-4	0.18	0.68	0.027	1830	-37	-53	-35	-17
V-1	0.26	0.45	<0.003	1950	+22	-14	+2	-3
V-2	0.27	0.45	<0.003	1965	+28	-1	+9	+8
V-3	0.28	0.46	0.005	1850	+11	-16	-5	+8
V-4	0.29	0.45	0.018	1990	+27	-20	-5	-1
V-5	0.21	0.67	<0.003	2000	-4	-23	-10	-23
V-6	0.19	0.67	0.004	1980	0	-30	-27	-18
V-7	0.22	0.67	0.006	2000	-21	-50	-41	-22
V-8	0.19	0.66	0.017	1990	-16	-64	-34	-31

*Composition of the commercially finished 3/4-in. plate

**Acid-soluble aluminum content

†The transition temperature is defined as the temperature at which the average Charpy value is 12 ft-lb

temperature. A previous study on the effect of aluminum indicated that the transition temperature would be lowered less than 10 F by the amounts of aluminum present in these steels. The reproducibility of the Charpy test is not sufficient to detect changes of less than 10 F consistently.

The Charpy transition temperature of the steel plates rolled from 1 3/4 to 3/4 in. in the laboratory mill generally increased with increases in finishing temperature. In Fig. 3 their average Charpy transition temperatures are plotted against their finishing temperatures. The transition temperatures of the plates finish-rolled in the commercial mills are also shown. On the average, an increase of 100 F in finishing temperature was found to raise the transition temperature 6 F. The data for plates from the same heats that had been rerolled in the laboratory fit straight lines very well. The variation in slopes of the lines, however, cannot be explained on the basis of the information available. The transition temperatures of the plates finished in commercial mills were always higher than those of plates which had been finish-rolled in the laboratory. In some cases this difference in transition temperature was as much as 20 F for plate finish-rolled at the same temperature. These differences in transition temperatures were not caused by differences in ferrite grain size. One possible explanation for this difference might be that the plate finished in the commercial mills cooled more slowly after rolling than did the

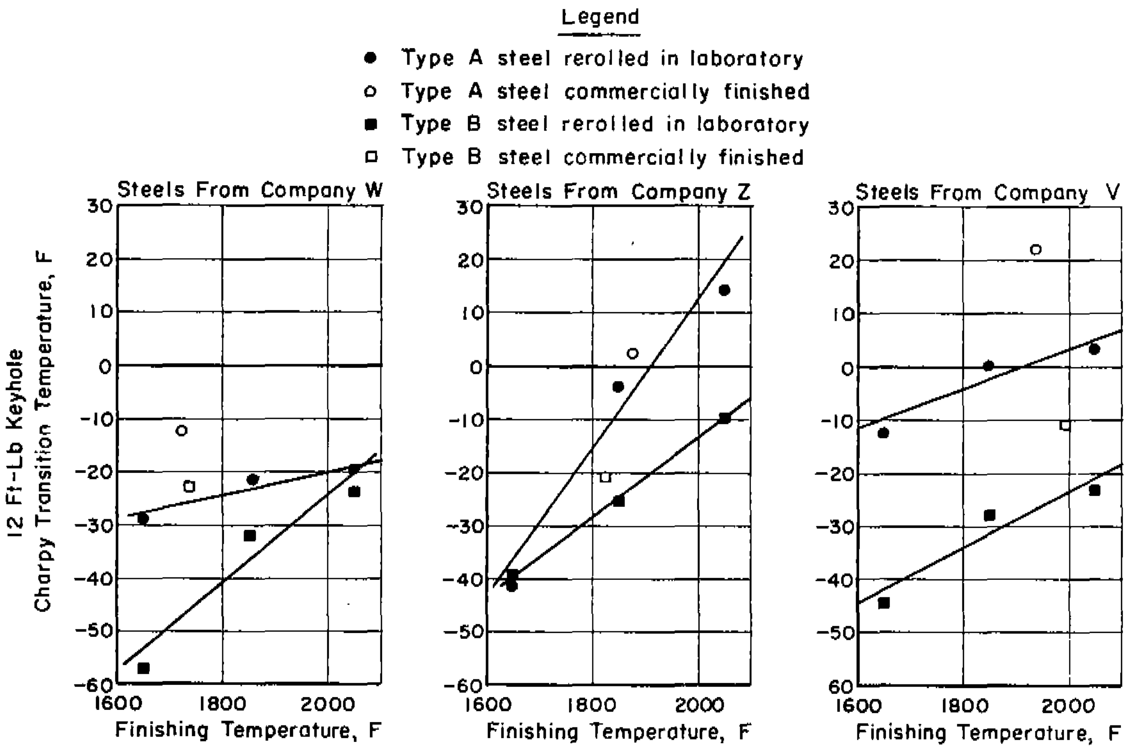

FIGURE 3. EFFECT OF FINISHING TEMPERATURE ON THE KEYHOLE CHARPY TRANSITION TEMPERATURE OF EXPERIMENTAL OPEN-HEARTH STEELS

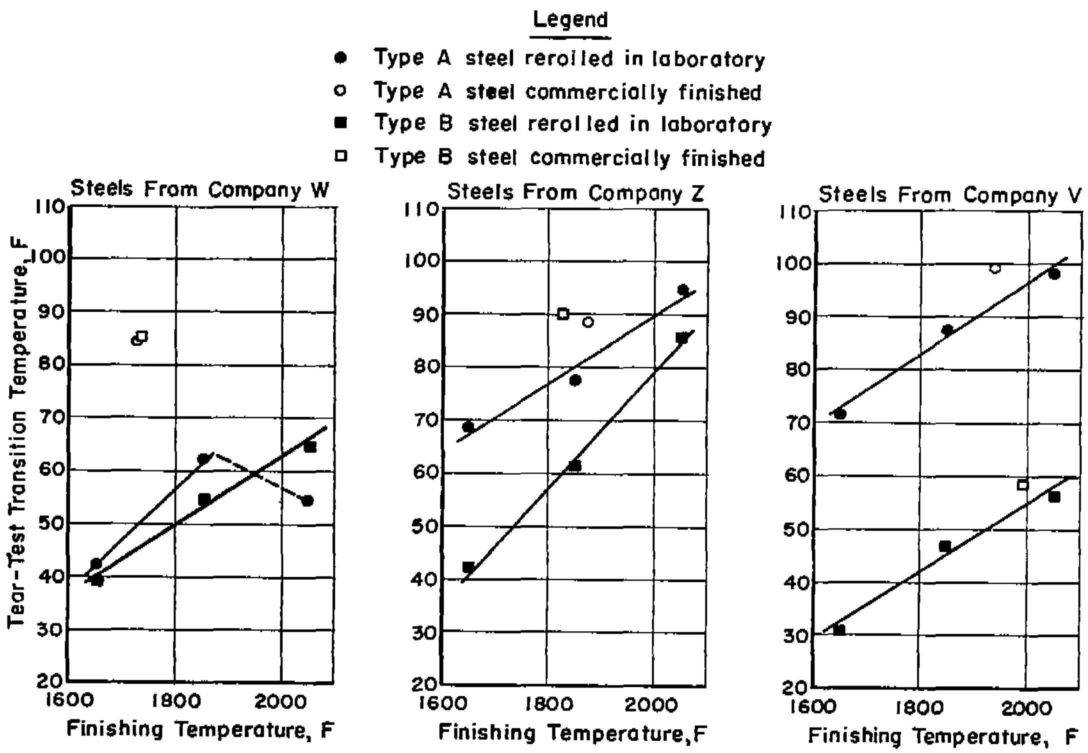

FIGURE 4. EFFECT OF FINISHING TEMPERATURE ON THE p=0.5 PROBABILITY OF BRITTLE FRACTURE TEAR-TEST TRANSITION TEMPERATURE

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plate rerolled in the laboratory. The amount of reduction during the finishing passes may likewise be a factor. Slower cooling of the plate has been shown(7) to result in a higher transition temperature.

TEAR TEST PROPERTIES

Four tear test specimens of each steel were broken at each 10 F interval in the transition range. These tests gave sufficient information to determine the tear test transition temperature by any one of three criteria. One criterion of the test, originated by Kahn and Imbembo(5), is the highest temperature at which one or more of four specimens will break with a fractured area having less than 50 per cent of the dull, fibrous type of fracture. This transition temperature can be determined from as few as five specimens and depends to a large extent on the performance of one specimen. The other two criteria, which are more reliable in research work, base the transition temperature on the performance of all specimens tested. In one case, the transition temperature is that temperature where the probability of brittle fracture, p, equals 0.5. In the other case, the transition temperature is that temperature where the fracture shows 50 per cent or more of brittle texture. Transition temperatures, based on either of the two latter criteria, are in close agreement(6). The criterion used by Kahn and Imbembo and the criterion based on the probability of brittle fracture, $p = 0.5$, were the only ones employed in this investigation to obtain the transition temperatures from the tear test data.

The transition temperatures of the open-hearth steels used in this investigation, based on the Kahn and Imbembo criterion, are given in Table 9; whereas the transition temperatures based on the criterion defined as the probability of brittle fracture, p = 0.5, are given in Table 10.

As was the case with the transition temperatures in the Charpy test, the transition temperatures in the tear test were affected only slightly by variations in the acid-soluble aluminum contents of the plates up to 0.043 per cent. The indications are that increasing the aluminum content above 0.01 per cent decreased the tear test transition temperature slightly.

The effect of finishing temperature on the tear test transition temperature based on the p = 0.5 probability of brittle fracture is shown clearly by the curves in Fig. 4. A decrease in finishing temperature lowered the transition temperature appreciably, the actual change being an average reduction in the transition temperature of 8 F on decreasing the finishing temperature 100 F. This reduction is slightly more than the 6 F shown in an earlier section of this report for the change in Charpy transition temperature with a reduction of 100 F in finishing temperature.

For the same finishing temperature, plates finish-rolled on commercial mills had tear test transition temperatures that were higher than those for plates finish-rolled in the laboratory.

TABLE 9. TEAR TEST TRANSITION TEMPERATURES OF THE EXPERIMENTAL OPEN-HEARTH STEELS BASED ON KAHN AND IMBEMBO CRITERION

Steel	Composition, %			Commercially Rolled Plate		Transition Temperature of Laboratory Rerolled Plate, F		
	C	Mn	Al	Finishing Temp, F	Transition Temp, F	Finished at 1650 F	Finished at 1850 F	Finished at 2050 F
W-1	0.23	0.52	<0.003	1700	80	50	80	60
W-2	0.23	0.52	<0.003	1750	90	40	60	70
W-3	0.23	0.52	<0.003	1750	100	70	80	60
W-4	0.23	0.52	0.020	1700	80	70	70	70
W-5	0.23	0.78	<0.003	1700	110	30	60	100
W-6	0.22	0.80	<0.003	1725	110	40	60	70
W-7	0.20	0.80	<0.003	1800	80	60	60	70
W-8	0.21	0.78	0.029	1725	80	30	40	70
Z-5	0.27	0.50	<0.003	1890	90	90	90	110
Z-6	0.27	0.51	<0.003	1850	110	90	90	90
Z-7	0.27	0.49	0.006	1855	90	60	80	100
Z-8	0.27	0.50	0.043	1890	80	60	80	80
Z-1	0.19	0.67	<0.003	1820	60	50	60	100
Z-2	0.19	0.68	<0.003	1810	60	60	80	100
Z-3	0.18	0.68	0.003	1830	70	50	70	90
Z-4	0.19	0.68	0.027	1830	50	30	60	90
V-1	0.26	0.45	<0.003	1950	90	70	100	110
V-2	0.27	0.45	<0.003	1965	120	90	90	90
V-3	0.28	0.46	0.005	1850	100	80	80	100
V-4	0.29	0.45	0.018	1990	120	60	100	110
V-5	0.21	0.67	<0.003	2000	70	50	50	90
V-6	0.19	0.67	0.004	1980	60	30	40	60
V-7	0.22	0.67	0.006	2000	70	40	70	60
V-8	0.19	0.66	0.017	1990	60	30	80	50

TABLE 10. TEAR TEST TRANSITION TEMPERATURES OF THE EXPERIMENTAL OPEN-HEARTH STEELS BASED ON THE CRITERION OF THE PROBABILITY OF BRITTLE FRACTURE, p, EQUAL TO 0.5

Steel	Composition, %			Commercially Rolled Plate		Transition Temperature of Laboratory Rolled Plate, F		
	C	Mn	Al	Finishing Temp, F	Transition Temp, F	Finished at 1650 F	Finished at 1850 F	Finished at 2050 F
W-1	0.23	0.52	<0.003	1700	81	40	64	40
W-2	0.23	0.52	<0.003	1750	87	40	55	65
W-3	0.23	0.52	<0.003	1750	98	49	63	55
W-4	0.23	0.52	0.020	1700	70	59	66	58
W-5	0.23	0.78	<0.003	1700	108	35	56	75
W-6	0.22	0.80	<0.003	1725	105	45	65	66
W-7	0.20	0.80	<0.003	1800	71	53	57	64
W-8	0.21	0.78	0.029	1725	57	23	40	53
Z-5	0.27	0.50	<0.003	1890	90	76	85	107
Z-6	0.27	0.51	<0.003	1850	100	83	90	90
Z-7	0.27	0.49	0.006	1855	90	62	71	99
Z-8	0.27	0.50	0.043	1890	75	54	64	81
Z-1	0.19	0.67	<0.003	1820	65	45	61	92
Z-2	0.19	0.68	<0.003	1810	57	62	75	89
Z-3	0.18	0.68	0.003	1830	55	42	59	80
Z-4	0.19	0.68	0.027	1830	38	19	50	83
V-1	0.26	0.45	<0.003	1950	90	68	90	103
V-2	0.27	0.45	<0.003	1965	105	80	90	95
V-3	0.28	0.46	0.005	1850	93	73	85	95
V-4	0.29	0.45	0.018	1990	110	65	85	100
V-5	0.21	0.67	<0.003	2000	55	36	35	59
V-6	0.19	0.67	0.004	1980	50	29	41	55
V-7	0.22	0.67	0.006	2000	67	30	52	64
V-8	0.19	0.67	0.017	1990	61	26	58	47

Again the explanation may be that the plates finished on commercial mills were cooled from the rolling temperature at a lower rate than plates rolled in the laboratory. The amount of reduction during the finishing passes may likewise be a factor. As mentioned before, slow cooling has been shown[7] to raise the transition temperature.

AUSTENITE GRAIN-COARSENING TEMPERATURE

The austenite grain-coarsening temperature was determined for each of the 32 experimental steels after heating test specimens 3/8 by 1/2 by 5 in. in size in a temperature gradient furnace for periods of one hour and four hours. The furnace used for the work resembled the one described by Halley[4]. It had a temperature graident of 400 F from one end of the specimen to the other. The specimens were quenched in oil immediately after being taken from the furnace, after which they were sectioned and etched. From an examination of the etched surfaces and the known temperature gradient in the specimens, the temperatures at which the austenite grains tended to coarsen after heating times of one and four hours could be determined.

The mean coarsening temperature for each steel is given in Table 11. Austenite grains larger than 4.5 on the ASTM scale were considered coarse. The mean austenite grain-coarsening temperature was lowered by increasing the heating time from one to four hours, indicating that the austenite grains still continued to grow after holding at temperature for more than one hour.

