SERIAL NO. **SSC-88**

Sixth

PROGRESS REPORT

(Project SR-110)

on

INFLUENCE OF SILICON AND ALUMINUM ON THE PROPERTIES OF HOT-ROLLED STEEL

by

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Battelle Memorial Institute

Transmitted through

NATIONAL RESEARCH COUNCIL'S
COMMITTEE ON SHIP STEEL

Advisory to

SHIP STRUCTURE COMMITTEE

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July 1, 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 Sixth Progress Report, SSC-88, of the investigation entitled "Influence of Silicon and Aluminum on the Properties of Hot-Rolled Steel" 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

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Battelle Memorial Institute

under

Department of the Navy
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for

SHIP STRUCTURE COMMITTEE

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INFLUENCE OF SILICON AND ALUMINUM ON THE PROPERTIES OF HOT-ROLLED STEEL

INTRODUCTION

There are both advantages and disadvantages in using semikilled steels in place of killed steels for structural applications. One advantage of semikilled steels is that they provide a higher ingot to product yield. This is especially important to shipbuilders in the time of national emergency. By using semikilled steel for hull plates, a greater number of ships can be built from the same ingot tonnage. However, unless these semikilled steel plates do not fail in service, the advantage of the higher product yield is of no importance.

The performance of hull plates is closely associated with the ductile-to-brittle transition temperature, and this in turn is dependent on the composition and degree of deoxidation of the steel. A low transition temperature is desirable because it indicates that the steel structure is less likely to fail under multiaxial stress condition that can develop at low ambient temperatures.

Killed steels are known to have lower transition temperatures than semikilled steels. It is believed that the better qualities of killed steels in this respect are due mainly to the low oxygen contents of the steel. The principal deoxidizers, aluminum, silicon, and manganese, lower the oxygen content. Fundamental studies(1,2) have shown that the oxygen content remaining after the addition of one of these three elements is influenced by the residual amounts of the other two present. In the current study, therefore, various amounts of silicon and aluminum were added to steels containing different manganese contents for the purpose of studying the influence of silicon and aluminum on the notched-bar properties of hot-rolled steels.

Eleven types of steels were studied of the nominal compositions shown in Table 1. Both the Navy tear test and the keyhole Charpy test were used in this investigation. The temperature at which the plates were finish rolled was carefully controlled at 1850 F, and all plates were rolled to 3/4-in. thickness, followed by testing in the as-rolled condition.

MATERIALS AND TESTING METHODS

The total number of steels prepared in the laboratory for this study was ninety-five. The charge consisting of ingot iron and ferrosilicon equivalent to 0.10 per cent silicon was melted in a 200-lb. induction furnace under an atmosphere of argon to insure low, uniform nitrogen contents. After the charge was melted and the desired temperature was obtained, the melt was partly deoxidized with either silicomanganese or aluminum. Aluminum was used for this purpose in only those steels with very low silicon contents, where the finished steel was to contain some aluminum. This initial deoxidizing addition was made to obtain consistent recoveries of subsequent additions of

TABLE 1. NOMINAL COMPOSITIONS OF VARIOUS TYPES OF STEELS STUDIED

Type No.	Nominal Composition, per cent						
	C	Mn	Si	P	S	N	Al
I	0.25	0.45	Various	0.015	0.025	0.004	None
II	0.21	0.60	Various	0.015	0.025	0.004	None
III	0.21	0.75	Various	0.015	0.025	0.004	None
IV	0.19	1.00	Various	0.015	0.025	0.004	None
V	0.21	0.75	Various	0.015	0.025	0.004	0.03
VI	0.25	0.45	0.01	0.015	0.025	0.004	Various
VII	0.25	0.45	0.05	0.015	0.025	0.004	Various
VIII	0.25	0.45	0.10	0.015	0.025	0.004	Various
IX	0.21	0.75	0.01	0.015	0.025	0.004	Various
X	0.21	0.75	0.05	0.015	0.025	0.004	Various
XI	0.21	0.75	0.10	0.015	0.025	0.004	Various

ferromanganese, ferrosilicon, and aluminum. Carbon, in the form of graphite, was added either just prior to tap or to the final aluminum addition. The entire heat of 200 lb. was poured directly into a 6 by 6-in. big-end-up mold. The ingots of semikilled steel were capped with a steel plate. The killed steels, on the other hand, were poured with a hot-top containing 14 per cent of the total volume of the ingot.

The ingots were processed by heating to 2250 F, followed by forging to slabs 1 3/4 in. thick and 6 in. wide. After reheating to 2250 F, the slabs were rolled to 0.9-in. gage, using reductions of approximately 1/6 in. per pass. The 0.9-in. thick plates were immediately recharged in a furnace held at 1850 F. After 30 minutes in the furnace at 1850 F, the plates were rolled to 3/4 in. in one pass. Following the final pass, the plates were stacked on edge on a brick floor with a brick separating one from another, where they were allowed to cool in air.

Drillings for chemical analysis were taken from the plates at locations corresponding to the top and bottom of each ingot. Carbon, manganese, silicon, phosphorus, sulfur, and nitrogen contents of each sample were determined. The averages of the two analyses for each ingot are given in Table 2. The analysis of each steel was carefully controlled, so that the contents of phosphorus, sulfur, and nitrogen varied only slightly from average values of 0.017, 0.027, and 0.004 per cent, respectively, for these elements. In some cases, as could be expected, carbon

TABLE 2. CHEMICAL COMPOSITION, FERRITE GRAIN SIZE, AND AUSTENITE GRAIN-COARSENING TEMPERATURE OF EXPERIMENTAL STEELS

Heat Number	Chemical Composition, per cent							Number of Ferrite Grains/ Sq. In. at 100X	Austenite Grain-Coarsening Temp, F
	C	Mn	Si	P	S	N	Al(1)		
				Type I (0.25% C, 0.45% Mn) Steels					
A6602	0.23	0.51	0.02	0.010	0.018	0.003	-	71	1515
A7663	0.22	0.44	0.03	0.015	0.027	0.003	-	84	1505
A6650	0.22	0.46	0.04	0.012	0.023	0.004	-	101	1510
A7449	0.20	0.43	0.04	0.014	0.022	0.004	-	91	1515
A8132	0.23	0.44	0.04	0.015	0.027	0.005	-	77	1470
A6556	0.23	0.44	0.05	0.017	0.025	0.004	-	103	1500
A6705	0.21	0.49	0.05	0.016	0.025	0.004	-	85	1505
A6555	0.22	0.47	0.06	0.016	0.024	0.003	-	88	1510
A6594	0.21	0.48	0.11	0.018	0.027	0.003	-	79	1545
A6657	0.23	0.48	0.14	0.016	0.021	0.004	-	73	1525
A7526	0.26	0.43	0.20	0.017	0.027	0.004	-	75	1515
A8728	0.25	0.44	0.20	0.016	0.030	0.005	-	96	1515
A8922	0.25	0.45	0.22	0.020	0.026	0.003	-	89	1515
A8747	0.25	0.44	0.26	0.020	0.026	0.002	-	79	1505
B865	0.22	0.54	0.29	0.015	0.032	0.005	-	72	-
A6696	0.24	0.54	0.31	0.015	0.023	0.005	-	75	1540
A8729	0.28	0.44	0.38	0.015	0.030	0.005	-	99	1530
B866	0.22	0.54	0.38	0.016	0.031	0.005	-	79	-
A8923	0.25	0.49	0.48	0.021	0.024	0.003	-	104	1530
B867	0.22	0.55	0.54	0.015	0.030	0.005	-	92	-
				Type II (0.21% C, 0.60% Mn) Steels					
A8151	0.20	0.57	0.10	0.016	0.030	0.004	-	82	-
A9265	0.20	0.60	0.12	0.020	0.029	0.003	-	64	1515
A8375	0.21	0.60	0.17	0.015	0.028	0.004	-	68	-
A9266	0.21	0.61	0.20	0.021	0.031	0.004	-	83	1515
A8376	0.21	0.60	0.26	0.015	0.028	0.004	-	79	1540
A9275	0.20	0.65	0.39	0.017	0.033	0.004	-	73	1565