TABLE 11. AUSTENITE GRAIN-COARSENING TEMPERATURES OF TWENTY-FOUR OPEN-HEARTH STEELS OF VARIOUS ALUMINUM CONTENTS (Specimens heated one and four hours)

Steel	Composition, per cent C	Mn	S	Al*	Aluminum Added, lb/ton of steel	Mean of Austenite Grain-Coarsening Temp, F 1-Hour Treatment	4-Hour Treatment
Z-1	0.19	0.67	0.04	<0.003	0.19	1600	1525
Z-2	0.19	0.68	0.04	<0.003	0.38	1675	1585
Z-3	0.18	0.68	0.04	0.003	0.75	1755	1740
Z-4	0.18	0.68	0.04	0.027	1.50	1840	1800
Z-5	0.27	0.50	0.06	<0.003	0.19	1600	1530
Z-6	0.27	0.51	0.06	<0.003	0.38	1605	1515
Z-7	0.27	0.49	0.06	0.006	0.75	1695	1640
Z-8	0.27	0.50	0.06	0.043	1.50	1785	1740
V-1	0.26	0.45	0.08	<0.003	0	1740	1640
V-2	0.27	0.45	0.07	<0.003	0.09	1725	1640
V-3	0.28	0.46	0.08	0.005	0.54	1705	1625
V-4	0.29	0.45	0.07	0.018	0.84	1790	1760
V-5	0.21	0.67	0.07	<0.003	0	1665	1535
V-6	0.19	0.67	0.06	0.004	0.09	1615	1600
V-7	0.22	0.67	0.07	0.006	0.54	1725	1715
V-8	0.19	0.66	0.07	0.017	0.84	1795	1750
W-1	0.23	0.52	0.09	<0.003	0	1650	1585
W-2	0.23	0.52	0.10	<0.003	0.25	1695	1610
W-3	0.23	0.52	0.09	<0.003	0.50	1660	1580
W-4	0.23	0.52	0.10	0.020	1.00	1765	1750
W-5	0.23	0.78	0.09	<0.003	0	1740	1630
W-6	0.22	0.80	0.08	<0.003	0.25	1680	1615
W-7	0.20	0.80	0.08	<0.003	0.50	1740	1685
W-8	0.21	0.78	0.08	0.029	1.00	1850	1825

*Acid-soluble-aluminum content.

The effect of acid-soluble aluminum in the steels on their austenite grain-coarsening temperatures is shown in Fig. 5. An increase in the acid-soluble aluminum content, as would be expected, increased the grain-coarsening temperatures of the steels. Halley[4] found the same effect of acid-soluble aluminum in somewhat similar steels containing 0.23 per cent of silicon.

INFLUENCE OF NORMALIZING ON THE PROPERTIES OF KILLED AND SEMIKILLED STEELS

Sections of six of the plates finish-rolled on commercial mills were normalized by heating for one hour at 1650 F and air cooling. Three of the plates contained either no aluminum or the minimum quantity used by the supplier. These plates were therefore made from semikilled steels and were of Type B composition. They represented plate from each of the three suppliers. The other three plates were also of Type B steel and represented plate from the three suppliers. They, however, contained the maximum quantities of aluminum that were added by the three suppliers. Steels in the latter plates were fully killed.

The ferrite grain size and the Charpy transition temperatures of the six steels before and after normalizing are shown in Table 12. Included in the table are data on the steels in the as-received condition (as-rolled commercially) and after rerolling from 1 3/4- to 3/4-in. plate in the laboratory using a finishing temperature of 1650 F.

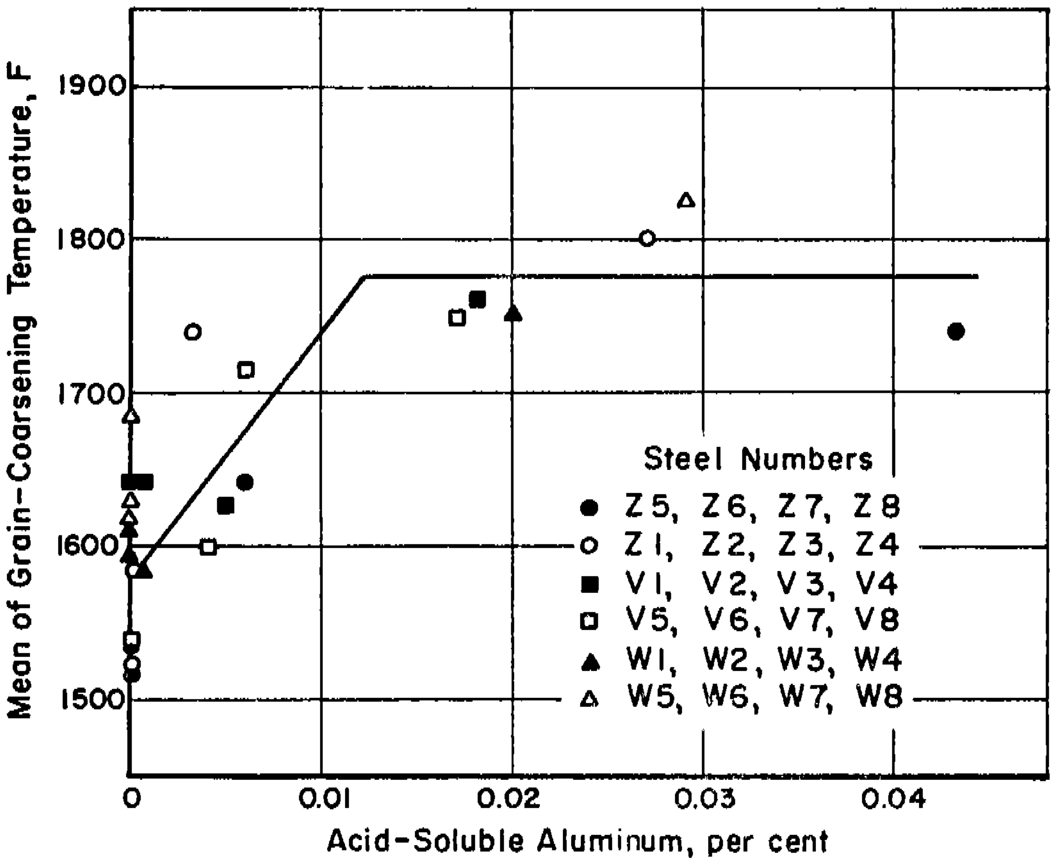

FIGURE 5. EFFECT OF ACID-SOLUBLE ALUMINUM CONTENT ON AUSTENITE GRAIN-COARSENING TEMPERATURE OF THE OPEN-HEARTH STEELS

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TABLE 12. FERRITE GRAIN SIZE AND KEYHOLE CHARPY TRANSITION TEMPERATURES OF SIX PLATE STEELS IN THREE DIFFERENT CONDITIONS

	Semikilled Steels			Killed Steels		
Steels:	Z-1	V-5	W-5	Z-4	V-8	W-8
Composition:						
Carbon, per cent	0.19	0.21	0.23	0.18	0.19	0.21
Manganese, per cent	0.67	0.67	0.78	0.68	0.66	0.78
Silicon, per cent	0.04	0.07	0.09	0.04	0.07	0.08
Aluminum, per cent	$<$0.003	$<$0.003	$<$0.003	0.027	0.017	0.029
No. of Ferrite Grains Per 0.0001 Sq. In.						
Commercially Rolled	67	64	66	65	58	107
Normalized at 1650 F	95	99	128	232	186	204
Finished at 1650 F	91	97	107	114	88	101
Charpy Transition Temperature, F						
Commercially Rolled	-18	-4	-8	-37	-16	-37
Normalized at 1650 F	-4	-15	-35	-81	-82	-95
Finished at 1650 F	-37	-23	-50	-53	-64	-62

Normalizing from 1650 F refined the ferrite grain size of all the plates, but the change in grain size was much more pronounced for the killed steels. The grain size of the killed steels changed about one to two numbers on the ASTM scale. On the other hand, the grain sizes of the normalized, semikilled steels changed less than one ASTM number and were almost the same as those of plates finished at 1650 F.

Apparently, when rolling was finished at 1650 F, air cooling produced approximately the same ferrite grain size in both semikilled and aluminum killed steels. This is because all plates were heated to 2250 F or higher before rolling and therefore had coarse austenite grains when rolling started. Probably this coarse grain size persisted during rolling. As might be deduced from Table 11, however, aluminum influences the austenite grain size developed on reheating from room temperature to 1650 F. Table 12 shows that reheating to this temperature produces coarse ferrite grains in semikilled steel but fine ferrite grains in aluminum killed steels. The final ferrite grain size is a function of the austenite grain size and the cooling rate which characterizes the normalizing treatment. A finer austenite grain size, other conditions remaining the same, produces a finer ferrite grain size in the steel.

The changes of ferrite grain size produced by normalizing are also reflected by changes in the Charpy transition temperatures.

Plates having the finest ferrite grain sizes have the lowest transition temperatures. After normalizing from 1650 F, the three aluminum killed steels had Charpy transition temperatures below -80 F.

SUMMARY

The results obtained in this investigation on experimental open-hearth steels of ship plate composition justify the following conclusions:

1. The Charpy and tear test transition temperatures of hot-rolled plates were not changed significantly by aluminum contents in the range up to 0.04 per cent.
2. Variations in the temperature of the final hot-rolling pass in the range from 1650 F to 2050 F influenced the transition temperature of the laboratory rolled steel. Each increase of 100 F in finishing temperature raised the transition temperature 6 F in Charpy keyhole tests and 8 F in tear tests.
3. The ferrite grain size of hot-rolled steels of ship plate composition was independent of variations in aluminum content up to 0.04 per cent. Higher finishing temperatures produced coarser ferrite grain sizes.

4. Steels containing more than 0.01 per cent acid-soluble aluminum had higher austenite grain-coarsening temperatures than semikilled steels. Therefore, normalizing aluminum killed steels from 1650 F produced finer ferrite grains than normalizing semikilled steels from the same temperature.

5. Normalizing from 1650 F lowered the Charpy transition temperatures of the ship plate steels investigated. The beneficial effects of normalizing were more pronounced for aluminum killed steels than for semikilled steels.

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A P P E N D I X

TABLE A-1. TENSILE-TEST DATA FOR EXPERIMENTAL OPEN-HEARTH STEEL COMMERCIALLY ROLLED TO 3/4-INCH PLATE

Steel	Specimen	Tensile Strength, psi	Yield Strength, psi Upper	Yield Strength, psi Lower	Elongation in 8 Inches, %
W-1	1	65,700	34,650	34,350	30.0
	2	65,600	35,100	33,850	29.5
W-2	1	66,100	33,550	33,200	28.0
	2	65,700	33,600	32,900	27.5
W-3	1	65,700	37,400	34,000	28.5
	2	65,800	35,800	34,800	27.5
W-4	1	65,200	36,600	33,800	29.5
	2	66,000	37,200	34,200	28.5
W-5	1	70,800	36,700	36,200	27.5
	2	71,000	37,500	37,100	28.0
W-6	1	70,700	38,900	36,200	28.0
	2	70,400	39,300	37,300	27.0
W-7	1	67,600	35,800	34,700	29.0
	2	67,700	36,100	35,200	29.0
W-8	1	67,500	36,600	35,900	28.5
	2	67,700	36,200	35,000	28.5
V-1	1	64,900	35,000	34,100	28.0
	2	63,000	33,100	32,000	29.5
V-2	1	64,100	34,200	32,200	30.0
	2	64,000	33,800	32,800	31.5
V-3	1	64,900	37,800	35,300	30.0
	2	65,100	37,800	34,200	30.0
V-4	1	64,600	35,000	32,500	28.5
	2	64,800	34,800	32,400	28.0
V-5	1	59,300	32,600	31,200	32.0
	2	60,800	33,500	31,500	32.0
V-6	1	61,900	35,000	32,900	30.0
	2	60,100	33,600	32,200	33.0
V-7	1	62,900	36,000	32,900	27.0
	2	62,700	34,800	32,800	28.0
V-8	1	62,100	33,300	32,000	29.5
	2	61,200	33,000	32,500	31.0
Z-1	1	61,000	34,700	33,200	30.5
	2	61,100	34,600	33,200	30.0
Z-2	1	61,200	33,800	32,700	30.5
	2	61,700	34,000	32,900	31.0
Z-3	1	59,700	33,400	32,700	32.0
	2	59,700	33,500	32,100	31.5
Z-4	1	59,700	33,400	32,700	32.0
	2	59,800	33,400	32,100	32.5
Z-5	1	64,700	34,400	33,500	29.0
	2	64,200	33,600	32,700	28.0
Z-6	1	65,200	34,400	33,200	29.0
	2	65,300	33,900	33,000	29.0
Z-7	1	65,300	35,000	33,200	29.5
	2	66,000	35,800	33,300	29.0
Z-8	1	65,900	34,300	33,400	29.0
	2	66,100	35,100	34,000	29.0

TABLE A-2. KEYHOLE CHARPY TEST DATA FOR EXPERIMENTAL OPEN-HEARTH STEELS FROM COMPANY W

Steel	Testing Temperature, F	Charpy Value, ft-lb First Test	Second Test	Third Test	Fourth Test
	Rolled in Commercial Mill				
W-1	-50	4	4	3	3
	-40	3	4	5	4
	-30	5	9	11	4
	-20	16	5	3	6
	-10	23	13	15	22
	0	22	23	22	20
	80	30	33	-	-
W-2	-40	5	4	22	4
	-30	6	7	6	13
	-20	3	20	7	4
	-10	23	14	23	6
	0	24	11	19	19
	10	21	23	26	26
	20	27	28	-	-
	80	32	30	-	-
W-3	-20	3	5	4	3
	-10	11	5	4	9
	0	19	12	6	4
	10	21	14	20	5
	20	22	19	24	10
	30	23	24	23	21
	80	28	28	-	-
W-4	-40	4	4	4	6
	-30	8	10	4	7
	-20	13	4	6	6
	-10	6	4	23	20
	0	7	23	21	16
	10	22	22	5	23
	20	25	24	23	21
	80	32	29	-	-
W-5	-20	12	7	12	11
	-10	6	10	13	20
	0	20	18	15	14
	10	19	10	20	22
	20	20	14	16	20
	30	24	21	11	20
	40	25	26	29	24
	80	31	33	-	-
W-6	-20	7	4	17	4
	-10	25	20	19	21
	0	7	9	7	21
	10	16	25	20	9
	20	25	19	17	15
	30	25	25	25	22
	40	27	27	26	26
	80	31	33	-	-
W-7	-70	3	4	14	4
	-60	5	2	4	10
	-50	3	4	20	5
	-40	8	21	23	5
	-30	21	24	26	25
	-20	23	24	24	23
	0	30	27	-	-
	80	37	38	-	-
W-8	-60	7	5	4	4
	-50	5	8	6	3
	-40	15	7	6	10
	-30	9	22	15	9
	-20	17	23	21	26
	0	30	27	-	-
	80	40	38	-	-
	Rolled in the Laboratory Mill at 1650 F				
6 W-1	-60	4	3	3	3
	-50	4	4	14	3
	-40	17	13	5	3
	-30	5	22	4	19
	-20	21	20	23	14
	-10	21	24	23	26
	0	23	23	-	-
	80	34	34	-	-

TABLE A-2 (Continued)

Steel	Testing Temperature, F	Charpy Value, ft-lb First Test	Second Test	Third Test	Fourth Test
6 W-2	-40	9	4	3	3
	-30	19	6	22	4
	-20	5	24	20	22
	-10	8	24	7	18
	0	7	7	7	23
	10	28	28	24	26
	20	29	27	31	29
	40	31	30	-	-
6 W-3	-60	4	3	3	3
	-50	16	6	4	3
	-40	6	6	4	7
	-30	7	3	21	20
	-20	24	23	22	20
	0	26	26	-	-
	80	35	35	-	-
6 W-4	-50	5	3	4	5
	-40	7	4	11	8
	-30	11	18	21	17
	-20	21	20	24	20
	0	24	19	23	23
	80	35	34	-	-
6 W-5	-70	3	2	2	6
	-60	11	3	10	11
	-50	22	13	4	19
	-40	5	6	18	10
	-30	23	21	25	24
	-20	25	28	25	28
	0	28	27	-	-
	80	39	-	-	-
6 W-6	-60	5	3	4	3
	-50	20	13	4	16
	-40	4	24	4	11
	-30	29	27	6	26
	-20	25	26	9	30
	-10	32	32	25	33
	0	35	33	-	-
	80	48	44	-	-
6 W-7	-80	4	5	4	3
	-70	9	5	19	5
	-60	21	8	8	12
	-40	27	26	28	24
	0	32	30	-	-
	80	42	-	-	-
6 W-8	-80	7	24	3	2
	-70	4	8	10	6
	-60	17	14	20	19
	-50	10	24	7	18
	-40	19	22	29	29
	0	34	33	-	-
	80	44	46	-	-
Rolled in the Laboratory Mill at 1850 F					
8 W-1	-30	4	5	4	8
	-20	4	4	3	6
	-10	18	6	3	20
	0	18	19	17	18
	10	19	24	25	20
	20	22	27	21	13
	30	27	26	28	30
	80	35	34	-	-
8 W-2	-40	3	3	-	-
	-30	4	4	3	4
	-20	4	4	4	7
	-10	5	5	22	18
	0	25	25	6	24
	10	22	24	27	26
	80	33	33	-	-
8 W-3	-40	11	4	20	21
	-30	4	5	25	6
	-20	21	19	13	22
	-10	18	19	22	25
	0	10	21	25	20
	10	30	27	22	26
	20	27	27	27	28
	40	28	34	-	-
	80	33	33	36	40

TABLE A-2 (Continued)

Steel	Testing Temperature, F	Charpy Value, ft-lb First Test	Second Test	Third Test	Fourth Test
8 W-4	-60	3	3	4	5
	-50	3	12	4	5
	-40	5	6	6	7
	-30	15	13	16	10
	-10	23	21	21	20
	0	20	20	18	21
	10	21	21	25	22
	80	39	35	-	-
8 W-5	-50	3	5	3	3
	-40	7	5	4	4
	-30	5	5	4	5
	-20	19	5	18	13
	-10	6	24	29	23
	0	22	26	24	27
	80	40	34	-	-
8 W-6	-40	4	5	4	4
	-30	5	4	5	4
	-20	21	4	6	33
	-10	17	6	20	11
	0	31	27	31	9
	10	30	13	33	34
	20	34	36	36	36
	80	42	43	-	-
8 W-7	-70	2	4	4	3
	-60	3	6	8	9
	-50	5	21	22	3
	-40	27	9	3	25
	-30	23	25	25	20
	-20	25	25	16	25
	-10	29	26	19	32
	0	28	28	-	-
	80	38	39	-	-
8 W-8	-60	5	11	3	4
	-50	10	4	3	7
	-40	22	15	5	10
	-30	29	24	18	19
	-20	27	8	29	27
	-10	31	29	30	30
	0	30	31	-	-
	80	43	43	-	-
Rolled in the Laboratory Mill at 2050 F					
20 W-1	-40	6	4	3	3
	-30	4	19	3	8
	-20	7	4	14	10
	-10	20	6	17	20
	0	18	19	6	21
	10	17	23	24	26
	40	28	29	-	-
	80	33	32	-	-
20 W-2	-40	3	3	3	4
	-30	6	9	3	4
	-20	19	18	4	22
	-10	10	22	15	10
	0	5	24	20	20
	10	24	23	25	28
	40	29	29	-	-
	80	36	34	-	-
20 W-3	-40	3	5	3	4
	-30	3	11	6	8
	-20	27	26	25	15
	-10	24	28	21	23
	0	28	29	15	25
	10	29	28	30	26
	80	37	38	-	-
20 W-4	-40	4	4	3	6
	-30	5	13	8	5
	-20	14	20	7	18
	-10	24	6	14	24
	0	24	25	21	9
	10	24	24	25	25
	80	34	33	-	-
20 W-5	-30	3	4	3	3
	-20	5	9	22	22

TABLE A-2 (Continued)

Steel	Testing Temperature, F	Charpy Value, ft-lb First Test	Second Test	Third Test	Fourth Test
20 W-5 (Cont)	-10	9	7	24	23
	0	6	19	8	28
	10	27	24	28	26
	20	29	25	-	-
	40	31	32	-	-
	80	36	38	-	-
20 W-6	-20	5	7	5	5
	-10	16	20	5	7
	0	9	6	8	19
	10	31	28	11	28
	20	34	33	30	30
	40	35	35	-	-
	80	40	38	-	-
20 W-7	-60	3	3	7	3
	-50	7	5	3	7
	-40	27	23	3	7
	-30	11	24	25	3
	-20	31	28	9	15
	-10	8	31	30	28
	0	26	36	33	29
	80	44	44	-	-
20 W-8	-60	6	5	5	3
	-50	10	15	3	4
	-40	9	8	7	24
	-30	22	26	24	6
	-20	27	24	24	5
	-10	33	29	30	33
	0	11	28	34	29
	10	31	37	30	35
	80	40	43	-	-

TABLE A-3 KEYHOLE CHARPY TEST DATA FOR EXPERIMENTAL OPEN-HEARTH STEELS FROM COMPANY V

Steel	Testing Temperature F	Charpy Value, ft-lb First Test	Second Test	Third Test	Fourth Test
	Rolled in Commercial Mill				
V-1	0	9	3	5	6
	10	4	5	6	4
	20	13	22	20	5
	30	23	22	9	23
	40	23	22	11	22
	50	22	23	23	25
	80	27	34	-	-
V-2	0	4	5	4	8
	10	5	8	4	8
	20	4	7	6	11
	30	12	20	20	17
	40	11	19	13	20
	50	24	23	22	21
	60	21	19	22	23
	80	26	27	-	-
V-3	-20	4	4	3	3
	-10	4	9	4	4
	0	8	9	5	9
	10	10	17	20	7
	20	20	17	12	17
	30	24	10	17	21
	40	20	24	20	22
	80	25	26	-	-
V-4	0	3	6	4	5
	10	6	13	8	6
	20	16	9	12	10
	30	15	9	21	17
	40	11	11	21	13
	50	18	26	21	23
	60	15	23	24	26
	80	27	26	-	-

TABLE A-3. (Continued)

Steel	Testing Temperature F	Charpy Value, ft-lb First Test	Second Test	Third Test	Fourth Test
	Rolled in Commercial Mill				
V-5	-30	3	4	3	4
	-20	5	4	9	9
	-10	22	8	4	9
	0	5	7	7	24
	10	28	26	31	30
	20	30	33	30	33
	40	34	32	-	-
	80	39	38	-	-
V-6	-20	5	5	4	4
	-10	5	7	5	20
	0	19	7	7	6
	10	8	8	28	24
	20	26	28	26	29
	40	29	31	-	-
	80	34	38	-	-
V-7	-40	3	5	4	4
	-30	4	23	8	4
	-20	4	12	11	21
	-10	23	10	9	24
	0	27	27	25	15
	10	26	27	29	29
	80	34	32	-	-
V-8	-30	5	7	5	9
	-20	6	6	14	11
	-10	21	22	19	21
	0	26	21	9	18
	10	27	23	26	26
	40	30	32	-	-
	80	35	36	-	-
	Rolled in the Laboratory Mill at 1650 F				
6 V-1	-30	5	5	5	3
	-20	5	8	12	10
	-10	20	4	19	17
	0	19	22	20	18
	10	25	21	22	21
	20	25	21	-	-
	80	23	27	32	30
6 V-2	-30	3	3	4	4
	-20	4	4	9	4
	-10	15	4	4	4
	0	4	20	20	5
	10	20	17	19	20
	20	24	21	21	21
	40	25	22	-	-
	80	30	26	-	-
6 V-3	-40	5	4	4	3
	-30	3	17	5	5
	-20	4	3	4	8
	-10	21	20	22	16
	0	20	18	21	8
	10	19	24	20	21
	40	26	26	-	-
	80	28	26	-	-
6 V-4	-30	6	6	4	5
	-20	19	9	12	12
	-10	19	18	19	20
	0	19	19	18	18
	10	22	18	23	23
	20	13	24	-	-
	80	32	32	-	-

TABLE A-3. (Continued)

Steel	Testing Temperature F	Charpy Value, ft-lb First Test	Second Test	Third Test	Fourth Test
	Rolled in the Laboratory Mill at 1650 F				
6 V-5	-40	4	4	4	4
	-30	5	5	25	5
	-20	19	6	5	25
	-10	31	28	7	29
	0	29	29	26	29
	80	43	45	-	-
6 V-6	-50	4	4	4	4
	-40	5	10	4	5
	-30	5	20	27	6
	-20	25	27	7	27
	-10	27	30	28	31
	0	26	32	-	-
	80	40	40	-	-
6 V-7	-70	3	4	3	5
	-60	3	4	4	9
	-50	24	5	4	21
	-40	27	21	22	25
	-30	26	28	5	27
	-20	32	29	31	31
	0	30	34	-	-
	80	42	44	-	-
6 V-8	-80	3	3	3	5
	-70	14	24	5	5
	-60	4	3	6	25
	-50	16	23	24	7
	-40	22	26	25	28
	0	32	32	-	-
	80	39	46	-	-
	Rolled in the Laboratory Mill at 1850 F				
8 V-1	-20	5	3	4	7
	-10	8	16	5	4
	0	10	18	9	4
	10	21	19	5	17
	20	23	15	23	21
	30	25	23	23	23
	40	25	25	-	-
	80	29	31	-	-
8 V-2	-20	3	3	3	4
	-10	9	3	4	4
	0	20	4	7	4
	10	19	20	5	8
	20	19	19	21	6
	30	22	24	23	21
	40	25	25	-	-
	80	29	29	-	-
8 V-3	-20	3	5	5	4
	-10	6	9	12	12
	0	16	8	20	19
	10	18	20	21	21
	20	21	20	23	22
	40	24	24	-	-
	80	31	28	-	-
8 V-4	-30	5	4	5	4
	-20	10	5	4	6
	-10	4	8	5	11
	0	17	16	16	19
	10	19	17	25	22
	20	21	26	23	23
	40	25	28	-	-
	80	28	32	-	-

TABLE A-3. (Continued)

Steel	Testing Temperature F	Charpy Value, ft-lb First Test	Second Test	Third Test	Fourth Test
	Rolled in the Laboratory Mill at 1850 F				
8 V-5	-30	5	6	4	25
	-20	25	5	25	6
	-10	9	26	6	6
	0	7	8	28	8
	10	20	35	28	8
	20	15	36	33	35
	40	35	33	-	-
	80	39	46	-	-
8 V-6	-40	6	4	3	5
	-30	25	22	11	18
	-20	23	26	6	4
	-10	30	8	27	27
	0	32	35	7	18
	10	28	31	34	32
	20	36	36	-	-
	40	36	38	-	-
	80	47	40	-	-
8 V-7	-60	3	4	3	3
	-50	4	3	5	5
	-40	4	22	8	25
	-30	20	29	20	29
	-20	27	28	30	25
	0	33	29	-	-
	80	44	43	-	-
8 V-8	-50	4	4	4	3
	-40	4	4	6	4
	-30	26	5	23	23
	-20	27	28	23	28
	0	29	31	-	-
	80	36	41	-	-
	Rolled in the Laboratory Mill at 2050 F				
20 V-1	-20	8	4	7	3
	-10	14	12	4	3
	0	20	19	5	4
	10	16	21	20	21
	20	20	22	20	19
	40	23	25	-	-
	80	30	31	-	-
20 V-2	-10	5	4	5	5
	0	3	13	6	15
	10	10	8	11	14
	20	19	18	20	21
	30	20	21	24	20
	40	22	25	-	-
	80	28	28	-	-
20 V-3	-10	6	3	4	4
	0	14	7	6	6
	10	9	17	9	16
	20	22	20	16	9
	30	17	24	21	22
	40	21	23	22	28
	80	28	28	-	-
20 V-4	-20	4	5	5	4
	-10	6	6	17	5
	0	17	12	16	5
	10	12	19	21	11
	20	22	24	20	22
	40	25	27	-	-
	80	31	28	-	-

TABLE A-3. (Continued)

Steel	Testing Temperature F	Charpy Value, ft-lb First Test	Second Test	Third Test	Fourth Test
		Rolled in the Laboratory Mill at 2050 F			
20 V-5	-40	4	3	4	3
	-30	12	4	4	4
	-20	4	23	28	5
	-10	7	25	21	23
	0	29	6	23	26
	10	32	29	30	8
	20	30	31	36	33
	40	33	35	35	34
	80	40	48	-	-
20 V-6	-50	4	3	5	3
	-40	3	3	3	5
	-30	12	20	16	9
	-20	22	4	5	7
	-10	6	21	28	28
	0	7	27	30	10
	10	31	28	33	32
	20	33	38	-	-
	40	38	36	-	-
	80	41	39	-	-
20 V-7	-30	7	4	4	3
	-20	27	17	14	16
	-10	24	24	18	28
	0	16	25	23	31
	10	23	29	30	29
	80	40	39	-	-
20 V-8	-40	6	5	3	3
	-30	14	20	24	4
	-20	22	30	26	15
	-10	27	24	27	10
	0	33	32	28	31
	40	35	33	-	-
	80	44	42	-	-

TABLE A-4. KEYHOLE CHARPY TEST DATA FOR EXPERIMENTAL OPEN-HEARTH STEELS FROM COMPANY Z

Steel	Testing Temperature, F	Charpy Value, ft-lb First Test	Second Test	Third Test	Fourth Test
		Rolled in Commercial Mill			
Z-1	-30	8	4	5	6
	-20	6	9	21	4
	-10	27	25	30	22
	0	6	28	29	25
	10	28	28	30	22
	20	28	29	29	31
	80	38	41	--	--
Z-2	-40	6	5	6	5
	-30	7	7	11	14
	-20	6	4	4	15
	-10	19	6	9	19
	0	21	14	7	22
	10	26	21	26	21
	20	26	25	25	25
Z-3	-50	4	4	6	6
	-40	4	5	5	8
	-30	17	5	5	6
	-20	15	8	9	7
	-10	29	12	29	10
	0	21	29	28	25
	80	41	--	--	--
Z-4	-60	5	3	4	3
	-50	6	7	4	8
	-40	21	7	20	13
	-30	9	12	18	15
	-20	23	27	25	24
	0	27	22	--	--
	80	37	38	--	--
Z-5	-20	4	5	5	6
	-10	3	4	8	9
	0	20	19	10	5
	10	19	14	22	17
	20	24	24	21	20
	80	27	29	--	--

TABLE A-4. (Continued)

Steel	Testing Temperature, F	Charpy Value, ft-lb First Test	Second Test	Third Test	Fourth Test
		Rolled in Commercial Mill (Continued)			
Z-6	-30	4	3	3	3
	-20	6	4	5	3
	-10	8	11	10	4
	0	15	5	8	18
	10	9	15	18	15
	20	21	13	16	21
	30	22	23	25	24
	40	24	22	23	22
Z-7	-30	6	3	4	4
	-20	3	4	4	3
	-10	3	8	10	4
	0	9	6	5	7
	10	18	16	18	11
	20	9	10	20	8
	30	18	20	20	19
	40	21	21	20	20
Z-8	-30	4	5	3	--
	-20	3	11	4	4
	-10	11	15	6	7
	0	12	11	6	11
	10	18	17	11	18
	20	21	20	17	13
	30	22	20	21	21
	40	23	24	24	25
		Rolled in the Laboratory Mill at 1650 F			
6 Z-1	-50	3	3	5	5
	-40	10	5	22	13
	-30	16	24	22	10
	-20	25	26	25	27
	0	27	30	--	--
	80	37	39	--	--
6 Z-2	-40	5	4	3	7
	-30	13	4	11	21
	-20	19	21	13	24
	-10	23	27	15	19
	0	26	23	23	24
	80	35	33	33	34
6 Z-3	-50	3	4	3	4
	-40	21	10	4	11
	-30	22	18	22	14
	-20	16	18	19	19
	-10	22	31	23	24
	0	21	22	--	--
	80	38	--	--	--
6 Z-4	-70	3	3	3	7
	-60	6	12	6	3
	-50	7	20	16	16
	-40	16	18	22	21
	-30	13	20	21	22
	-20	28	24	22	29
	80	37	37	39	--
6 Z-5	-30	5	3	6	4
	-20	10	3	8	9
	-10	16	19	10	14
	0	18	22	20	12
	10	19	18	18	21
	20	19	21	20	20
6 Z-6	-30	3	3	4	5
	-20	6	4	4	11
	-10	16	17	11	14
	0	17	15	17	15
	20	16	16	16	19
	30	18	22	19	17
	40	17	20	21	19
	50	21	19	24	20
	60	21	20	22	21
	80	24	25	--	--