TABLE 2. (CONTINUED)

Heat Number	Chemical Composition, per cent							Number of Ferrite Grains/ Sq. In. at 100X	Austenite Grain-Coarsening Temp, F
	C	Mn	Si	P	S	N	Al$^{(1)}$		
Type III (0.21% C, 0.75% Mn) Steels									
A6651	0.19	0.74	0.01	0.017	0.023	0.005	-	72	1505
A6603	0.21	0.84	0.02	0.017	0.022	0.003	-	85	1530
A7664	0.18	0.69	0.03	0.015	0.026	0.003	-	83	1525
A6641	0.19	0.81	0.04	0.016	0.022	0.004	-	71	1510
A6588	0.21	0.79	0.06	0.011	0.024	0.004	-	64	1525
A6557	0.22	0.75	0.07	0.016	0.025	0.005	-	94	1525
A6584	0.20	0.76	0.07	0.014	0.022	0.004	-	92	1515
A7450	0.21	0.76	0.07	0.016	0.025	0.004	-	78	1540
A6595	0.20	0.81	0.12	0.017	0.024	0.004	-	85	1510
A8378	0.18	0.74	0.13	0.018	0.029	0.004	-	80	-
A6695	0.19	0.84	0.16	0.015	0.023	0.004	-	74	1525
A9262	0.18	0.76	0.17	0.022	0.028	0.003	-	88	1535
A7528	0.20	0.74	0.20	0.017	0.029	0.004	-	87	1530
A6697	0.19	0.85	0.29	0.015	0.023	0.005	-	69	1535
B868	0.19	0.84	0.31	0.018	0.030	0.006	-	74	-
A8730	0.20	0.72	0.38	0.015	0.030	0.004	-	82	1530
B869	0.18	0.86	0.42	0.013	0.031	0.004	-	77	-
B870	0.18	0.86	0.52	0.016	0.030	0.006	-	78	-
Type IV (0.19% C, 1.00% Mn) Steels									
A9271	0.18	1.06	0.06	0.017	0.030	0.003	-	59	1520
A9272	0.17	1.02	0.15	0.016	0.030	0.004	-	67	1530
A9273	0.18	1.06	0.24	0.018	0.029	0.004	-	73	1530
A9274	0.20	1.36	0.34	0.019	0.031	0.005	-	79	-
Type V (0.21% C, 0.75% Mn, 0.03% Al$^{(1)}$) Steels									
A8904	0.20	0.72	0.02	0.017	0.029	0.004	0.026	84	1760
A7319	0.18	0.81	0.02	0.017	0.022	0.004	0.032	92	1750
A7662	0.20	0.75	0.05	0.016	0.028	0.003	0.033	80	1730
A8905	0.20	0.74	0.08	0.018	0.029	0.003	0.036	89	1760
A8906	0.20	0.74	0.14	0.020	0.029	0.004	0.038	97	1775

TABLE 2. (CONTINUED)

Heat Number	Chemical Composition, per cent							Number of Ferrite Grains/ Sq. In. at 100X	Austenite Grain-Coarsening Temp, F
	C	Mn	Si	P	S	N	Al(1)		
A8907	0.20	0.75	0.20	0.018	0.028	0.005	0.034	86	1770
A8908	0.20	0.77	0.20	0.018	0.028	0.005	0.039	77	1770
A8909	0.20	0.77	0.32	0.018	0.028	0.004	0.035	76	1750
B871	0.19	0.86	0.37	0.018	0.028	0.006	0.042	77	-
B872	0.19	0.86	0.47	0.015	0.028	0.005	0.043	85	-
B873	0.18	0.87	0.57	0.014	0.032	0.005	0.039	96	-
Type VI (0.25% C, 0.45% Mn, 0.01% Si) Steels									
A6648	0.27	0.59	0.01	0.016	0.021	0.004	0.001	58	1540
A8736	0.22	0.46	0.01	0.019	0.024	0.004	0.002	77	1540
A8737	0.20	0.40	0.01	0.021	0.028	0.004	0.006	85	1535
A6707	0.20	0.50	0.01	0.019	0.025	0.003	0.027	73	1670
A9263	0.21	0.45	0.01	0.020	0.028	0.003	0.028	90	1720
A9264	0.20	0.47	0.01	0.019	0.028	0.003	0.031	84	1725
A6708	0.21	0.52	0.01	0.020	0.025	0.004	0.046	93	1690
A8142	0.21	0.46	0.01	0.016	0.028	0.004	0.073	82	1705
A8143	0.24	0.46	0.02	0.016	0.030	0.004	0.038	91	1685
A6709	0.21	0.53	0.01	0.018	0.025	0.004	0.127	87	1785
Type VII (0.25% C, 0.45% Mn, 0.05% Si) Steels									
A7531	0.22	0.48	0.05	0.016	0.032	0.003	0.006	78	1510
A8136	0.25	0.47	0.04	0.017	0.027	0.004	0.019	68	1665
A7322	0.25	0.51	0.05	0.015	0.023	0.005	0.030	83	1690
A7661	0.21	0.45	0.05	0.016	0.033	0.003	0.034	88	-
A8137	0.25	0.45	0.05	0.016	0.029	0.003	0.061	91	1680
A7529	0.25	0.41	0.05	0.016	0.028	0.004	0.091	89	1655
A8745	0.25	0.52	0.05	0.017	0.026	0.003	0.211	78	1705
Type VIII (0.25% C, 0.45% Mn, 0.10% Si) Steels									
A8738	0.23	0.47	0.10	0.018	0.030	0.004	0.059	88	1725
A8350	0.24	0.46	0.09	0.015	0.028	0.003	0.099	75	-
A8739	0.23	0.46	0.09	0.017	0.031	0.006	0.128	85	1690
A8351	0.24	0.49	0.09	0.016	0.029	0.003	0.166	92	-
A8740	0.24	0.47	0.09	0.018	0.031	0.003	0.260	84	1600

TABLE 2. (CONTINUED)

Heat Number	Chemical Composition, per cent							Number of Ferrite Grains/ Sq. In. at 100X	Austenite Grain-Coarsening Temp, F
	C	Mn	Si	P	S	N	Al(1)		
Type IX (0.21% C, 0.75% Mn, 0.01% Si) Steels									
A6649	0.22	0.87	0.01	0.015	0.022	0.004	0.001	91	1495
A8145	0.18	0.72	0.01	0.018	0.028	0.003	0.016	86	1625
A7320	0.20	0.85	0.02	0.016	0.025	0.004	0.019	74	1710
A8146	0.19	0.78	0.01	0.019	0.028	0.002	0.064	85	1740
Type X (0.21% C, 0.75% Mn, 0.05% Si) Steels									
A7660	0.20	0.74	0.05	0.017	0.032	0.003	0.004	84	-
A8144	0.21	0.79	0.04	0.018	0.028	0.003	0.019	86	1720
A7530	0.21	0.71	0.05	0.018	0.027	0.003	0.084	93	1765
A8141	0.19	0.77	0.04	0.017	0.029	0.004	0.150	95	1645
A8746	0.19	0.64	0.01	0.017	0.027	0.003	0.192	84	1720
Type XI (0.21% C, 0.75% Mn, 0.10% Si) Steels									
A8741	0.20	0.73	0.09	0.016	0.028	0.004	0.062	74	1775
A8352	0.20	0.74	0.09	0.018	0.029	0.004	0.093	92	-
A8742	0.21	0.77	0.09	0.018	0.028	0.004	0.131	84	-
A8353	0.21	0.66	0.09	0.014	0.027	0.004	0.167	73	1640
A8743	0.22	0.76	0.10	0.019	0.028	0.004	0.269	91	-

(1) Acid-soluble aluminum contents.

and manganese were slightly above or below the nominal composition for a particular type of steel. Silicon and also aluminum, when present, were varied intentionally within a series of steels of a given type.

Duplicate standard strip tensile specimens, using full thickness of the plate, were prepared from each heat. Using these specimens, the upper and lower yield strengths, the tensile strength, and the elongation values were determined. The upper yield strength was taken as the highest strength obtained before the drop of beam, while the lower yield strength was taken as the lowest strength after the drop of beam and before the ultimate strength was reached. The elongation was measured over an 8-in. gage length.

The tear tests were made using the type of specimen and procedure described by Kahn and Imbembo(3). The specimens were prepared from the 6-in. wide hot-rolled plates after cutting them down the center to give strips 3 in. wide. The specimens were taken parallel to the direction of rolling and notched from the edge opposite the cut surface. This was done to insure that the sections to be tested had cooled from the hot-rolling temperature without having been affected by the more rapid cooling of the edges. The plates had been placed on edge and cooled in still air after the final hot-rolling pass.

The tear test transition temperature was defined by two different methods. One definition, developed by Kahn and Imbembo(3), defines transition temperature as the highest temperature at which one or more in a group of four test specimens exhibited a fracture area having less than 50 per cent of the ductile-shear type of fracture. This transition temperature, referred to later as the Kahn transition temperature, can be determined by as few as five test specimens. Another definition of transition temperature, more suitable for research work but requiring more test specimens, is based on the 50 per cent probability of brittle specimens. Here four specimens are tested at 10 F intervals throughout the transition. In all cases, a specimen was classified as brittle if less than 50 per cent of the fractured area showed the dull, ductile-shear type of fracture.

Keyhole Charpy specimens were taken parallel to the direction of rolling and notched normal to the surface of the plate. Four tests were made at intervals of 10 F, using a pendulum with an available striking energy of 220 ft-lb and a velocity of 18.1 ft. per second. The transition temperature can be defined in these tests as the temperature at which the average energy-temperature curve crosses within the 12 or 20 ft-lb level. The transition temperatures at both energy levels are reported in the present investigation.

EFFECT OF SILICON AND ALUMINUM ON FERRITE GRAIN SIZE

The ferrite grain size of each steel was determined by the grain-counting method(4). The grain counts given in Table 2 show the average number of ferrite grains per 0.0001 sq. in. of steel. For steels with equal amounts of ferrite, the larger numbers indicate smaller ferrite grains. The average ferrite grain count of the ninety-five steels studied was 82 ferrite grains per 0.0001 sq. in. of steel. The maximum deviation from this average for the ninety-five steels was 24 grains, which is equivalent to approximately 1/2 ASTM grain-size number. Silicon and aluminum appeared to have no influence on ferrite grain size of the experimental steels air cooled after a finishing pass at 1850 F.

These plates had been heated to 2250 F before rolling; during rolling they cooled to 1850 F. There is little doubt that all of the plates had a coarse austenite grain size at the end of this rolling operation. All of the plates had a coarse ferrite grain size after cooling to room temperature. Therefore, questions arose concerning the effect of reheating and air cooling on the ferrite grain size of the plates containing different amounts of silicon and aluminum. For this reason, the ferrite grain size of seven ABS semikilled Class B steels and seven aluminum-treated Class C steels were determined before and after normalizing at 1650 F. There was no difference in the ferrite grain size between the two grades of steel in the as-rolled condition. For both grades of steel, normalizing produced finer ferrite grain sizes. On the average, the ferrite grain size of Class B steels increased one ASTM number, while the grain size of Class C steels increased 1.8 ASTM numbers. An increase in the ASTM number indicates a smaller grain size.

Ferrite grain size is known to influence the Charpy transition temperature of the steel(12). Epstein(8) reported average decreases of 38 F in keyhole Charpy transition temperature by normalizing Class B steel and 65 F by normalizing Class C steel. The transition temperature of both classes of steel changed proportionally with the change in ferrite grain size.

These experiments indicate that the major benefits of fine-grained deoxidation practices are obtained in normalized rather than in hot-rolled plates. Variations in deoxidation practice do not seem to have a marked influence on the ferrite grain size of plates in the rolled condition if they are rolled by identical practices.

EFFECT OF SILICON AND ALUMINUM ON THE AUSTENITE GRAIN-COARSENING TEMPERATURE

Specimens 1/2 by 5/8 by 5 in. were heated for four hours in a temperature-gradient furnace similar to the one used by Halley(5). The hot end of the specimen was over 1900 F, while the cold end was under 1500 F. This provided a temperature differential of more than 400 F in five inches of specimen. All specimens were oil quenched after the four-hour treatment. The specimens were then sectioned longitudinally, polished, and etched. Knowing the temperature gradient and the position of each specimen within the furnace, the grain-coarsening temperature could be determined by examining the etched surface for change in grain size.

The grain-coarsening temperatures for a number of experimental steels are reported in Table 2. Silicon had no effect on the austenite grain-coarsening temperature.

The average coarsening temperature of the steels containing no aluminum and various amounts of silicon was 1524 F. Aluminum contents over 0.01 per cent raised the coarsening temperature approximately 200 F to an average temperature of 1725 F. It must be remembered that, before rolling, the experimental plates were heated to 2250 F; much higher than the highest grain-coarsening temperature determined. The experimental steels, therefore, probably had coarse austenite grains during and after the final rolling reduction.

EFFECT OF SILICON AND ALUMINUM ON THE TENSILE PROPERTIES

Duplicate strip tensile tests were made from the 3/4-in. plates rolled from the ninety-five experimental steels. Test data for each test specimen are given in Tables A-1 through A-11 of the Appendix. A summary of the tensile properties is given in Tables 3 and 4.

Formulas given in Table 5, showing the influence of silicon on tensile and yield point, were determined by multiple-correlation methods. The data used to determine these formulas were corrected for small variations in carbon and manganese of each steel in question from the nominal composition of its type. The factors used in making these minor corrections were derived from a comprehensive

TABLE 3. PROPERTIES OF LABORATORY STEELS WITH VARIOUS SILICON CONTENTS

		Tensile Properties				Charpy Properties			Tear-Test Transition Temperature, F	
			Yield Point, psi			Energy Absorbed	Transition Temperature, F			
Heat Number	Silicon Content, %	Tensile Strength, psi	Upper	Lower	Elong in 8", %	at 80 F, ft-lb	12 ft-lb	20 ft-lb	Kahn	Probability of 50% Brittle Specimens
					Type I (0.25% C, 0.45% Mn) Steels					
A6602	0.02	60,000	33,550	32,950	30.5	31	0	+14	80	72
A7663	0.03	61,100	35,050	34,500	31.5	31	+2	+23	80	75
A6650	0.04	60,550	35,600	34,250	28.0	32	+4	+25	80	72
A7449	0.04	60,750	35,600	34,200	31.5	31	-1	+16	70	70
A8132	0.04	61,000	36,450	34,500	30.5	29	+9	+33	100	93
A6556	0.05	61,600	37,950	35,000	31.0	31	-7	+4	70	70
A6705	0.05	63,000	37,050	35,900	24.5	31	-15	+5	90	63
A6555	0.06	62,700	38,850	36,050	27.5	32	-3	+12	80	68
A6594	0.11	62,450	37,100	35,700	30.0	33	-29	-7	80	62
A6657	0.14	63,350	34,200	33,650	26.5	34	-28	-2	70	64
A7526	0.20	65,000	36,950	34,900	29.0	32	-34	-12	70	71
A8728	0.20	66,600	39,300	38,400	28.5	30	-38	-12	80	74
A8922	0.22	65,900	38,100	35,900	27.5	30	-36	-14	100	85
A8747	0.26	66,100	37,100	35,850	28.5	30	-41	-17	90	78
B865	0.29	66,850	38,200	36,200	26.0	30	-23	-3	90	79
A6696	0.31	67,200	37,400	36,650	26.0	32	-56	-28	70	68
A8729	0.38	73,450	40,650	39,300	27.0	25	-38	+5	90	85
B866	0.38	68,500	39,500	37,500	27.0	29	-40	-17	60	60
A8923	0.48	70,400	39,800	39,300	28.5	28	-59	-21	100	94
B867	0.54	70,600	40,300	39,200	26.5	28	-64	-33	80	75
					Type II (0.21% C, 0.60% Mn) Steels					
A8151	0.10	60,300	35,550	34,100	30.5	33	-38	-24	70	55
A9265	0.12	61,200	35,750	34,250	28.5	—	-17	-5	90	71
A8375	0.17	62,100	36,650	35,250	28.0	35	-37	-31	60	54
A9266	0.20	63,600	36,700	35,400	29.0	—	-33	-18	50	46
A8376	0.26	64,300	37,050	36,200	28.0	36	-27	-11	70	54
A9275	0.39	67,350	40,100	39,500	24.5	32	-51	-22	80	60