TABLE A-4. (Continued)

Steel	Testing Temperature, F	Charpy Value, ft-lb First Test	Second Test	Third Test	Fourth Test
	Rolled in the Laboratory Mill at 1650 F (Continued)				
6 Z-7	-30	4	4	3	6
	-20	7	4	6	14
	-10	13	9	9	6
	0	16	15	10	15
	10	16	5	15	15
	20	15	15	17	15
	30	16	18	18	16
	40	20	21	19	20
6 Z-8	-30	8	4	4	4
	-20	3	4	6	13
	-10	15	16	13	13
	0	15	15	14	14
	10	12	17	16	16
	20	16	17	16	16
	30	16	20	17	18
	40	20	20	17	19
	50	20	20	22	21
	Rolled in the Laboratory Mill at 1850 F				
8 Z-1	-40	3	3	3	5
	-30	4	5	10	25
	-20	24	18	22	25
	-10	23	22	25	23
	0	7	23	25	26
	10	31	30	27	30
	20	32	30	29	30
8 Z-2	-30	6	3	4	3
	-20	15	6	17	13
	-10	10	9	20	11
	0	15	22	20	22
	10	22	22	20	22
	20	25	24	25	23
8 Z-3	-40	4	3	3	4
	-30	5	7	10	15
	-20	14	15	13	4
	-10	17	8	20	19
	0	24	22	25	24
8 Z-4	-60	3	4	3	3
	-50	9	4	5	6
	-40	3	6	20	4
	-30	4	15	14	21
	-20	26	23	24	18
	0	29	30	--	--
	80	36	41	--	--
8 Z-5	-30	3	3	3	--
	-20	5	7	10	6
	-10	14	5	14	17
	0	17	14	14	16
	10	17	18	19	20
	20	18	5	19	18
	30	21	20	21	22
	40	22	22	22	22
8 Z-6	-20	8	5	3	3
	-10	6	9	8	5
	0	4	7	6	16
	20	17	18	18	18
	30	19	18	19	17
	40	20	18	18	20
	50	22	23	23	21
	60	22	23	26	21

TABLE A-4. (Continued)

Steel	Testing Temperature, F	Charpy Value, ft-lb First Test	Second Test	Third Test	Fourth Test
	Rolled in the Laboratory Mill at 1850 F (Continued)				
8 Z-7	-10	4	4	4	5
	0	11	8	10	9
	10	6	10	12	--
	20	14	13	--	--
	30	16	15	16	17
	40	19	18	17	17
	60	20	21	19	18
	70	22	20	20	21
	80	22	20	21	22
8 Z-8	-20	4	5	4	4
	-10	6	4	10	5
	0	13	14	10	--
	20	18	15	17	14
	30	17	16	16	17
	40	21	18	17	18
	50	20	19	20	19
	60	20	21	20	21
	Rolled in the Laboratory Mill at 2050 F				
20 Z-1	-30	4	5	7	3
	-20	4	5	15	5
	-10	17	21	5	13
	0	25	20	16	23
	10	23	23	25	9
	20	23	27	25	25
20 Z-2	-20	4	4	5	6
	-10	14	6	8	8
	0	13	11	10	13
	10	13	23	22	21
	20	28	24	22	22
	30	21	28	30	18
	40	28	28	--	--
20 Z-3	-30	5	5	9	5
	-20	4	6	4	7
	-10	10	6	5	16
	0	30	8	8	8
	10	30	28	15	29
	20	30	30	26	28
	80	39	37	--	--
20 Z-4	-50	3	4	3	5
	-40	7	3	3	5
	-30	3	11	4	4
	-20	15	6	5	8
	-10	22	23	9	28
	0	21	27	26	23
	80	38	39	--	--
20 Z-5	-20	3	5	5	4
	-10	4	7	4	12
	0	9	6	13	9
	10	7	8	11	17
	20	15	19	15	18
	30	20	14	20	22
	40	22	21	21	20
	80	25	25	--	--
20 Z-6	-20	3	3	4	3
	-10	6	3	5	10
	0	10	8	12	8
	10	17	14	19	9
	20	18	19	6	5
	30	22	9	19	19
	40	24	22	24	22
	80	25	27	--	--

TABLE A-4. (Continued)

Steel	Testing Temperature, F	Charpy, ft-lb First Test	Second Test	Third Test	Fourth Test
		Rolled in the Laboratory Mill at 2050 F (Continued)			
20 Z-7	0	6	7	6	6
	10	16	9	4	18
	20	17	16	8	7
	30	10	15	18	13
	40	18	21	20	17
	50	19	23	22	23
	80	22	23	--	--
20 Z-8	-10	8	5	3	4
	0	4	14	8	5
	10	5	7	7	--
	20	14	9	10	14
	30	15	17	18	14
	40	18	20	17	19
	50	19	19	18	22
	60	21	21	21	20
	80	22	22	--	--

TABLE A-5. NAVY TEAR-TEST DATA FOR EXPERIMENTAL OPEN-HEARTH STEEL FROM COMPANY W

Steel	Specimen	Testing Tempera-ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
			Rolled in Commercial Mill			
W-1	H1	70	40,300	833	50	10
	C2	70	41,100	842	417	45
	D1	70	40,450	707	67	3
	D2	70	40,450	790	108	12
	J1	80	40,050	675	575	94
	J2	80	40,150	757	183	28
	H2	80	40,550	775	83	13
	A2	80	39,600	850	100	10
	A1	90	40,150	790	766	100
	B1	90	39,950	775	707	100
	B2	90	40,000	885	757	100
	C1	90	39,700	750	675	95
W-2	P2	60	39,950	766	92	3
	M2	70	40,300	775	100	6
	N1	70	40,250	740	150	5
	N2	70	40,800	784	200	15
	P1	70	40,400	757	133	4
	M1	80	40,250	790	58	5
	J2	80	40,400	725	590	98
	G2	80	40,750	784	83	20
	J1	80	39,650	725	258	25
	A1	90	40,200	740	150	20
	D2	90	40,200	757	100	20
	G1	90	39,800	784	584	100
	C2	90	40,150	750	675	100
	A2	100	40,350	815	565	100
	B1	100	40,050	775	609	100
	B2	100	39,550	725	616	100
	C1	100	39,200	707	565	98

TABLE A-5. (Continued)

Steel	Specimen	Testing Tempera-ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
			Rolled in Commercial Mill (Continued)			
W-3	M2	80	38,300	757	158	16
	A1	80	39,000	734	83	12
	L1	90	39,050	800	150	16
	L2	90	38,300	665	158	15
	M1	90	38,450	690	158	21
	A2	90	38,300	658	150	18
	B1	100	39,150	675	609	100
	C2	100	38,100	650	534	100
	D1	100	38,300	665	590	99
	D2	100	37,650	625	316	40
	H1	110	39,200	766	508	100
	H2	110	38,200	700	258	50
	J1	110	37,750	658	590	92
	J2	110	37,550	650	565	100
W-4	N1	50	40,150	734	100	9
	N2	50	40,100	757	50	3
	P1	50	40,850	850	183	20
	P2	50	40,050	734	125	4
	L1	60	38,500	690	17	4
	L2	60	39,200	665	466	70
	M1	60	40,350	750	633	100
	M2	60	41,650	824	633	100
	A1	70	38,600	690	142	15
	H2	70	38,700	675	17	13
	J1	70	38,950	684	167	10
	J2	70	39,350	740	534	75
	B1	80	39,000	707	433	87
	B2	80	39,150	690	565	100
	C1	80	38,150	658	675	100
	C2	80	38,350	616	167	13
	A2	90	38,000	650	650	100
	D1	90	38,700	675	550	80
	D2	90	38,200	650	707	100
	H1	90	38,900	700	584	100
W-5	A1	60	43,200	815	133	7
	A2	80	41,100	707	67	15
	L1	100	39,850	725	292	40
	L2	100	39,850	740	225	18
	B1	100	40,200	715	250	33
	J2	100	40,300	700	167	20
	B2	110	39,900	559	358	52
	C1	110	39,100	700	658	100
	C2	110	39,750	684	450	57
	D1	110	39,600	609	316	32
	D2	120	38,450	616	616	92
	H1	120	38,800	675	690	100
	H2	120	39,800	707	633	100
	J1	120	39,300	700	650	100
W-6	A1	70	42,800	815	75	7
	N2	80	42,700	824	25	5
	A2	90	41,750	775	208	25
	M1	90	41,650	800	58	4
	M2	90	42,700	850	158	19
	N1	90	41,100	757	100	4
	L1	100	42,100	808	757	100
	L2	100	41,450	750	216	14
	B2	100	40,950	734	734	100
	C1	100	42,200	784	225	17

TABLE A-5. (Continued)

Steel	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
			Rolled in Commercial Mill (Continued)			
W-6 (cont'd)	B1	110	41,500	715	565	70
	J2	110	42,500	750	609	80
	J1	110	40,450	684	334	25
	C2	110	42,250	715	325	40
	D1	120	40,200	707	516	80
	D2	120	40,650	665	734	100
	H1	120	41,000	750	650	90
	H2	120	42,450	775	707	100
W-7	M1	50	46,500	1,225	142	3
	M2	50	44,350	1,240	208	14
	N1	50	45,700	1,060	183	5
	N2	50	44,450	940	183	6
	L2	60	45,350	1,090	550	86
	P1	60	44,250	900	408	44
	P2	60	44,800	915	200	13
	Q1	60	45,150	1,025	92	5
	H1	70	43,550	860	734	100
	H2	70	43,800	925	375	30
	D1	70	42,900	800	790	100
	D2	70	43,400	885	842	100
	L1	80	43,950	1,010	266	23
	J1	80	44,200	900	925	100
	J2	80	44,050	925	200	13
	A2	80	43,400	833	125	13
	A1	90	43,650	915	775	100
	B2	90	42,250	808	875	100
	C1	90	43,700	885	775	100
	C2	90	43,400	910	734	100
W-8	L1	30	44,650	925	133	5
	L2	30	44,700	975	50	3
	N1	30	44,450	1,000	67	5
	N2	30	44,050	1,077	292	10
	M1	40	44,250	950	400	45
	M2	40	43,750	940	242	15
	N1	40	44,400	975	183	12
	P1	40	43,550	866	584	68
	N1	50	43,800	891	684	85
	P2	50	43,800	910	541	76
	Q1	50	42,800	815	150	3
	Q2	50	42,850	--	--	13
	A2	60	42,500	1,033	417	47
	L2	60	42,250	891	725	100
	M1	60	43,600	925	740	100
	M2	60	44,100	961	734	100
	J1	70	42,800	900	616	82
	J2	70	42,550	875	559	75
	A1	70	42,600	891	775	100
	B1	70	45,050	1,100	308	30
	B2	80	42,700	910	734	100
	C1	80	42,400	815	808	100
	C2	80	42,800	833	167	10
	L1	80	41,700	790	750	100
	K1	80	43,600	935	300	30
	A1	90	43,650	915	775	100
	B2	90	42,250	808	875	100
	C1	90	43,750	885	775	100
	C2	90	43,400	910	734	100

TABLE A-5. (Continued)

Steel	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
			Rolled in Laboratory Mill at 1650 F			
6 W-1	P1	10	42,550	940	158	12
	P2	10	40,650	824	142	5
	Q1	10	41,250	891	183	17
	Q2	10	42,200	866	108	3
	N1	20	41,750	891	367	43
	N2	20	43,000	833	675	100
	M1	20	39,750	808	17	2
	M2	20	39,250	958	466	65
	K1	30	39,500	800	75	3
	K2	30	37,400	750	525	70
	L1	30	39,100	766	83	3
	L2	30	38,450	850	133	8
	C2	40	38,950	800	125	12
	D1	40	36,600	715	559	65
	D2	40	38,450	808	58	3
	H1	40	38,200	790	690	100
	H2	50	37,850	775	50	10
	J1	50	36,850	766	484	70
	J2	50	38,100	766	67	10
	A2	50	38,400	750	150	10
	A1	60	37,050	784	650	100
	B1	60	37,400	815	616	100
	B2	60	38,950	860	550	83
	C1	60	36,750	750	616	98
6 W-2	K2	30	40,600	910	200	2
	D1	30	40,550	808	142	5
	D2	30	39,950	734	108	4
	H1	30	39,400	842	158	5
	B1	40	40,250	850	92	5
	H2	40	40,350	775	541	90
	J1	40	39,600	815	534	67
	J2	40	39,000	757	92	5
	A2	50	39,400	850	784	100
	B2	50	39,300	850	609	100
	C1	50	39,750	850	459	74
	C2	50	39,350	808	590	100
	A1	60	39,450	860	633	100
6 W-3	S1	20	38,900	885	58	3
	S2	20	39,150	950	67	1
	T1	20	39,600	910	442	50
	T2	20	38,350	775	408	45
	P1	30	38,000	833	250	23
	P2	30	38,550	915	208	15
	R1	30	39,550	940	658	100
	R2	30	40,000	975	108	7
	N1	40	37,950	860	275	45
	N2	40	39,700	961	459	60
	M2	40	39,550	940	650	98
	B1	50	39,050	800	58	3
	K1	50	39,000	815	167	10
	L1	50	39,150	866	665	86
	M1	50	39,400	925	700	100
	K2	60	38,450	740	757	100
	L2	60	37,700	860	800	97
	A2	60	38,200	860	475	73
	B2	60	38,600	958	92	7

TABLE A-5. (Continued)

Steel	Specimen	Testing Tempera-ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
		Rolled in Laboratory Mill at 1650 F (Continued)				
6 W-3 (cont'd)	A1	70	38,500	850	824	100
	C1	70	38,450	808	700	100
	C2	70	38,600	975	633	100
	D1	70	38,750	833	108	3
	D2	80	37,200	860	690	100
	H1	80	37,550	808	684	100
	H2	80	38,900	950	707	100
	J1	80	38,550	866	642	100
6 W-4	N1	40	39,700	875	100	7
	N2	40	39,850	891	133	20
	P1	40	40,850	975	158	8
	P2	40	40,000	900	266	30
	K2	50	40,050	824	108	7
	L1	50	39,000	757	67	4
	L2	50	39,500	750	500	79
	A2	50	42,400	1,170	292	33
	K1	60	39,550	875	584	100
	B1	60	38,950	833	891	100
	B2	60	39,750	850	108	6
	A1	60	39,600	875	616	100
	C1	70	38,850	775	58	27
	C2'	70	38,500	775	725	100
	D1'	70	38,800	790	642	100
	D2'	70	38,800	766	740	100
	C2	80	38,100	766	600	98
	D1	80	38,550	757	815	100
	D2	80	38,800	842	565	97
	C1'	80	37,900	775	866	100
6 W-5	H1	30	42,050	915	158	10
	J1	30	41,800	891	234	15
	J2	30	41,900	935	108	3
	C1	30	42,350	984	534	60
6 W-3 (cont'd)	B2	40	42,050	910	658	100
	C2	40	41,500	842	625	95
	D1	40	41,500	910	609	95
	D2	40	41,950	915	684	100
	B1	50	41,150	900	642	100
	A2	60	42,400	935	690	100
	A1	70	41,700	910	684	100
6 W-6	D2	30	44,550	1,170	150	3
	H1	30	44,600	1,140	133	5
	H2	30	44,750	1,120	83	3
	B2	40	43,200	1,090	150	6
	J1	40	42,250	958	100	5
	J2	40	43,100	1,033	125	4
	K1	40	43,650	1,140	158	5
	C1	50	43,000	1,125	665	100
	C2	50	43,750	1,140	684	100
	D1	50	43,250	1,025	740	100
	B1	50	43,400	1,120	715	100
	A2	60	43,900	1,090	734	100
	A1	70	43,100	1,040	684	100
6 W-7	M2	40	42,850	891	142	3
	K2	40	43,300	975	58	3
	L1	40	43,400	1,080	142	4
	L2	40	42,550	915	142	4
	D1	50	42,250	1,090	700	100
	D2	50	42,550	990	715	100
	H1	50	41,950	990	815	100
	A1	50	43,900	1,175	125	10

TABLE A-5. (Continued)

Steel	Specimen	Testing Tempera-ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
6 W-7 (cont'd)	A2	60	42,400	935	292	23
	H2	60	42,300	915	750	100
	J1	60	40,950	950	740	100
	J2	60	42,700	940	860	100
	B1	70	42,150	1,020	910	100
	B2	70	42,300	940	633	91
	C1	70	42,100	1,040	875	100
	C2	70	41,950	910	633	98
6 W-8	K1	10	43,850	975	534	60
	K2	10	43,900	1,000	193	5
	L1	10	42,750	910	392	30
	L2	10	43,700	1,010	417	43
	B2	20	43,700	1,020	283	30
	H2	20	43,050	1,020	808	100
	J1	20	44,200	1,080	300	28
	J2	20	43,400	1,025	740	100
	N1	30	42,300	975	690	100
	B1	30	42,750	975	675	100
	C1	30	43,500	1,077	707	97
	C2	30	42,950	990	358	35
	A2	40	43,450	1,033	690	100
	D1	40	42,900	1,000	750	100
	D2	40	41,900	910	766	100
	H1	40	43,050	1,020	750	95
	A1	50	42,100	961	740	100
		Rolled in Laboratory Mill at 1850 F				
8 W-1	R1	30	41,650	850	466	52
	R2	40	40,800	842	325	28
8 W-1 (cont'd)	P1	50	41,650	961	334	35
	P2	50	41,150	950	117	5
	Q1	50	41,200	961	142	8
	Q2	50	41,900	961	508	75
	K1	60	37,350	790	125	4
	K2	60	38,050	833	167	18
	L1	60	37,700	842	492	69
	L2	60	37,950	750	75	3
	N1	70	40,700	875	700	100
	N2	70	39,850	790	750	100
	A1	70	38,700	891	450	70
	A2	70	38,650	775	83	12
	B1	80	37,500	808	508	80
	B2	80	37,500	700	665	99
	C1	80	37,150	790	665	100
	C2	80	38,100	750	100	20
	M1	90	39,750	824	725	100
	M2	90	40,350	891	665	100
	D1	90	36,200	734	675	100
	D2	90	37,500	725	200	23
	H1	100	36,400	757	700	100
	H2	100	37,150	725	633	96
	J1	100	35,200	707	650	100
	J2	100	36,000	642	684	100
8 W-2	K1	50	40,100	866	150	7
	K2	50	40,600	915	342	29
	L1	50	40,250	910	50	2
	L2	50	41,800	1,060	125	3
	M1	60	40,150	885	584	93
	H1	60	38,700	866	500	79
	D1	60	39,750	1,000	58	6
	D2	60	39,900	935	125	7

TABLE A-5. (Continued)

Steel	Specimen	Testing Tempera- ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
		Rolled in Laboratory Mill at 1850 F (Continued)				
8 W-2 (cont'd)	H2	70	38,750	935	500	00
	J1	70	39,750	891	700	100
	J2	70	39,200	842	142	17
	B1	70	39,850	824	108	10
	A2	80	39,350	850	734	100
	B2	80	39,350	842	700	100
	C1	80	38,650	815	609	100
	C2	80	38,900	784	650	100
	A1	90	40,000	935	700	100
8 W-3	R1	30	41,300	940	417	75
	R2	30	40,450	866	150	20
	S1	30	38,400	915	200	20
	S2	30	38,150	790	275	23
	P2	40	39,000	990	665	100
	Q1	40	37,050	950	734	100
	Q2	40	39,900	975	700	100
	N1	50	40,000	1,010	690	100
	N2	50	37,850	860	358	40
	P1	50	38,100	891	658	100
	M2	50	40,000	925	125	4
	L1	60	37,950	775	100	3
	L2	60	38,400	833	684	100
	M1	60	39,800	925	133	11
	B1	60	38,850	866	108	5
	K1	70	38,350	940	100	4
	K2	70	36,800	757	234	28
	A2	70	38,300	860	690	100
	B2	70	37,600	775	108	6
	A1	80	37,200	815	665	100
	J2	80	36,750	757	625	100
	C1	80	36,550	766	690	100
	C2	80	37,400	784	92	15
	D1	90	36,350	784	750	100
	D2	90	37,600	842	734	100
	H2	90	36,600	766	642	100
	J1	90	36,700	757	750	100
8 W-4	K1	50	38,500	766	75	4
	K2	50	39,250	815	58	3
	L1	50	40,200	958	142	12
	L2	50	39,400	850	117	4
	C2	60	39,250	866	466	70
	D1	60	39,250	833	92	3
	D2	60	39,800	925	400	48
	H1	60	38,450	860	108	5
	H2	70	37,500	750	775	100
	J1	70	38,350	800	158	18
	J2	70	38,250	842	550	96
	A1	70	39,550	852	108	10
	A2	80	39,750	935	633	100
	B1	80	37,800	866	866	100
	B2	80	39,000	860	534	87
	C1	80	38,250	808	590	100
8 W-5	P1	30	35,150	766	609	100
	P2	30	37,500	775	616	100
	Q1	30	37,000	715	658	100
	Q2	30	35,700	625	625	100
	K1	40	41,200	833	590	80
	K2	40	41,150	875	675	100
	L1	40	41,150	833	665	100
	L2	40	40,850	833	500	67

TABLE A-5. (Continued)

Steel	Specimen	Testing Tempera- ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
		Rolled in Laboratory Mill at 1850 F (Continued)				
8 W-5 (cont'd)	M1	50	35,550	715	616	100
	N1	50	36,200	750	600	100
	N2	50	37,700	790	625	100
	H1	50	41,350	860	725	100
	H2	60	40,250	833	700	100
	J1	60	40,900	860	658	100
	J2	60	40,850	885	690	100
	C1	60	42,050	925	316	25
	C2	70	39,200	--	--	100
	D1	70	39,800	784	715	100
	D2	70	39,600	790	675	100
	B2	70	41,200	900	675	100
	B1	80	40,450	866	675	100
	A2	100	40,300	833	707	100
	A1	110	40,250	891	684	100
8 W-6	B2	60	42,150	1,175	350	40
	D2	60	42,700	1,190	334	28
	H1	60	41,750	1,077	242	15
	H2	60	42,300	1,100	133	5
	C1	70	41,950	1,080	1,130	100
	C2	70	42,000	1,077	707	100
	D1	70	42,400	1,175	684	100
	B1	70	42,200	1,130	675	100
	A2	80	41,400	1,025	1,275	100
	A1	90	42,000	1,140	790	100
8 W-7	K1	40	42,900	961	142	5
	K2	40	42,250	1,067	92	4
	L1	40	43,000	958	117	3
	L2	40	43,100	1,150	133	3
8 W-7	H1	50	42,150	958	158	8
	H2	50	41,600	1,067	108	5
	J1	50	41,750	990	625	99
	J2	50	42,500	1,100	125	5
	A1	60	42,750	1,040	400	55
	C2	60	40,200	1,050	891	75
	D1	60	41,750	990	150	10
	D2	60	41,450	1,020	642	90
	A2	70	40,900	975	590	75
	B1	70	42,050	961	675	100
	B2	70	41,450	950	757	100
	C1	70	41,650	961	675	100
8 W-8	K1	30	41,600	--	--	3
	D1	30	41,900	961	392	45
	D2	30	40,300	800	316	28
	H1	30	43,500	1,200	292	12
	H2	40	41,000	891	784	100
	J1	40	41,200	958	559	80
	J2	40	40,600	866	433	45
	B1	40	41,350	958	167	6
	A2	50	41,450	990	790	100
	B2	50	41,950	984	784	100
	C1	50	41,100	935	734	100
	C2	50	41,900	975	784	100
	A1	60	41,250	900	784	100
		Rolled in Laboratory Mill at 2050 F				
20 W-1	N1	20	37,850	750	425	53
	N2	20	38,350	790	67	2
	P1	20	37,850	790	100	3
	D1	20	36,800	935	42	2

TABLE A-5. (Continued)

Steel	Specimen	Testing Tempera-ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
		Rolled in Laboratory Mill at 2050 F (Continued)				
20 W-1 (cont'd)	M2	30	37,900	784	690	100
	D2	30	37,250	866	684	100
	H1	30	37,200	784	125	7
	C2	30	34,800	642	658	100
	M1	40	37,000	775	642	100
	C1	40	36,800	784	650	100
	H2	40	36,000	508	658	100
	J1	40	35,600	675	117	2
	B2	50	34,400	700	633	100
	L1'	50	36,750	725	342	48
	L2'	50	35,000	625	642	100
	J2	50	35,100	734	609	100
	L1	60	37,650	658	665	100
	L2	60	36,400	750	600	100
	K1	60	35,400	658	258	22
	B1	60	35,800	734	658	100
	K2	70	33,800	665	609	100
	M1	70	35,900	800	565	100
	M2	70	36,500	766	609	100
	A2	70	34,100	625	625	100
	A1	80	35,800	684	650	100
20 W-2	L1	40	39,600	910	50	4
	L2	40	39,500	900	83	3
	M1	50	39,300	875	83	3
	M2	50	39,400	875	92	3
	K1	50	38,500	775	266	27
	K2	50	38,800	775	117	5
	B1	60	37,850	734	492	80
	M2	60	38,300	815	108	5
	J1	60	37,700	734	275	30
	J2	60	38,950	885	325	33
20 W-2	H2	70	38,600	860	550	99
	A2	70	37,950	766	541	95
	C1	70	39,050	940	575	98
	C2	70	37,700	808	183	12
	A1	80	37,500	790	625	100
	D1	80	36,900	757	650	100
	D2	80	37,050	725	534	80
	H1	80	38,650	866	600	92
20 W-3	L1	40	37,150	750	133	6
	M2	40	38,600	915	92	4
	L2	40	37,800	900	367	46
	C1	40	38,200	950	108	7
	K1	50	36,250	766	300	30
	B2	50	36,750	850	665	100
	C2	50	37,400	1,077	283	31
	K2	50	37,300	885	75	3
	B1	60	36,850	850	665	100
	J2	60	37,650	940	590	97
	D1	60	37,300	891	541	74
	D2	60	37,300	910	358	35
	A2	70	36,700	824	700	100
	H1	70	37,250	925	642	75
	H2	70	36,300	850	665	100
	J1	70	36,750	860	616	93
	A1	90	37,300	910	658	100
20 W-4	M1	40	38,700	790	167	15
	M2	40	38,600	808	142	7
	M1'	40	39,450	915	133	10
	M2'	40	39,400	915	183	18

TABLE A-5. (Continued)

Steel	Specimen	Testing Tempera-ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
		Rolled in Laboratory Mill at 2050 F (Continued)				
20 W-4 (cont'd)	K1	50	38,000	790	675	100
	L2	50	38,350	815	544	78
	K2	50	38,650	784	266	15
	L1	50	38,300	800	375	74
	H1	60	37,750	808	508	70
	H2	60	37,000	784	400	50
	J1	60	37,250	790	600	97
	J2	60	37,650	800	575	94
	C2	70	37,300	775	125	5
	D1	70	37,500	784	700	100
	D2	70	38,350	860	216	17
	A2	70	38,350	833	242	25
	B1	80	37,100	740	442	60
	B2	80	37,400	757	725	100
	C1	80	37,800	824	707	100
	A1	80	35,800	684	684	100
20 W-5	S1	60	35,000	650	665	100
	S2	60	36,150	675	658	100
	A1	70	41,600	1,125	158	10
	P1	70	33,900	584	658	100
	P2	70	35,500	734	584	100
	R1	70	35,400	725	665	100
	K1	70	39,950	875	92	4
	K2	70	40,400	910	383	48
	L2	70	42,100	1,050	75	3
	M2	80	40,100	860	283	25
	R2	80	35,200	725	633	100
	N2	80	35,200	690	625	100
	A2	80	40,550	860	658	90
	B1	80	39,050	815	142	12
	N1	90	34,750	633	616	100
	B2	90	39,950	842	625	95
	C1	90	39,000	808	675	97
	C2	90	39,900	860	208	20
	L1	100	40,200	900	740	97
	M1	100	39,900	815	750	95
	Q1	100	33,900	684	584	100
	Q2	100	33,050	609	625	100
	D1	100	39,000	875	757	100
	D2	100	39,000	800	208	25
	H1	110	39,100	915	725	100
	H2	110	38,900	833	266	35
	J1	110	39,150	925	675	100
	J2	110	39,000	833	775	100
20 W-6	L1	50	41,900	1,140	142	8
	L2	50	41,850	1,060	442	45
	M1	50	42,350	1,120	100	3
	M2	50	41,700	1,033	108	5
	K2	60	41,900	1,150	100	4
	J1	60	40,200	1,020	642	90
	J2	60	41,800	1,170	208	8
	K1	70	41,150	1,080	590	72
	B1	70	41,250	1,125	658	73
	B2	70	40,650	1,033	367	35
	H1	70	41,350	1,077	133	6
	H2	70	41,150	1,060	117	5
	C1	80	40,100	1,100	715	100
	C2	80	40,950	1,033	675	98
	D1	80	40,750	1,050	665	95
	A2	80	41,300	1,077	715	100
	A1	90	39,950	975	675	100

TABLE A-5. (Continued)

Steel	Specimen	Testing Tempera-ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
		Rolled in Laboratory Mill at 2050 F (Continued)				
20 W-7	M1	50	40,700	935	250	24
	K2	50	40,900	--	--	47
	L2	50	42,300	1,100	266	32
	M2	50	41,550	975	484	62
	L1	60	40,650	950	715	100
	D1	60	39,950	925	508	70
	D2	60	41,150	1,000	250	22
	H1	60	41,750	1,077	715	100
	K1	70	40,850	1,025	358	43
	N1	70	41,900	1,060	775	100
	J1	70	40,650	1,067	609	70
	J2	70	40,000	940	775	100
	A1	70	40,250	940	142	10
	H2	80	40,900	1,090	700	100
	B1	80	40,550	1,020	815	100
	B2	80	39,700	891	757	100
	C1	80	40,400	984	775	100
	C2	80	38,700	891	842	100
20 W-8	P1	30	42,400	958	75	3
	P2	30	42,250	1,020	66	53
	Q1	30	40,200	842	158	5
	S2	30	41,000	842	158	43
	Q2	40	41,450	1,010	100	5
	R1	40	41,600	990	650	85
	R2	40	42,350	1,060	316	35
	S1	40	42,500	1,050	150	10
	N2	50	40,400	958	800	100
	A1	50	39,750	910	417	40
	L1	50	40,300	935	690	97
	K1	50	41,000	935	133	4
	K2	50	40,500	910	158	15
	M2	50	39,700	790	725	95
	A2	60	40,700	915	358	68
	B1	60	40,150	940	67	2
	H2	60	40,200	850	833	100
	H1	70	40,800	875	800	100
	B2	70	40,700	1,033	342	25
	N1	70	41,750	1,020	715	100
	M1	70	39,700	842	466	46
	L2	70	41,150	850	734	100
	C1	80	41,400	1,200	700	100
	C2	80	39,900	1,080	784	100
	D1	80	39,500	935	740	100
	D2	80	40,400	1,025	750	100