TABLE 3. (CONTINUED)

Heat Number	Silicon Content, %	Tensile Properties: Tensile Strength, psi	Tensile Properties: Yield Point, psi Upper	Tensile Properties: Yield Point, psi Lower	Tensile Properties: Elong in 8", %	Charpy Properties: Energy Absorbed at 80 F, ft-lb	Charpy Properties: Transition Temperature, F 12 ft-lb	Charpy Properties: Transition Temperature, F 20 ft-lb	Tear-Test Transition Temperature, F: Kahn	Tear-Test Transition Temperature, F: Probability of 50% Brittle Specimens
Type III (0.21% C, 0.75% Mn) Steels										
A6651	0.01	62,300	37,200	35,700	28.5	38	-32	-24	70	60
A6603	0.02	64,900	37,550	36,850	23.0	37	-44	-29	80	65
A7664	0.03	62,300	36,100	34,800	29.5	34	-19	-7	80	69
A6641	0.04	62,850	36,550	35,350	24.0	38	-36	-25	80	65
A6588	0.06	62,350	35,550	34,900	28.0	37	-33	-20	60	55
A6557	0.07	61,700	36,200	35,500	30.0	40	-33	-13	70	57
A6584	0.07	61,950	36,350	35,400	30.5	39	-27	-6	70	55
A7450	0.07	61,550	35,050	34,200	32.5	33	-26	-13	60	50
A6595	0.12	63,400	38,350	36,150	27.5	42	-58	-43	40	26
A8378	0.13	61,800	37,950	35,150	31.5	39	-46	-30	60	45
A6695	0.16	64,300	38,450	36,700	26.5	39	-77	-57	30	27
A9262	0.17	63,050	39,000	36,250	27.5	—	-55	-44	50	29
A7528	0.20	63,650	36,350	35,950	32.5	44	-55	-40	50	45
A6697	0.29	66,950	39,050	37,800	29.5	43	-45	-29	60	50
B868	0.31	66,700	40.200	39,150	27.5	37	-23	-6	70	60
A8730	0.38	67,350	38,800	37,850	29.0	35	-27	-11	70	64
B869	0.42	67,700	40,450	39,200	26.5	38	-12	+1	80	65
B870	0.52	69,650	42,700	41,700	27.0	33	-26	-10	70	64
Type IV (0.19% C, 1.00% Mn) Steels										
A9271	0.06	63,400	37,350	36,250	29.5	42	-39	-28	40	34
A9272	0.15	64,700	37,500	37,050	30.0	—	-48	-37	50	42
A9273	0.24	67,000	39,450	37,750	28.0	40	-43	-26	60	43
A9274	0.34	75,900	46,250	45,150	24.5	—	-55	-40	90	89

TABLE 3. (CONTINUED)

		Tensile Properties				Charpy Properties			Tear-Test Transition Temperature, F	
Heat Number	Silicon Content, %	Tensile Strength, psi	Yield Point, psi Upper	Yield Point, psi Lower	Elong in 8", %	Energy Absorbed at 80 F, ft-lb	Transition Temperature, F 12 ft-lb	Transition Temperature, F 20 ft-lb	Kahn	Probability of 50% Brittle Specimens
					Type V (0.21% C, 0.75% Mn, 0.03% Al) Steels					
A8904	0.02	63,100	36,250	35,200	29.5	—	-29	-13	70	72
A7319	0.02	59,250	35,200	33,850	30.0	41	-36	-24	80	69
A7662	0.05	62,450	36,300	34,450	28.5	38	-42	-29	60	55
A8905	0.08	64,000	37,750	35,950	28.5	36	-54	-46	60	51
A8906	0.14	64,950	38,100	36,150	29.5	41	-55	-42	70	57
A8907	0.20	64,600	37,600	36,350	29.0	40	-70	-51	60	45
A8908	0.20	65,050	38,750	36,750	30.5	41	-77	-60	70	54
A8909	0.32	66,600	40,750	38,850	23.5	39	-86	-68	50	43
B871	0.37	67,700	40,000	39,950	23.5	41	-88	-80	70	57
B872	0.47	69,450	43,050	41,800	26.0	41	-98	-73	60	58
B873	0.57	71,000	43,850	42,700	25.5	40	-93	-65	80	61

TABLE 4. PROPERTIES OF LABORATORY STEELS WITH VARIOUS ALUMINUM CONTENTS

Heat Number	Aluminum Content, %	Tensile Properties				Charpy Properties			Tear-Test Transition Temperature, F	
		Tensile Strength, psi	Yield Point, psi		Elong in 8", %	Energy Absorbed at 80 F, ft-lb	Transition Temperature, F			Probability of 50% Brittle Specimens
			Upper	Lower			12 ft-lb	20 ft-lb	Kahn	
					Type VI (0.25% C, 0.45% Mn, 0.01% Si) Steels					
A6648	0.001	65,800	38,000	37,200	27.0	30	-1	+20	100	100
A8736	0.002	57,800	33,750	32,200	26.0	35	+6	+22	110	94
A8737	0.006	57,100	32,550	31,550	29.5	32	+2	+19	120	104
A6707	0.027	59,000	35,400	33,400	28.5	36	-16	0	90	84
A9263	0.028	58,400	34,450	33,850	31.5	34	-18	+4	80	76
A9264	0.031	58,200	33,500	31,650	33.0	36	-8	-1	80	80
A6708	0.046	61,550	38,350	35,450	30.0	35	-14	-2	80	71
A8142	0.073	58,350	33,850	32,800	27.0	36	-16	-4	70	69
A8143	0.038	61,400	35,150	33,550	31.5	30	+2	+19	80	85
A6709	0.127	59,850	35,750	34,150	33.0	42	-56	-41	50	42
					Type VII (0.25% C, 0.45% Mn, 0.05% Si) Steels					
Avg 6 steels	0.000	61,600	36,910	34,980	32.2	31	-2	+16	82	73
A7531	0.006	60,550	35,550	33,950	32.5	34	-10	+2	80	70
A8136	0.019	63,400	35,950	34,150	31.0	29	-2	+14	90	91
A7322	0.030	61,150	35,150	33,800	31.0	35	-26	-7	90	72
A7661	0.034	59,800	33,300	32,800	31.0	34	-19	-6	80	70
A8137	0.061	60,800	35,250	33,450	31.0	33	-13	+2	70	65
A7529	0.091	62,450	37,750	34,800	31.5	31	-23	-5	80	70
A8745	0.211	63,750	36,800	34,700	28.0	34	-40	-27	50	39

TABLE 4. (CONTINUED)