TABLE A-6. NAVY TEAR-TEST DATA FOR EXPERIMENTAL OPEN-HEARTH STEELS FROM COMPANY V

Steel	Specimen	Testing Tempera-ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
		Rolled in Commercial Mill				
V-1	A1	70	38,100	707	108	5
	K1	80	38,100	--	--	2
	A2	80	37,550	740	58	5
	J1	80	38,700	740	25	4
	J2	80	38,300	684	92	5
	B2	90	37,650	734	525	98
	C1	90	37,700	734	565	100
	C2	90	37,900	775	117	8
	H2	90	37,300	707	183	22
	B1	100	36,800	725	559	100
	D1	100	37,500	775	534	100
	D2	100	37,050	725	525	100
	H1	100	37,550	690	824	100
V-2	A1	70	38,600	690	133	5
	A2	80	37,600	642	83	5
	M1	80	38,150	690	67	4
	N1	80	38,100	690	100	3
	K1	80	38,300	700	25	5
	B2	90	37,800	633	108	12
	M2	90	37,450	707	208	12
	L2	90	38,000	757	541	100
	R2	90	38,850	707	484	87
	Q1	100	37,750	715	734	100
	Q2	100	37,850	715	183	20
	R1	100	38,450	684	117	15
	B1	100	39,800	950	484	99
	C1	100	37,750	690	92	15
	C2	110	37,550	675	167	20
	N2	110	37,350	658	150	19
	P1	110	37,300	658	609	100
	D1	120	37,250	700	1,258	100
	D2	120	38,450	725	590	100
	H1	120	38,200	800	575	100
	H2	120	37,150	684	175	20
	J1	130	37,650	658	600	100
	J2	130	37,750	665	875	100
	L1	130	36,600	665	609	100
	P2	130	36,600	642	450	70
V-3	A1	70	37,600	609	175	10
	A2	80	38,850	740	58	10
	K1	80	38,250	700	193	16
	L1	80	39,350	766	158	15
	L2	80	39,100	740	234	25
	M1	80	39,000	750	133	6
	M2	90	38,550	740	425	60
	D2	90	38,750	734	975	100
	H1	90	38,550	690	541	97
	H2	90	38,750	800	100	10
	K2	100	38,300	707	925	100
	J1	100	38,000	690	550	99
	J2	100	37,900	750	575	100
	B1	100	37,150	665	183	35
	B2	110	38,400	757	715	100
	C1	110	37,250	600	707	100
	C2	110	37,950	690	600	100
	D1	110	37,600	658	625	100
V-4	A1	50	40,000	675	108	5
	A2	60	38,550	642	50	3
	B1	70	38,500	684	92	4

TABLE A-6. (Continued)

Steel	Specimen	Testing Tempera- ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
		Rolled in Commercial Mill (Continued)				
V-4 (Cont'd)	B2	80	38,000	690	58	3
	P1	90	38,400	766	125	12
	P2	90	37,550	690	250	14
	Q1	90	37,150	815	108	10
	Q2	90	37,750	642	100	7
	C1	100	37,950	700	308	30
	L2	100	38,500	775	108	15
	N1	100	37,500	700	575	97
	N2	100	37,850	633	559	100
	C2	110	37,650	616	590	100
	D1	110	38,250	684	559	100
	D2	110	37,700	609	675	100
	H1	110	38,050	675	50	15
	M1	120	37,300	616	600	100
	L1	120	36,850	600	633	100
	M2	120	38,950	860	559	100
	H2	120	37,700	609	208	20
	K1	130	37,050	684	575	98
	K2	130	37,600	658	584	100
	J1	130	37,450	609	650	100
	J2	130	37,850	633	642	100
V-5	M1	30	40,500	958	193	10
	N1	30	41,000	1,033	67	3
	N2	30	39,500	1,000	316	28
	P2	30	39,950	1,077	117	4
	A2	40	39,300	961	234	20
	K2	40	38,900	958	83	5
	M2	40	39,600	990	534	70
	P1	40	39,700	958	67	3
	A1	50	39,050	975	584	78
	B1	50	39,550	1,060	466	51
	R1	50	39,700	891	100	5
	R2	50	40,150	1,000	125	7
	Q1	60	38,600	885	117	5
	Q2	60	39,200	784	275	10
	L2	60	38,100	885	642	85
	B2	60	38,800	910	125	8
	C2	70	38,350	885	633	98
	D2	70	38,450	900	100	5
	K1	70	38,250	940	1,258	100
	L1	70	39,400	940	609	95
	H1	80	39,100	984	650	100
	H2	80	38,750	875	665	100
	J1	80	38,350	1,020	784	100
	J2	80	37,600	850	650	93
V-6	J2	30	39,750	900	417	22
	B1	30	40,050	784	575	54
	P1	30	40,250	915	367	40
	P2	30	40,400	891	167	11
	K2	30	40,350	1,000	167	8
	L2	30	41,100	684	125	5
	N1	40	39,900	915	125	3
	N2	40	39,600	875	67	2
	A2	40	39,900	940	658	92
	B2	40	40,000	961	117	3
	K1	50	39,500	915	725	100
	A1	50	39,100	866	950	100
	C1	50	40,000	875	833	100
	C2	50	39,500	875	108	4

TABLE A-6. (Continued)

Steel	Specimen	Testing Tempera- ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
		Rolled in Commercial Mill (Continued)				
V-6 (Cont'd)	D1	60	39,750	958	275	28
	L1	60	39,350	875	642	81
	M1	60	39,200	910	325	33
	M2	60	39,700	900	350	40
	D2	70	39,000	850	1,483	100
	H1	70	39,300	925	616	98
	H2	70	38,150	808	684	100
	J1	70	38,200	875	707	100
V-7	K1'	50	40,500	850	417	45
	K2'	50	40,050	790	83	5
	M1	50	39,350	775	266	3
	A1	50	39,200	833	200	11
	J1	60	39,750	958	100	5
	A2	60	39,450	950	92	5
	K1	60	39,150	850	940	100
	K2	60	40,450	925	325	41
	B1	70	37,950	815	534	75
	B2	70	38,850	915	150	10
	H1	70	38,100	784	50	5
	H2	70	38,900	891	334	30
	C1	80	39,350	875	642	100
	C2	80	39,600	975	750	100
	D1	80	38,350	833	684	100
	D2	80	38,150	850	757	100
V-8	A1	50	40,250	950	316	35
	H2	50	39,700	833	125	5
	J1	50	39,000	790	150	8
	J2	50	38,400	766	193	15
	A2	60	38,550	784	466	25
	D1	60	38,800	690	808	100
	D2	60	40,100	891	425	50
	H1	60	38,850	1,040	325	37
	B1	70	39,200	808	700	100
	B2	70	39,850	958	658	100
	C1	70	38,500	766	734	100
	C2	70	39,650	958	715	100
		Rolled in Laboratory Mill at 1650 F				
6 V-1	K1	50	38,400	715	83	3
	K2	50	38,350	734	92	2
	L2	50	39,100	757	83	2
	M2	50	39,850	725	183	4
	A2	60	39,200	725	658	100
	D1	60	37,500	665	83	4
	D2	60	38,050	715	117	4
	H2	60	38,750	750	75	3
	J1	70	38,250	684	150	4
	J2	70	37,350	715	108	4
	A1	70	39,000	740	492	40
	L1	70	37,850	625	100	7
	B1	80	38,000	740	675	100
	B2	80	37,900	750	700	100
	C1	80	38,050	784	633	100
	C2	80	37,400	707	1,508	100
6 V-2	L2	60	36,500	700	83	3
	M1	60	38,100	715	50	2
	M2	60	37,900	700	83	3
	A2	60	40,000	958	100	12

TABLE A-6. (Continued)

Steel	Specimen	Testing Tempera- ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
		Rolled in Laboratory Mill at 1650 F (Continued)				
6 V-2 (Cont'd)	L1	70	37,400	734	108	5
	A1	70	37,300	675	633	100
	B2	70	38,000	715	167	15
	B1	80	37,800	707	633	100
	C1	80	37,150	700	175	10
	K1	80	37,550	750	50	2
	C2	90	36,600	700	633	100
	D1	90	37,000	650	707	100
	D2	90	37,450	734	665	100
	H1	90	37,350	715	50	15
	K2	100	36,600	665	584	100
	H2	100	37,350	750	1,525	100
	J1	100	38,000	757	700	100
	J2	100	38,600	833	642	100
6 V-3	L1	60	39,000	740	75	2
	B1	60	38,500	715	50	3
	K1	60	39,450	850	54	2
	K2	60	38,900	833	150	4
	L2	70	38,350	790	75	5
	A2	70	40,200	875	1,342	100
	H2	70	38,250	808	550	98
	B2	70	38,650	800	158	15
	J1	80	38,750	800	625	97
	J2	80	38,450	766	642	100
	C1	80	38,300	784	675	100
	C2	80	38,350	833	92	10
	A1	90	38,250	700	675	100
	D1	90	38,000	775	1,383	100
	D2	90	37,550	740	775	98
	H1	90	38,600	824	1,190	100
6 V-4	D2	60	39,150	757	75	4
	H1	60	38,200	715	158	10
	H2	60	39,650	808	50	3
	B2	60	39,400	766	167	7
	C1	70	38,700	824	1,367	100
	C2	70	38,200	750	1,516	100
	D1	70	39,000	766	675	100
	B1	70	38,700	775	1,050	100
	A2	80	38,350	690	775	100
	A1	90	38,600	800	541	100
6 V-5	B2	20	40,200	1,033	125	4
	N2	30	39,500	1,000	150	7
	A2	30	41,000	1,080	675	100
	B1	30	40,350	1,020	690	100
	C1	30	41,300	1,175	100	4
	N1	40	39,950	1,067	684	100
	A1	40	40,600	1,060	784	100
	C2	40	40,000	1,080	565	7
	L2	40	40,150	1,050	1,817	100
	K2	50	39,750	866	2,030	100
	M2	50	40,150	1,050	790	100
	H2	50	40,600	1,080	784	100
	D1	50	39,300	1,080	158	5
	D2	60	40,200	1,190	1,641	100
	H1	60	38,700	961	815	100
	J1	60	39,050	1,067	766	100
	J2	60	39,100	1,000	790	100

TABLE A-6. (Continued)

Steel	Specimen	Testing Tempera- ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
		Rolled in Laboratory Mill at 1650 F (Continued)				
6 V-6	D1	20	41,400	1,170	108	3
	L1	20	40,700	1,130	350	31
	L2	20	40,750	1,077	216	11
	H1	20	41,050	--	--	10
	B2	30	40,250	1,080	800	100
	C1	30	41,000	1,025	800	94
	C2	30	41,350	1,125	690	94
	J2	30	42,050	1,267	150	12
	D2	40	39,100	975	824	100
	H2	40	40,350	1,090	766	100
	J1	40	40,000	1,060	565	74
	B1	40	40,650	1,150	1,000	100
	A2	50	39,200	1,025	1,988	100
	B1	60	39,850	1,040	1,300	100
6 V-7	M2	10	40,600	1,010	308	20
	K1	20	40,900	1,067	92	5
	L1	20	40,850	1,025	625	75
	L2	20	40,600	1,000	75	3
	M1	20	41,100	1,090	108	3
	H2	30	39,950	958	833	100
	J1	30	40,100	940	242	14
	J2	30	39,700	958	684	98
	K2	30	40,450	975	117	3
	B1	40	40,300	1,060	193	13
	D1	40	39,000	975	790	100
	D2	40	39,000	915	815	100
	H1	40	40,400	1,040	584	58
	A2	50	39,200	915	1,620	100
	B2	50	39,800	990	815	100
	C1	50	40,050	1,010	808	100
	C2	50	40,400	940	1,425	100
	A1	60	39,950	990	740	100
6 V-8	L1	10	41,850	1,020	175	7
	L2	10	42,150	1,120	67	2
	M1	10	42,850	1,100	200	18
	K2	10	41,650	1,025	167	5
	K1	20	41,900	1,077	757	100
	H2	20	41,600	1,080	83	2
	J1	20	41,850	1,067	67	2
	J2	20	42,150	1,090	275	27
	B1	30	41,700	1,080	516	58
	B2	30	41,200	990	766	100
	D2	30	40,600	961	700	99
	H1	30	40,850	990	108	7
	A2	40	40,850	1,025	766	100
	C1	40	40,750	1,010	961	100
	C2	40	41,050	1,033	1,792	100
	D1	40	42,300	1,200	1,080	100
	A1	50	40,100	984	833	100
		Rolled in Laboratory Mill at 1850 F				
8 V-1	K1	70	37,350	684	100	7
	K2	70	37,750	734	92	5
	L1	70	37,800	784	100	6
	M1	70	38,100	700	133	4

TABLE A-6. (Continued)

Steel	Specimen	Testing Tempera-ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
		Rolled in Laboratory Mill at 1850 F (Continued)				
8 V-1	A1	80	37,150	715	150	10
(Cont'd)	L2	80	36,500	665	1,367	100
	M1'	90	37,550	700	108	7
	A2	90	36,800	715	565	100
	B1	90	37,500	715	642	100
	B2	90	37,000	642	208	25
	C1	100	38,300	815	633	100
	C2	100	36,600	665	1,267	100
	D1	100	35,900	609	216	12
	J2	100	37,300	784	633	100
	D2	110	36,400	690	1,500	100
	H1	110	37,450	775	633	100
	H2	110	36,350	707	1,716	100
	J1	110	37,450	833	684	100
8 V-2	H1	80	37,300	658	75	10
	H2	80	37,300	725	108	8
	J1	80	37,150	690	133	10
	J2	80	37,150	725	83	7
	A1	90	36,800	665	158	10
	C2	90	36,150	616	158	12
	D1	90	35,800	633	600	100
	D2	90	36,900	684	534	100
	A2	100	36,350	665	609	100
	B1	100	36,050	707	625	100
	B2	100	36,400	675	642	100
	C1	100	36,000	590	707	100
8 V-3	A2	80	37,000	750	167	15
	C2	80	37,800	707	108	7
	D1	80	37,500	740	100	10
	D2	80	37,650	750	117	10
	A1	90	38,600	757	642	100
	B1	90	38,250	808	600	100
	B2	90	38,400	800	541	100
	C1	90	37,800	725	565	100
8 V-4	B1	70	37,800	734	50	4
	L2	70	37,500	--	--	4
	K2	70	37,750	800	600	100
	K1	70	37,100	715	142	4
	A2	80	36,500	642	1,025	95
	B2	80	37,150	707	1,367	100
	C2	80	37,200	715	100	8
	A1	90	37,400	715	1,562	100
	C1	90	37,450	734	75	15
	M1	90	36,850	715	700	100
	L1	100	36,900	675	242	17
	M2	100	37,200	700	633	100
	J2	100	36,650	690	625	100
	D1	100	37,500	784	108	12
	D2	110	36,900	740	590	100
	H1	110	36,950	725	1,267	100
	H2	110	37,050	734	1,558	100
	J1	110	36,850	700	650	100
8 V-5	P1	10	39,200	1,060	92	3
	P2	10	40,350	1,080	108	3
	Q1	10	39,850	1,040	92	3
	H1	10	41,050	1,160	150	10
	N1	20	39,950	1,025	83	3
	N2	20	40,000	808	58	2
	C2	20	40,350	1,130	684	95
	D1	20	40,100	1,160	117	4

TABLE A-6. (Continued)

Steel	Specimen	Testing Tempera-ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
		Rolled in Laboratory Mill at 1850 F (Continued)				
8 V-5	M2'	30	39,900	1,080	125	7
(Cont'd)	D2	30	39,450	1,100	584	84
	A2	30	40,400	1,067	734	73
	J2	30	40,050	1,067	142	5
	M1'	40	40,100	1,020	125	5
	A1	40	39,450	1,020	725	100
	B2	40	39,100	1,020	367	32
	M2	40	39,350	990	108	4
	B1	50	38,800	975	1,190	100
	C1	50	39,050	975	757	100
	J1	50	39,200	1,077	950	95
	M1	50	38,700	950	133	7
	K1	60	38,700	990	700	100
	K2	60	38,800	1,020	534	85
	L1	60	39,400	1,040	1,534	100
	L2	60	38,200	950	675	99
8 V-6	K1	30	39,500	990	67	2
	D1	30	39,000	975	142	6
	D2	30	39,200	990	183	12
	J2	30	39,700	1,040	100	4
	H1	40	40,000	1,010	142	6
	H2	40	40,500	1,060	824	100
	J1	40	39,900	1,077	484	56
	B1	40	39,600	1,040	484	45
	A2	50	37,300	915	757	70
	B2	50	39,450	990	815	100
	C1	50	39,450	1,050	860	100
	C2	50	39,750	1,020	684	97
	A1	60	39,250	1,060	766	100
8 V-7	P1	30	39,600	900	225	15
	P2	30	41,050	1,050	150	8
	Q1	30	40,050	860	175	4
	Q2	30	39,900	984	133	10
	M1	40	40,500	1,050	616	90
	M2	40	39,300	915	766	95
	N1	40	39,750	961	308	20
	N2	40	39,400	950	83	3
	K1	50	38,800	961	50	5
	L2	50	38,500	915	815	100
	A2	50	38,500	958	50	3
	L1	50	39,300	984	800	100
	A1	60	38,450	940	850	100
	B1	60	39,550	1,000	707	95
	B2	60	38,700	1,010	790	100
	C1	60	38,500	961	58	5
	K2	70	37,100	--	--	100
	C2	70	37,250	885	784	100
	D1	70	38,650	1,010	715	97
	D2	70	37,400	910	216	10
	H1	80	37,200	833	815	100
	H2	80	36,950	885	842	100
	J1	80	38,500	940	1,675	100
	J2	80	37,450	935	815	100
8 V-8	R1	30	40,000	984	125	8
	R2	30	40,500	1,020	75	6
	S1	30	39,250	935	500	55
	S2	30	39,700	940	67	3
	L2	40	39,600	1,010	665	85
	M1	40	40,150	990	150	10