Heat Number	Aluminum Content, %	Tensile Properties: Tensile Strength, psi	Tensile Properties: Yield Point, psi Upper	Tensile Properties: Yield Point, psi Lower	Tensile Properties: Elong in 8", %	Charpy Properties: Energy Absorbed at 80 F, ft-lb	Charpy Properties: Transition Temperature, F 12 ft-lb	Charpy Properties: Transition Temperature, F 20 ft-lb	Tear-Test Transition Temperature, F: Kahn	Tear-Test Transition Temperature, F: Probability of 50% Brittle Specimens
Type VIII (0.25% C, 0.45% Mn, 0.10% Si) Steels										
A6594	0.000	62,450	37,100	35,700	30.0	33	-29	-7	80	62
A8738	0.059	63,550	37,250	34,700	31.0	32	-24	-10	80	72
A8350	0.099	63,100	36,450	34,800	30.0	34	-38	-20	90	67
A8739	0.128	62,500	36,700	34,550	32.0	33	-32	-13	60	52
A8351	0.166	63,600	36,250	35,150	30.0	33	-55	-30	40	45
A8740	0.260	64,300	36,350	35,250	29.0	35	-57	-34	40	40
Type IX (0.21% C, 0.75% Mn, 0.01% Si) Steels										
A6649	0.001	64,700	37,700	36,850	24.0	36	-27	-19	80	75
A8145	0.016	59,550	34,550	33,100	32.0	39	-15	-8	80	75
A7320	0.019	59,950	34,400	33,400	31.5	41	-40	-24	70	70
A7319	0.032	59,250	35,200	33,850	30.0	41	-36	-24	80	69
A8146	0.064	60,600	34,750	34,000	31.5	45	-47	-42	60	56
Type X (0.21% C, 0.75% Mn, 0.05% Si) Steels										
Avg 2 steels	0.000	62,600	36,050	35,120	26.0	37	-34	-22	70	60
A7660	0.004	61,400	36,050	34,600	31.0	40	-34	-22	70	65
A8144	0.019	62,150	36,100	33,850	25.5	38	-36	-25	50	55
A7662	0.033	62,450	36,300	34,450	28.5	38	-42	-29	60	55
A7530	0.084	62,550	36,600	35,400	31.0	42	-74	-61	40	45
A8141	0.150	62,650	37,950	36,150	28.5	40	-66	-48	10	15
A8746	0.192	57,800	33,100	32,450	33.0	44	-69	-58	30	30

TABLE 4. (CONTINUED)

		Tensile Properties				Charpy Properties			Tear-Test Transition Temperature, F	
			Yield Point, psi			Energy Absorbed at 80 F, ft-lb	Transition Temperature, F			
Heat Number	Aluminum Content, %	Tensile Strength, psi	Upper	Lower	Elong in 8", %		12 ft-lb	20 ft-lb	Kahn	Probability of 50% Brittle Specimens
					Type XI (0.21% C, 0.75% Mn, 0.10% Si) Steels					
Avg 5 steels	0.000	62,080	36,780	35,280	30.5	39	-38	-21	60	47
A8905	0.036	64,000	37,750	35,950	28.5	36	-54	-46	60	51
A8741	0.062	62,200	35,850	34,200	27.5	40	-48	-37	60	54
A8352	0.093	63,400	37,350	35,800	32.5	36	-60	-32	70	46
A8742	0.131	64,300	37,050	36,400	30.5	36	-76	-59	40	42
A8353	0.167	63,100	36.500	35,400	30.5	39	-83	-60	20	19
A8743	0.269	63,550	36,650	35,350	30.0	36	-68	-64	80	80

TABLE 5. EQUATIONS FOR CALCULATING THE TENSILE STRENGTH AND YIELD STRENGTH OF HOT-ROLLED STEELS WITH DIFFERENT SILICON CONTENTS

Type of Steel	No. of Heats	Range of Silicon, per cent	Equation
Type I	20	0.02-0.54	Tensile Strength, psi = 63,464 + 15,311 x % Si Standard Error of Estimate = 1385 psi
			Upper Yield Point, psi = 36,701 + 6,389 x % Si Standard Error of Estimate = 1579 psi
Type II	6	0.10-0.39	Tensile Strength, psi = 59,336 + 20,614 x % Si Standard Error of Estimate = 532 psi
			Upper Yield Point, psi = 34,372 + 13,324 x % Si Standard Error of Estimate = 578 psi
Type III	18	0.01-0.52	Tensile Point, psi = 62,476 + 16,624 x % Si Standard Error of Estimate = 1497 psi
			Upper Yield Point, psi = 36,313 + 11,217 x % Si Standard Error of Estimate = 1258 psi
Type IV	4	0.02-0.57	Tensile Strength, psi = 62,586 + 21,865 x % Si Standard Error of Estimate = 647 psi
			Upper Yield Point, psi = 35,429 + 20,777 x % Si Standard Error of Estimate = 1044 psi
Type V	11	0.02-0.57	Tensile Point, psi = 62,964 + 15,637 x % Si Standard Error of Estimate = 920 psi
			Upper Yield Point, psi = 36,233 + 13,475 x % Si Standard Error of Estimate = 698 psi

study(9) of the influence of carbon and manganese in semikilled steel. These factors were in good agreement with those determined by other investigators(6,7) from studies of killed steels. The factors were therefore applied to the high silicon and high aluminum steels in the present study. Such steels would also be of the killed type.

The formulas in Table 5 for steels of Types I, III, and V are in good agreement. The averages for these steels show that 0.01 per cent silicon raises the ultimate strength approximately 155 psi and the yield point 130 psi. These values agree with those reported for hot-rolled steel by other investigators(6,7). Fewer steels of Types II and IV were tested, and no explanation for the apparently more pronounced effect of silicon in such steels is available.

Aluminum in the range studied had no effect on either the tensile or the yield point.

EFFECT OF SILICON AND ALUMINUM ON CHARPY PROPERTIES

The silicon content was independently varied in five types of steels, while the aluminum content was varied in six. Four of the five types of steel with varying silicon contents had no aluminum added, while the fifth type contained approximately 0.03 per cent acid-soluble aluminum. This amount of aluminum is normally found in steels made by fine-grained practice. The effect of aluminum was studied in steels containing three different amounts of silicon, each at two levels of manganese contents.

Test data for each specimen are given in Tables A-23 through A-33 of the Appendix. The average energy-temperature curve was determined for each steel. From these curves, the temperatures shown in Tables 3 and 4 at the 12 and 20 ft-lb values were obtained.

The energy absorbed at room temperature is shown in Tables 3 and 4. Neither silicon nor aluminum in the steels affected the energy absorbed in breaking Charpy specimens at room temperature.

After adjusting the transition temperatures for small unintentional variations in carbon and manganese, regression equations shown in Tables 6 and 7 were derived by multiple-correlation methods. The small standard errors of estimate for each equation indicate that these formulas fit the data very well. Figs. 1(a) and 2 show the adjusted 12 ft-lb temperatures and the trend lines calculated from the appropriate equation. Fig. 1(b) presents some supplementary data obtained on two steels with other manganese contents.

The Charpy transition temperature was shown by the data to be lowered by small amounts of silicon, except for Type IV steels in Fig. 1(b) where the data are few and indicate no significant effect of silicon. After reaching a minumum value, the transition temperature remained constant or increased with additional silicon. The silicon content at which a minimum

TABLE 6. FORMULAS FOR CALCULATING KEYHOLE CHARPY TRANSITION TEMPERATURES FOR HOT-ROLLED STEELS WITH DIFFERENT SILICON CONTENTS

Type of Steel	Silicon Range, per cent	Formula
		12-Foot-Pound Keyhole Charpy Transition Temperature
Type I	0.02 - 0.54	Trans. Temp, F = 15.57 - 274 x % Si + 296 x $(\% \mathrm{Si})^2$ Standard Error of Estimate = 10.60 F
Type II	0.10 - 0.39	Trans. Temp, F = -22.25 - 48 x % Si Standard Error of Estimate = 10.10
Type III	0.01 - 0.20	Trans. Temp, F = -20.78 - 183 x % Si Standard Error of Estimate = 9.02 F
Type III	0.16 - 0.52	Trans. Temp, F = -78.46 + 154 x % Si Standard Error of Estimate = 13.16 F
Type IV	0.06 - 0.34	Trans. Temp, F = -26.79 - 139 % Si + 362 $(\% \mathrm{Si})^2$ Standard Error of Estimate = 3.59 F
Type V	0.02 - 0.57	Trans. Temp, F = -24.56 - 284 x % Si + 335 x $(\% \mathrm{Si})^2$ Standard Error of Estimate = 4.90 F
		20-Foot-Pound Keyhole Charpy Transition Temperature
Type I	0.02 - 0.54	Trans. Temp, F = 36.55 - 263 x % Si + 333 x $(\% \mathrm{Si})^2$ Standard Error of Estimate = 11.05 F
Type II	0.10 - 0.39	Trans. Temp, F = -17.98 + 8 x % Si Standard Error of Estimate = 11.42 F
Type III	0.01 - 0.20	Trans. Temp, F = -6.80 - 158 x % Si Standard Error of Estimate = 9.03 F
Type III	0.16 - 0.52	Trans. Temp, F = -61.34 + 159 x % Si Standard Error of Estimate = 12.63 F

TABLE 6. FORMULAS FOR CALCULATING KEYHOLE CHARPY TRANSITION TEMPERATURES FOR HOT-ROLLED STEELS WITH DIFFERENT SILICON CONTENTS (Continued)

Type of Steel	Silicon Range, per cent	Formula
		20-Foot-Pound Keyhole Charpy Transition Temperature
Type IV	0.06 - 0.34	Trans. Temp, F = -25.22 + 24 x % Si Standard Error of Estimate = 5.40 F
Type V	0.02 - 0.57	Trans. Temp, F = -8.46 - 308 x % Si + 429 x (% Si)^2 Standard Error of Estimate = 5.69 F

TABLE 7. FORMULAS FOR CALCULATING KEYHOLE CHARPY TRANSITION TEMPERATURES FOR HOT-ROLLED STEELS WITH DIFFERENT ALUMINUM CONTENTS

Type of Steel	Aluminum Range, per cent	Formula
		12-Foot-Pound Keyhole Charpy Transition Temperature
Type VI	0.001 - 0.127	Trans. Temp, F = 12.47 - 363 x % Al Standard Error of Estimate = 7.16 F
Type VII	0.000 - 0.211	Trans. Temp, F = -5.26 - 155 x % Al Standard Error of Estimate = 7.52 F
Type VIII	0.000 - 0.260	Trans. Temp, F = -14.71 - 157 x % Al Standard Error of Estimate = 7.34 F
Type IX	0.001 - 0.064	Trans. Temp, F = -16.29 - 345 x % Al Standard Error of Estimate = 8.81 F
Type X	0.000 - 0.192	Trans. Temp, F = -35.41 - 211 x % Al Standard Error of Estimate = 13.23 F
Type XI	0.000 - 0.269	Trans. Temp, F = -50.66 - 117 x % Al Standard Error of Estimate = 12.03 F
		20-Foot-Pound Keyhole Charpy Transition Temperature
Type VI	0.001 - 0.127	Trans. Temp, F = 32.09 - 380 x % Al Standard Error of Estimate = 4.90 F
Type VII	0.000 - 0.211	Trans. Temp, F = 12.61 - 175 x % Al Standard Error of Estimate = 5.89 F
Type VIII	0.000 - 0.260	Trans. Temp, F = 6.61 - 147 x % Al Standard Error of Estimate = 6.28 F
Type IX	0.001 - 0.064	Trans. Temp, F = -3.47 -384 x % Al Standard Error of Estimate = 9.15 F
Type X	0.000 - 0.192	Trans. Temp, F =-22.69 - 191 x % Al Standard Error of Estimate = 14.54 F
Type XI	0.000 - 0.269	Trans. Temp, F = -32.06 - 143 x % Al Standard Error of Estimate = 10.18 F

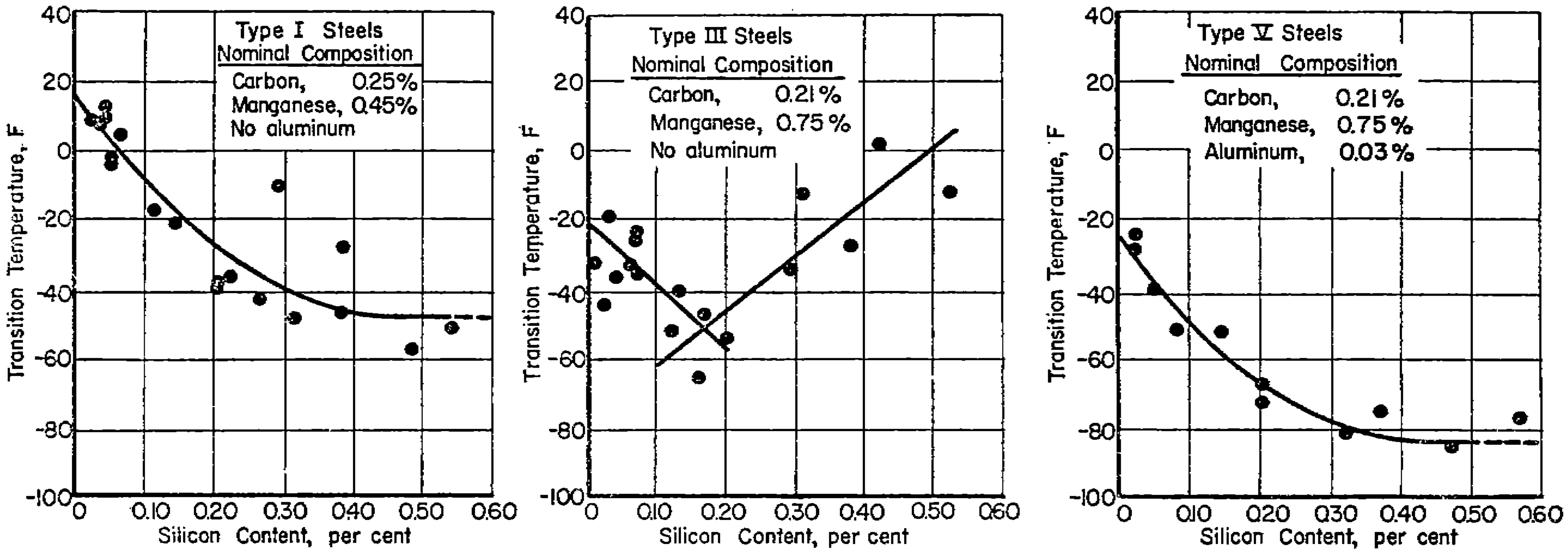

FIGURE 1(a) INFLUENCE OF SILICON ON THE 12-FOOT-POUND KEYHOLE CHARPY TRANSITION TEMPERATURES OF THREE TYPES OF STEEL

All transition temperatures corrected to correspond to the nominal composition of each steel.

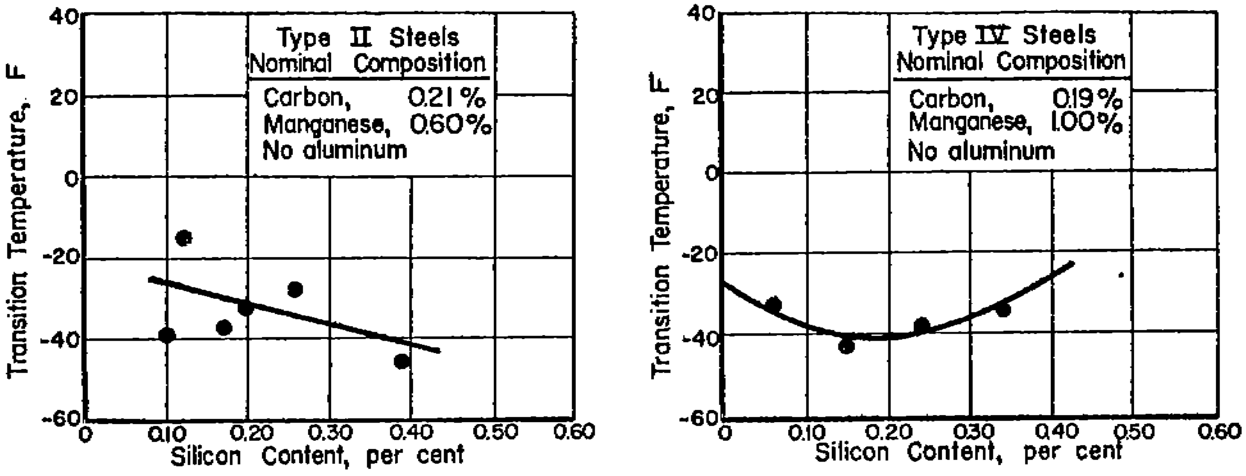

FIGURE 1(b) EFFECT OF SILICON ON THE 12 FT-LB KEYHOLE CHARPY TRANSITION TEMPERATURES OF TWO KINDS OF ALUMINUM-FREE STEEL.