TABLE A-6. (Continued)

Steel	Specimen	Testing Tempera- ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
		Rolled in Laboratory Mill at 1850 F (Continued)				
8 V-8	M2	40	39,700	900	133	5
(Cont'd)	A2	40	39,100	850	150	6
	Q1	50	39,100	940	100	3
	Q2	50	39,850	1,000	842	100
	A1	50	39,950	1,010	866	90
	B1	50	40,750	1,033	425	43
	P1	60	39,100	1,000	866	100
	P2	60	38,650	833	2,067	100
	B2	60	39,700	935	175	6
	C1	60	40,150	1,010	757	100
	N1	70	38,650	915	757	100
	N2	70	38,650	925	790	100
	K2	70	38,600	885	740	100
	C2	70	38,600	875	67	7
	L1	80	38,750	961	1,020	100
	D1	80	39,350	958	866	100
	D2	80	38,550	891	833	100
	H1	80	39,550	1,010	25	10
	K1	90	38,450	915	775	100
	H2	90	39,400	1,040	1,267	90
	J1	90	38,700	910	824	100
	J2	90	38,450	875	740	100
		Rolled in Laboratory Mill at 2050 F				
20 V-1	K2	90	36,600	750	117	7
	L1	90	35,100	675	75	10
	L2	90	36,300	740	125	10
	A2	90	36,350	684	92	12
	K1	100	36,300	715	584	100
	A1	100	35,850	715	800	100
	B1	100	34,250	665	67	10
	J2	100	36,050	707	193	22
	H1	110	36,100	707	616	100
	H2	110	36,150	725	665	100
	J1	110	35,800	700	633	100
	B2	110	36,050	740	250	25
	C1	120	35,100	700	616	100
	C2	120	35,900	740	700	100
	D1	120	35,250	690	675	100
	D2	120	36,300	725	642	100
20 V-2	A2	90	35,900	675	108	10
	C2	90	35,650	684	83	10
	D1	90	35,900	675	75	10
	D2	90	35,900	658	67	7
	A1	100	35,250	665	541	100
	B1	100	35,600	700	600	100
	B2	100	35,450	642	609	100
	C1	100	35,050	650	684	100
20 V-3	L1	80	37,200	766	83	2
	L2	80	37,600	775	100	5
	M1	80	37,250	757	58	2
	M2	80	36,700	750	67	3
	A1	90	37,300	740	58	10
	H2	90	36,550	715	83	10
	J1	90	37,500	808	559	97
	J2	90	36,800	725	92	10
	H1	100	37,050	725	1,160	100
	A2	100	36,900	740	590	100
	B1	100	37,750	790	559	95
	B2	100	37,150	757	358	35

TABLE A-6. (Continued)

Steel	Specimen	Testing Tempera- ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
		Rolled in Laboratory Mill at 2050 F (Continued)				
20 V-3	C1	110	36,350	700	665	100
(Cont'd)	C2	110	36,700	707	616	100
	D1	110	36,550	658	609	100
	D2	110	36,150	684	584	100
20 V-4	L2'	80	36,900	734	92	5
	M1	80	37,200	734	67	3
	M2	80	36,850	734	42	3
	N1	80	37,500	784	100	7
	K1	80	36,000	690	92	5
	K2	80	37,350	766	92	4
	N2	90	36,750	725	575	100
	B1	90	36,100	650	167	10
	L1	90	36,600	750	75	15
	L2	90	36,450	690	541	100
	L1'	100	36,500	725	125	13
	B2	100	36,200	707	133	13
	A2	100	35,650	642	950	100
	J2	100	36,100	--	--	99
	A1	110	38,300	940	584	100
	J1	110	36,150	665	225	27
	C1	110	36,250	734	700	100
	C2	110	35,900	715	142	15
	D1	120	35,800	707	650	100
	D2	120	36,800	707	642	100
	H1	120	36,400	740	675	100
	H2	120	35,600	675	665	100
20 V-5	U1	30	39,850	1,110	225	15
	U2	30	39,600	1,025	117	5
	V1	30	39,250	1,025	142	12
	B1	30	37,850	935	100	3
	B2	40	37,600	915	358	30
	C1	40	37,850	900	665	79
	C2	40	38,450	1,010	715	94
	A2	40	38,500	1,040	642	97
	T1	50	38,950	1,000	1,040	95
	T2	50	39,100	1,000	1,599	100
	A1	50	38,450	990	590	82
	H1	50	38,450	1,100	92	3
	R1	60	38,800	1,040	790	100
	S1	60	38,400	1,077	1,966	100
	S2	60	37,250	740	715	100
	H2	60	37,450	958	75	4
	Q2	70	39,000	1,110	1,841	100
	D1	70	37,500	1,010	875	100
	D2	70	36,950	950	784	100
	J1	70	37,350	975	100	7
	P1	80	37,950	1,033	1,333	100
	P2	80	37,750	1,020	715	100
	Q1	80	37,100	984	1,234	100
	J2	80	37,000	958	108	4
	N1	90	36,800	915	766	100
	N2	90	37,550	958	725	100
	L2	90	36,000	875	350	31
	M2	90	36,600	940	740	100
	K1	100	36,500	910	1,425	100
	K2	100	36,400	866	1,867	100
	L1	100	36,850	910	715	100
	M1	100	36,750	891	850	100

TABLE A-6. (Continued)

Steel	Specimen	Testing Tempera-ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
		Rolled in Laboratory Mill at 2050 F (Continued)				
20 V-6	P2	30	38,950	990	158	7
	Q1	30	39,300	1,050	67	3
	Q2	30	39,450	1,060	100	3
	R1	30	39,550	1,090	83	3
	K1	40	38,400	984	75	5
	K2	40	38,600	1,040	559	75
	L1	40	38,650	885	1,090	100
	M1	40	38,950	1,040	175	12
	N1	50	39,000	1,000	534	55
	N2	50	38,450	950	565	75
	P1	50	39,400	1,033	292	25
	M2	50	38,400	975	885	100
	L2	60	38,200	1,000	75	3
	A1	60	39,200	1,040	250	10
	J1	60	38,600	961	392	35
	J2	60	37,900	915	750	97
	A2	70	37,400	935	766	100
	B1	70	37,450	940	800	100
	B2	70	37,650	950	833	100
	C1	70	37,300	950	125	5
	C2	80	37,450	1,000	975	100
	D1	80	37,700	984	900	100
	D2	80	37,700	958	850	100
	H1	80	37,200	935	790	100
20 V-7	K1	50	37,500	734	125	12
	K2	50	36,700	850	316	30
	L1	50	37,950	875	167	9
	L2	50	38,100	958	125	5
20 V-7 (Cont'd)	H1	60	37,250	891	67	4
	H2	60	38,300	915	750	100
	J1	60	37,800	900	58	3
	J2	60	38,000	891	750	100
	C2	70	37,650	935	725	100
	D1	70	37,600	891	658	90
	D2	70	36,900	860	766	100
	A1	70	37,050	833	42	5
	A2	80	36,800	824	766	100
	B1	80	37,650	875	750	100
	B2	80	37,850	885	815	100
	C1	80	37,800	885	833	100
20 V-8	L1	30	38,950	900	92	3
	L2	30	39,300	1,020	125	7
	M1	30	39,450	984	183	10
	K2	30	38,850	940	442	32
	K1	40	39,200	958	616	89
	H2	40	37,400	860	100	2
	J1	40	37,700	833	142	3
	J2	40	38,200	875	534	58
	D1	50	37,950	910	234	7
	D2	50	37,200	808	375	33
	H1	50	37,900	875	715	96
	B1	50	39,300	1,120	92	3
	B2	60	38,150	925	740	100
	C1	60	38,450	958	550	70
	C2	60	38,250	1,020	734	98
	A2	60	37,200	866	808	100
	A1	70	36,200	790	1,100	98

TABLE A-7. NAVY TEAR-TEST DATA FOR EXPERIMENTAL OPEN-HEARTH STEELS FROM COMPANY Z

Steel	Specimen	Testing Tempera-ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
			Rolled in Commercial Mill			
Z-1	E1	50	39,350	875	358	35
	E2	50	38,900	833	100	10
	F1	50	41,000	1,080	100	5
	F2	50	39,350	940	50	5
	A1	60	40,000	1,220	92	10
	C2	60	38,950	891	150	8
	D1	60	39,200	984	100	10
	D2	60	40,100	1,040	142	13
	A2	70	39,500	961	734	100
	B1	70	39,100	984	633	81
	B2	70	39,100	935	690	100
	C1	70	39,300	990	650	99
Z-2	K1	40	39,500	790	100	5
	K2	40	38,150	725	316	30
	L1	40	38,900	800	108	8
	L2	40	40,400	958	100	4
	E2	50	37,100	650	658	100
	D2	50	36,200	616	158	12
	E1	50	37,950	734	158	10
	F1	50	38,050	715	258	20
	A2	60	36,250	590	734	100
	B1	60	38,050	815	425	65
	A1	60	37,450	690	175	10
	B2	60	37,150	642	367	47
	C1	70	37,350	725	650	100
	C2	70	35,800	590	665	100
	D1	70	37,550	--	--	100
	F2	70	36,900	734	609	100
Z-3	N1	40	38,400	910	600	86
	N2	40	38,600	925	75	3
	P1	40	38,200	875	216	22
	P2	40	37,850	860	92	3
	K1	50	39,050	1,090	684	100
	K2	50	38,700	740	183	15
	L1	50	38,600	875	100	8
	D2	50	38,200	891	133	13
	L2	60	38,500	900	684	100
	M1	60	38,550	935	125	13
	A1	60	37,700	866	565	73
	A2	60	37,800	866	167	23
	M2	70	38,450	875	433	62
	B1	70	37,750	990	584	100
	C1	70	38,000	990	665	96
	D1	70	37,100	842	292	37
	E1	80	36,750	800	642	100
	E2	80	37,100	800	650	100
	F1	80	37,050	750	658	100
	F2	80	37,150	850	625	100
Z-4	N1	20	41,900	1,250	433	53
	M1	20	39,050	1,077	133	5
	M2	20	39,950	915	193	20
	N2	20	39,450	900	117	3
	K1	30	39,100	875	92	3
	K2	30	39,250	860	358	42
	L1	30	39,300	808	650	96
	A1	30	38,000	842	275	25
	L2	40	39,050	875	625	100
	A2	40	38,650	875	466	65
	F2	40	37,300	734	675	100
	B1	40	38,400	900	125	10
	B2	50	37,900	885	675	100
	C1	50	38,700	915	500	70
	C2	50	38,100	891	665	100
	D1	50	38,500	910	300	38

TABLE A-7. (Continued)

Steel	Specimen	Testing Tempera-ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
		Rolled in Commercial Mill				
Z-4 (Cont'd)	D2	60	38,200	885	675	100
	E2	60	38,200	815	642	100
	F1	60	38,300	842	508	100
	E1	60	37,800	833	715	100
Z-5	E1	80	38,250	734	142	15
	E2	80	37,550	650	242	30
	F1	80	38,100	690	100	5
	F2	80	37,450	684	75	10
	C2	90	38,100	715	492	81
	D1	90	37,900	658	484	90
	D2	90	38,650	725	125	25
	A2	90	38,150	650	108	20
	A1	100	37,800	675	565	100
	B1	100	38,250	--	--	100
	B2	100	37,850	700	534	100
	C1	100	38,200	684	559	100
				--		
Z-6	M1	80	38,350	700	117	5
	M2	80	38,550	700	75	5
	N1	80	38,350	707	193	18
	N2	80	37,900	--	--	23
	K1	90	38,350	740	125	15
	K2	90	38,300	734	58	15
	L1	90	39,500	750	292	35
	A2	90	39,200	725	234	35
	L2	100	40,150	690	142	20
	A1	100	38,500	665	550	100
	B1	100	38,100	707	300	48
	F2	100	37,950	684	175	23
	B2	110	38,350	684	266	47
	E1	110	37,650	633	534	95
	E2	110	38,100	665	575	100
	F1	110	37,650	625	590	100
	C1	120	37,600	675	559	100
	C2	120	36,950	609	590	100
	D1	120	36,600	590	590	100
	D2	120	37,000	625	575	100
Z-7	E1	80	37,450	625	283	40
	E2	80	37,050	616	67	12
	F1	80	37,550	658	225	30
	F2	80	36,800	559	100	12
	D1	90	37,450	625	516	84
	D2	90	37,500	616	475	75
	C2	90	36,100	625	142	39
	A1	90	36,750	590	175	23
	A2	100	37,800	658	484	99
	B1	100	36,600	541	466	96
	B2	100	37,200	600	584	100
	C1	100	36,100	584	524	98
Z-8	K1	60	38,500	609	100	6
	K2	60	39,100	642	275	30
	L1	60	38,200	590	266	34
	L2	60	38,900	675	75	3
	F2	70	37,250	550	383	55
	A2	70	37,800	633	158	15
	E2	70	37,850	590	17	5
	F1	70	37,750	600	266	35
	E1	80	37,450	584	650	100
	A1	80	37,500	625	575	100
	C2	80	37,150	565	541	100
	D1	80	37,150	616	108	13
	D2	90	37,000	575	565	100
	B1	90	37,650	600	550	100
	B2	90	37,150	609	541	100
	C1	90	36,900	559	541	100

TABLE A-7. (Continued)

Steel	Specimen	Testing Tempera-ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
		Rolled in Laboratory Mill at 1650 F				
6 Z-1	K1	30	41,800	1,025	133	3
	K2	30	41,050	925	142	4
	L1	30	41,050	891	117	3
	N1	30	40,850	885	125	5
	A1	40	40,800	1,040	650	95
	A2	40	40,950	975	108	6
	J1	40	40,200	1,010	258	20
	J2	40	40,600	940	92	5
	L2	50	40,900	1,033	1,225	100
	B1	50	39,950	1,010	658	100
	B2	50	39,200	875	808	100
	C1	50	40,950	915	200	10
	C2	60	39,050	824	658	95
	D1	60	40,200	1,060	684	95
	D2	60	39,600	900	800	100
	H2	60	38,850	815	925	100
6 Z-2	A1	40	40,250	850	316	37
	K2	50	38,400	750	308	18
	A2	50	39,500	766	400	42
	J1	50	38,500	790	92	5
	J2	50	39,150	815	242	18
	H2	60	38,350	707	642	85
	D2	60	38,200	700	400	35
	H1	60	38,500	757	300	20
	B1	60	38,850	775	400	50
	B2	70	38,600	790	565	80
	C1	70	38,450	766	707	100
	C2	70	38,400	715	707	100
	D1	70	37,750	700	725	100
6 Z-3	P1	20	40,100	984	83	2
	P2	20	39,450	775	342	30
	R1	20	40,700	1,033	225	17
	R2	20	39,000	750	142	1
	A2	30	39,950	875	292	30
	K1	30	41,200	950	715	100
	K2	30	41,350	961	234	14
	L1	30	40,100	910	459	55
	A1	40	39,600	875	650	100
	B1	40	38,300	734	757	100
	B2	40	39,250	875	715	100
	C2	40	39,400	885	193	11
	D1	50	38,000	885	425	47
	N1	50	39,250	875	616	93
	N2	50	38,700	590	408	45
	L2	50	40,100	915	92	4
	D2	60	38,850	885	707	100
	H1	60	39,450	866	475	60
	H2	60	39,150	815	734	100
	J1	60	39,000	815	725	100
6 Z-4	N1	0	42,300	1,150	125	4
	N2	0	42,250	1,040	133	7
	P1	0	41,750	1,010	150	7
	P2	0	42,100	1,010	117	5
	K1	10	41,800	1,033	707	100
	K2	10	41,950	984	225	14
	L1	10	40,700	885	541	70
	L2	10	40,650	860	150	4
	J1	20	39,800	850	534	70
	J2	20	40,300	860	790	100
	H1	20	39,650	850	609	77
	H2	20	41,500	961	308	25