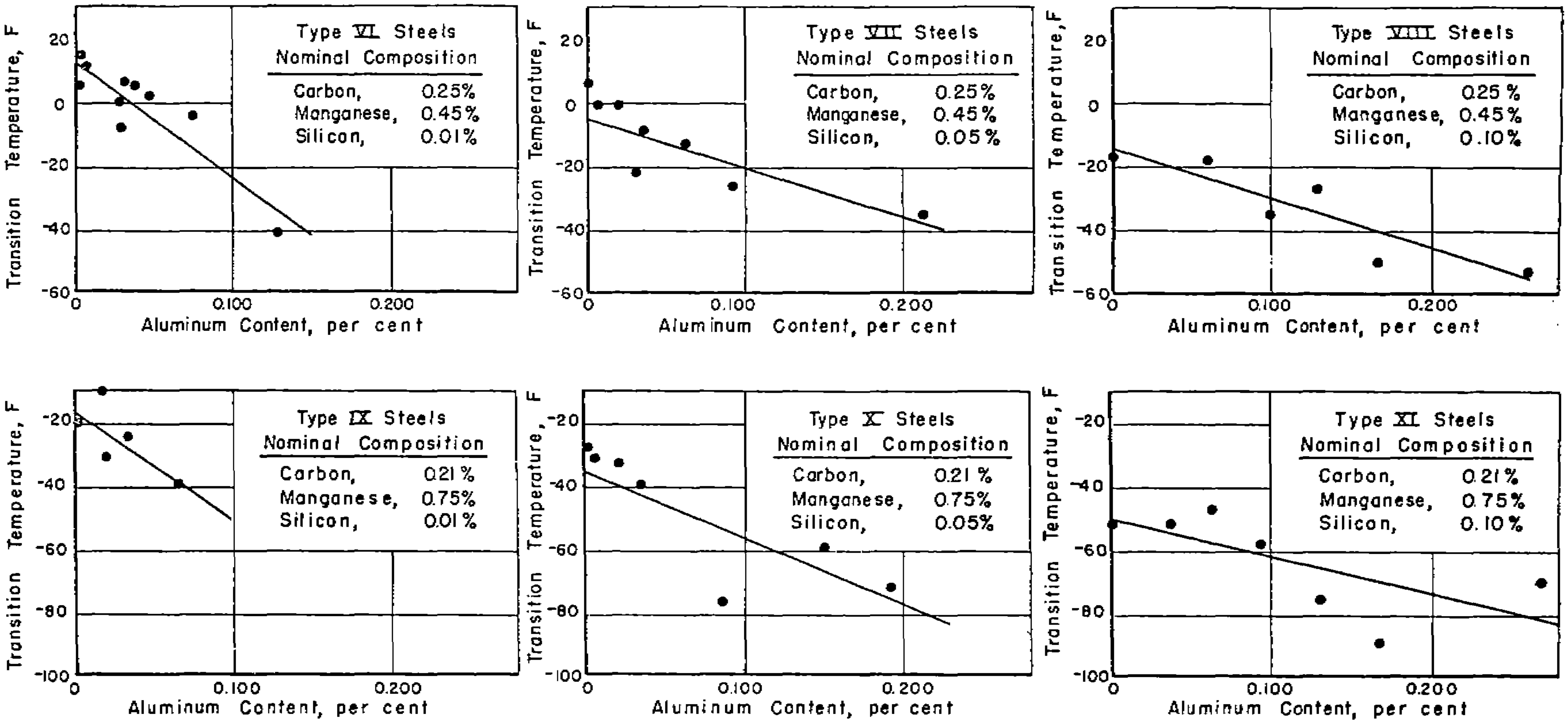

FIGURE 2 INFLUENCE OF ALUMINUM ON THE 12-FOOT-POUND KEYHOLE CHARPY TRANSITION TEMPERATURES OF SIX TYPES OF STEEL

All transition temperatures corrected to correspond to the nominal composition of each type of steel.

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transition temperature occurred depended on other constituents in the steel. For example, comparing the curves in Fig. 1(a) for Type I and Type III steels the inflection point(or minimum) was shifted to a lower silicon content when the manganese was increased.

The chart for Type III steels in Figure 1(a) indicates that there is an optimum silicon content for this grade of steel. The formulas in Table 6 for steels of Types I, IV, and V indicate that their transition temperatures increase after some critical silicon content is exceeded. The experimental data indicate, however, that if this inversion occurs, it takes place at higher silicon levels than those of interest in ship plate.

Data for the highest silicon contents investigated did not establish unequivocally whether or not high silicon contents are deleterious. In order to choose the shape of the trend lines plotted in Fig. 1, equations for both straight and curved lines expressing the relationship between silicon and keyhole Charpy transition temperatures were obtained by multiple-correlation analysis. The equations fitting the data better, on the basis of the "F" test and smaller standard errors, were used for plotting trend lines in Fig. 1.

The Type III steels give strong evidence that the effect of silicon on Charpy transition temperature reverses at a critical silicon content. Furthermore, the data for the Type I and Type V steels fit the trend lines reasonably well up to silicon contents where a point of inflection would be expected from the equations.

For these reasons, some speculations about behavior which could account for a reversal in the effect of silicon seem justified. Small amounts of silicon tend to deoxidize the steel, while larger amounts can serve as alloy additions as well. Iron alloys with low oxygen contents are known to have low transition temperatures(13), so that the first small additions of silicon to semi-killed grades of steel may be expected to lower the transition temperature. Additions of silicon large enough to have a difinite alloying effect have been shown to raise the transition temperature(10). Hence, the minimum transition temperatures indicated in the curves of Fig. 1 are expected to occur at silicon contents where the alloying effect offsets the deoxidizing influence of silicon.

In the presence of increasing amounts of manganese, less silicon is required to arrive at a minimum transition temperature, an indication of an interrelation in the deoxidizing effects of silicon and manganese.

Based on the results for aluminum-free steels, the 12 ft-lb Charpy transition temperature was lowered approximately 2 F by each increase of 0.01 per cent silicon up to about 0.20 per cent. In the low-manganese steels this beneficial effect of silicon continued up to about 0.50 per cent silicon.

The presence of 0.03 per cent aluminum lowered the Charpy transition temperatures of the steels studied. Figures 1(a) and 3

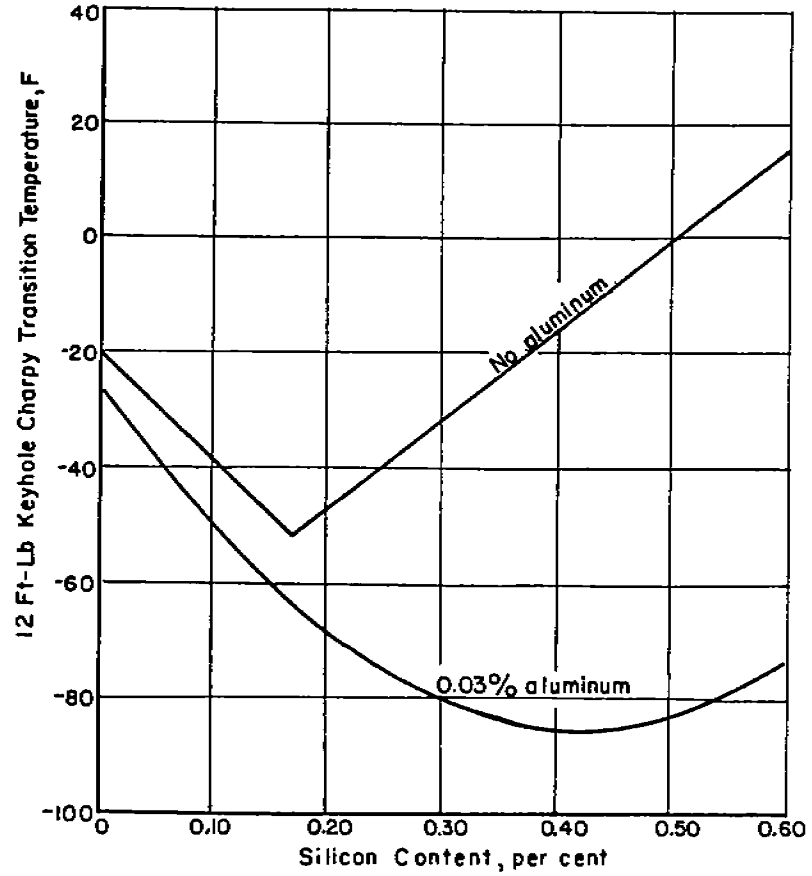

FIGURE 3. INFLUENCE OF SILICON ON THE KEYHOLE CHARPY TRANSITION TEMPERATURE OF STEELS CONTAINING 0.21% CARBON, 0.75% MANGANESE WITH AND WITHOUT ALUMINUM