TABLE A-7. (Continued)

Steel	Specimen	Testing Tempera-ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
		Rolled in Laboratory Mill at 1650 F				
6 Z-4 (Cont'd)	D1	30	40,450	860	492	55
	D2	30	39,500	800	334	27
	C2	30	39,900	842	208	5
	A2	30	38,450	--	--	5
	A1	40	38,300	766	690	100
	B1	40	38,850	860	700	100
	B2	40	39,100	815	725	100
	C1	40	39,050	824	690	100
6 Z-5	N1	60	38,450	609	83	3
	N2	60	39,450	642	67	3
	P1	60	38,550	665	117	5
	P2	60	38,550	625	92	3
	K1	70	38,800	675	590	98
	L1	70	38,700	675	575	95
	L2	70	38,900	690	67	10
	A2	70	38,550	650	83	10
	K2	80	38,300	700	466	75
	A1	80	38,250	700	541	95
	B1	80	38,300	707	550	99
	B2	80	38,250	584	108	15
	J2	90	38,450	690	575	100
	C1	90	37,650	650	565	100
	C2	90	38,050	684	565	100
	D1	90	37,100	590	225	30
	D2	100	37,450	658	590	100
	H1	100	37,900	642	559	100
	H2	100	37,250	642	550	100
	J1	100	37,050	600	600	100
6 Z-6	N2	60	38,300	633	75	3
	P1	60	39,950	684	125	5
	P2	60	39,250	707	92	5
	R1	60	39,900	775	125	5
	N1	70	39,100	734	483	65
	K1	70	38,550	565	234	27
	K2	70	39,350	609	442	65
	A1	70	37,900	584	58	10
	L1	80	38,000	590	633	100
	L2	80	39,150	684	83	25
	A2	80	38,300	650	133	12
	J2	80	37,350	590	167	20
	D2	90	38,100	590	408	60
	H1	90	37,450	584	158	20
	J1	90	37,400	590	193	25
	B1	90	37,150	609	193	30
	B2	100	37,000	616	342	50
	C1	100	37,100	559	516	92
	C2	100	37,150	559	383	55
	D1	100	36,250	584	484	87
6 Z-7	H1	50	38,150	575	150	8
	H2	50	37,400	609	258	35
	J1	50	37,250	565	50	2
	J2	50	37,750	575	367	47
	C2	60	37,500	534	575	92
	D1	60	38,100	584	75	20
	D2	60	37,550	550	183	12
	A1	60	36,800	1,000	225	42
	A2	70	37,450	575	534	100
	B1	70	36,600	508	550	99
	B2	70	36,850	565	525	100
	C1	70	36,450	541	565	100
6 Z-8	K1	40	40,400	700	83	2
	K2	40	38,200	550	167	9
	L1	40	38,300	484	250	26
	A2	40	37,800	565	83	2

TABLE A-7. (Continued)

Steel	Specimen	Testing Tempera-ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
		Rolled in Laboratory Mill at 1650 F				
6 Z-7 (Cont'd)	L2	50	38,500	508	200	7
	A1	50	37,250	541	600	98
	B1	50	36,750	541	534	100
	B2	50	37,550	559	125	5
	E2	60	36,650	508	650	100
	J1	60	37,400	565	584	100
	J2	60	37,500	559	575	100
	C1	60	37,400	684	175	15
	C2	70	37,850	575	367	57
	D1	70	37,050	584	534	100
	D2	70	37,550	575	600	100
	E1	70	37,600	559	590	100
		Rolled in Laboratory Mill at 1850 F				
8 Z-1	E1	50	38,400	833	133	5
	E2	50	38,700	1,020	466	45
	F1	50	38,200	935	58	5
	F2	50	38,300	860	50	3
	D2	60	38,250	815	559	62
	B1	60	39,150	891	750	97
	B2	60	39,100	900	117	5
	A1	60	40,250	1,100	150	10
	A2	70	38,800	935	715	87
	C1	70	38,800	961	642	99
	C2	70	37,550	775	808	100
	D1	70	38,750	975	925	100
8 Z-2	K1	60	37,750	740	167	5
	K2	60	38,600	784	83	4
	L1	60	37,900	790	383	30
	D1	60	37,200	725	75	5
	L2	70	38,300	740	334	30
	E2	70	37,850	740	58	15
	F1	70	36,500	757	342	40
	F2	70	37,400	784	658	100
	B1	80	36,650	650	757	100
	B2	80	37,100	725	408	55
	C1	80	37,500	707	633	78
	C2	80	36,550	675	417	34
	A1	90	37,050	866	740	100
	A2	90	37,100	707	750	100
	D2	90	37,450	824	534	63
	E1	90	36,800	516	550	80
8 Z-3	M1	40	39,250	940	142	4
	N1	40	40,150	1,033	300	30
	N2	40	38,650	784	334	25
	A2	40	38,900	866	341	25
	K1	50	39,250	875	108	5
	K2	50	38,500	808	292	27
	B1	50	38,200	784	642	90
	B2	50	38,450	775	350	30
	P1	60	39,500	915	92	5
	A1	60	37,350	734	750	100
	C1	60	37,400	757	550	65
	C2	60	38,700	915	208	20
	L1	70	36,850	700	715	100
	L2	70	37,750	750	700	100
	J2	70	37,500	815	690	100
	D1	70	38,050	824	275	28
	D2	80	38,150	850	707	100
	H1	80	36,650	757	707	100
	H2	80	37,600	790	700	100
	J1	80	37,550	766	725	100
8 Z-4	R1	20	40,450	958	150	7
	R2	20	40,750	1,033	200	5
	S1	20	39,600	885	100	3
	S2	20	40,200	975	75	2

TABLE A-7. (Continued)

Steel	Specimen	Testing Tempera- ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
			Rolled in Laboratory Mill at 1850 F			
8 Z-4 (Cont'd)	Q1	30	40,200	990	83	3
	Q2	30	39,850	990	100	3
	A1	30	39,900	975	442	60
	A2	30	39,550	940	266	22
	M1	40	40,000	1,050	550	73
	M2	40	39,900	1,020	133	15
	N1	40	39,850	961	408	42
	B1	40	38,700	866	325	32
	P2	50	40,600	1,020	158	10
	N2	50	38,850	910	358	40
	B2	50	37,900	833	715	100
	C1	50	38,500	833	316	34
	P1	60	40,050	984	316	35
	C2	60	38,150	842	258	22
	J1	60	38,400	833	158	10
	J2	60	37,600	833	266	30
	H1	70	38,500	940	715	100
	H2	70	37,850	900	725	100
	D1	70	38,250	800	766	100
	D2	70	37,300	808	700	100
8 Z-5	N1	70	37,650	642	67	2
	M2	70	38,800	625	117	3
	M1	70	39,500	600	242	19
	L2	70	37,700	658	92	6
	L1	80	38,150	725	584	100
	H2	80	38,200	690	67	15
	J1	80	37,800	590	193	15
	J2	80	38,050	590	125	12
	G1	90	37,150	484	--	100
	G2	90	38,100	616	550	92
	H1	90	37,650	650	108	20
	B1	90	37,650	600	316	48
	A2	100	38,000	625	584	100
	B2	100	38,000	600	790	100
	C1	100	35,950	500	516	87
	C2	100	37,700	642	584	100
8 Z-6	K1	70	38,300	665	67	10
	K2	80	37,200	565	75	7
	E2	80	36,350	609	275	40
	F1	80	35,850	590	367	60
	F2	80	36,050	550	75	12
	D1	90	35,000	550	559	100
	D2	90	35,650	609	484	85
	E1	90	36,150	650	142	20
	A2	90	36,100	541	193	23
	A1	100	35,450	534	575	100
	B1	100	35,550	584	525	97
	C1	100	35,750	584	516	100
	C2	100	35,400	541	559	100
	B2	110	36,400	559	525	100
8 Z-7	K1	60	37,000	550	67	3
	K2	660	36,200	516	58	2
	L1	60	36,150	516	193	15
	L2	60	37,000	541	33	2
	E1	70	35,550	550	383	87
	E2	70	36,000	534	500	85
	F1	70	36,400	516	565	100
	D2	70	36,100	565	208	32
	F2	80	35,200	559	508	95
	A2	80	36,100	559	525	100
	B1	80	35,500	508	516	100
	B2	80	35,850	484	216	20

TABLE A-7. (Continued)

Steel	Specimen	Testing Tempera- ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
			Rolled in Laboratory Mill at 1850 F			
8 Z-7 (Cont'd)	A1	90	35,150	459	590	100
	C1	90	35,500	459	575	100
	C2	90	34,850	459	534	100
	D1	90	35,500	525	525	100
8 Z-8	N1	50	37,600	541	42	1
	N2	50	38,500	658	75	15
	K1	50	36,500	525	208	25
	K2	50	36,700	541	42	3
	L1	60	36,850	559	408	67
	L2	60	37,250	584	258	38
	M1	60	36,950	508	200	10
	M2	60	37,300	534	616	100
	A2	70	36,600	500	534	85
	J1	70	36,450	508	565	100
	J2	70	36,800	541	516	85
	H2	70	36,000	633	175	25
	D1	80	35,900	559	565	100
	D2	80	37,250	590	550	100
	H1	80	36,900	508	559	100
	A1	80	36,300	534	183	15
	B1	90	35,350	508	584	100
	B2	90	34,600	541	541	100
	C1	90	35,750	565	541	100
	C2	90	36,350	516	575	100
			Rolled in Laboratory Mill at 2050 F			
20 Z-1	M1	70	38,050	833	225	15
	M2	70	37,850	833	75	3
	N1	70	38,400	875	193	10
	N2	70	37,650	800	158	7
	K1	80	37,900	808	665	77
	K2	80	38,350	833	193	10
	L1	80	38,850	915	234	20
	B1	80	38,150	925	33	7
	L2	90	38,550	891	83	13
	A2	90	38,050	833	684	91
	B2	90	37,100	790	250	30
	J2	90	36,550	784	258	25
	A1	100	37,650	842	675	82
	C1	100	36,600	775	725	96
	C2	100	38,350	910	740	100
	D1	100	37,950	833	459	50
	D2	110	37,050	757	466	60
	H1	110	36,650	790	508	53
	H2	110	37,300	808	784	100
	J1	110	36,350	766	700	100
20 Z-2	M1	70	36,500	757	67	2
	M2	70	38,300	833	83	5
	N1	70	37,150	800	167	12
	N2	70	37,700	734	75	2
	B1	80	38,000	808	92	8
	K1	80	36,300	725	766	100
	K2	80	37,900	824	334	33
	L1	80	36,600	707	250	20
	L2	90	37,200	766	350	35
	A2	90	38,300	866	625	78
	B2	90	37,150	808	600	80
	C1	90	36,850	784	50	10
	A1	100	37,900	815	700	100
	C2	100	37,100	808	484	55
	D1	100	36,600	690	775	100
	D2	100	36,250	715	350	35

TABLE A-7. (Continued)

Steel	Specimen	Testing Tempera-ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
		Rolled in Laboratory Mill at 2050 F				
20 Z-2	H1	110	36,850	766	707	100
(Cont'd)	H2	110	37,250	815	584	85
	J1	110	36,550	700	766	100
	J2	110	36,100	824	675	100
20 Z-3	N1	60	38,200	833	117	7
	N2	60	38,500	875	92	5
	P1	60	38,000	850	83	3
	P2	60	38,100	842	100	2
	L1	70	35,650	609	550	60
	L2	70	38,600	950	642	80
	M1	70	36,250	665	550	62
	M2	70	38,850	910	308	25
	H1	80	35,500	684	408	45
	H2	80	37,500	935	75	12
	J1	80	36,050	734	350	35
	J2	80	37,800	900	684	95
	D1	90	36,400	766	775	98
	D2	90	38,250	915	633	85
	A1	90	36,100	665	525	65
	A2	90	37,650	975	83	15
	B1	100	36,750	766	775	98
	B2	100	37,050	808	800	100
	C1	100	35,950	715	790	99
	C2	100	37,350	900	707	92
20 Z-4	K1	70	37,950	808	92	10
	K2	70	37,800	815	125	10
	L1	70	38,250	866	92	7
	A2	70	38,350	1,000	350	40
	L2	80	38,200	875	525	68
	A1	80	38,450	984	590	76
	J2	80	37,600	935	500	68
	B1	80	38,050	925	83	15
	H1	90	36,750	935	658	97
	H2	90	36,350	875	75	20
	B2	90	37,500	1,040	525	60
	J1	90	36,900	875	642	90
	C1	100	37,850	975	734	100
	C2	100	36,550	842	675	97
	D1	100	36,350	815	725	100
	D2	100	36,900	1,033	690	100
20 Z-5	K1	90	38,300	700	117	10
	K2	90	37,600	725	117	20
	L1	90	37,750	734	117	15
	L2	90	37,700	675	92	12
	D2	100	38,800	665	442	65
	H1	100	36,350	650	316	35
	H2	100	37,250	633	193	15
	A2	100	35,900	534	425	43
	A1	110	36,600	625	609	95
	B1	110	36,500	633	242	35
	J1	110	36,400	633	216	20
	J2	110	36,350	565	193	20
	B2	120	36,050	609	609	98
	C1	120	37,050	633	633	100
	C2	120	35,900	575	484	70
	D1	120	36,750	665	575	100
20 Z-6	K1	70	36,550	584	83	3
	H1	70	36,400	575	142	10
	H2	80	36,800	650	67	3
	J1	80	37,400	700	83	5
	J2	80	36,400	625	142	15
	K2	80	37,150	665	92	5

TABLE A-7. (Continued)

Steel	Specimen	Testing Tempera-ture, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	Shear in Fracture, %
			Rolled in Laboratory Mill at 2050 F			
20 Z-6	C2	90	36,600	675	450	65
(Cont'd)	D1	90	36,100	600	633	100
	D2	90	36,200	609	225	25
	A2	90	36,500	665	266	30
	A1	100	35,750	600	665	100
	B1	100	35,450	600	525	82
	B2	100	36,900	715	633	99
	C1	100	35,350	609	609	80
20 Z-7	A2	90	36,850	700	108	15
	H1	90	35,300	541	175	20
	H2	90	37,600	766	133	15
	J1	90	35,750	525	283	30
	A1	100	36,500	541	534	85
	J2	100	35,950	650	525	90
	B1	100	36,300	650	575	95
	B2	100	36,300	590	250	40
	C1	110	35,650	559	575	100
	C2	110	36,400	650	584	100
	D1	110	36,500	675	550	92
	D2	110	36,200	616	516	97
20 Z-8	H1	70	36,350	525	58	3
	H2	70	35,200	541	100	10
	J1	70	36,100	550	92	3
	J2	70	36,200	508	67	5
	D2	80	36,600	559	508	70
	B1	80	35,950	508	133	12
	C2	80	36,550	559	83	8
	D1	80	36,100	534	33	10
	A1	90	36,400	541	417	65
	A2	90	36,800	559	658	100
	B2	90	36,850	565	525	97
	C1	90	35,300	590	508	100