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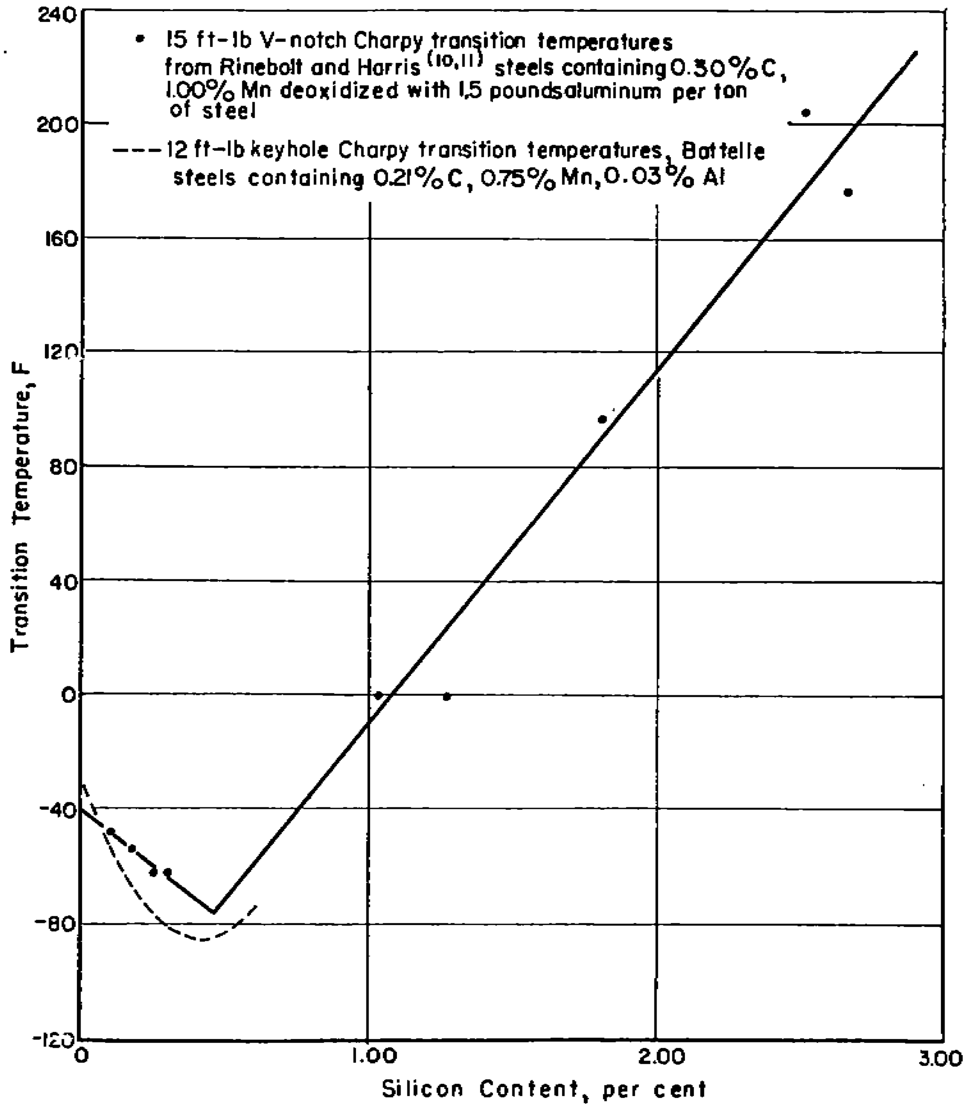

FIGURE 4. INFLUENCE OF SILICON ON TRANSITION TEMPERATURE AS REPORTED BY RINEBOLT AND HARRIS[10,11] AND BATTELLE

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show that the change produced by this small amount of aluminum depended on the silicon content of the steel. The addition of 0.03 per cent aluminum lowered the transition temperature 82 F in steels with 0.50 per cent silicon but only 11 F in steels with less than 0.17 per cent silicon. The data suggest that there was an interaction between the effects of silicon and aluminum on the Charpy transition temperature. That is, the optimum silicon content for minimum transition temperature apparently depended on the aluminum content as well as the amount of manganese present in the killed steel.

Rinebolt and Harris(10,11) concluded that variations in silicon contents up to 0.62 per cent had practically no influence on the 15 ft-lb V-notch Charpy transition temperature of aluminum-killed steels. Nevertheless, their data replotted in Fig. 4 show a drop of 36 F in the transition temperature by raising the silicon content to 0.45 per cent. Their tests showed that larger amounts of silicon raised the transition temperature rapidly. The trend line for their V-notch Charpy data and those for the keyhole Charpy data obtained in this investigation, as shown in the figure, were almost identical.

Fig. 2 shows that increasing the aluminum content lowered the Charpy transition temperatures of the experimental steels. The six types of steel used to study the effects of aluminum all contained 0.10 per cent silicon or less. Formulas for calculating the 12 and 20 ft-lb transition temperature for steels containing various amounts of aluminum are given in Table 7. Transition temperatures determined by both criteria responded similarly to increases in aluminum. The transition temperatures of steels containing 0.01 per cent silicon were reduced more by aluminum than those of steels containing 0.10 per cent silicon. On the average, each increase of 0.01 per cent aluminum in steels containing 0.01, 0.05, and 0.10 per cent silicon lowered the Charpy transition temperature 3.7, 1.8, and 1.4 F, respectively.

EFFECT OF SILICON AND ALUMINUM ON THE TEAR-TEST PROPERTIES

Four tear test specimens of each steel were broken at each 10 F interval throughout the transition zone. Data from each specimen, given in Tables A-12 through A-22 of the Appendix, were used to determine the transition temperature by two criteria. One criterion, developed by Kahn, defines the transition temperature as the highest temperature at which one or more of four specimens breaks with a brittle fracture. A brittle fracture is defined as one having less than 50 per cent of the fractured area exhibiting a dull, fibrous, ductile texture. A transition temperature by this criterion is based on the performance of only one specimen. This criterion sometimes gives an abnormally high transition temperature. For research purposes, such as for this investigation, a criterion based on the probability of 50 per cent brittle specimens seemed more desirable. This criterion takes into consideration the performance of every specimen tested. In the present study, transition temperatures by both criteria were reported and in most cases showed the same trends. However, the standard errors for the regression equations, based on the second criterion, were much smaller than those for equations based on transition temperatures set by Kahn's definition.

The transition temperatures shown in Tables 3 and 4 were adjusted for small unintentional variations in the carbon and manganese. Using the adjusted data and multiple-correlation methods, regression equations for calculating the influence of silicon and aluminum on tear test transition temperatures were determined. These formulas, shown in Tables 8 and 9, were used to establish the trend lines in Fig. 5 and 6. The choice of using either straight or curved trend lines was made on the basis of the type of equation giving the smallest standard error.

As in the Charpy tests, increasing the silicon content in the range up to 0.20 per cent lowered the transition temperatures in tear tests. This was true for all types of steel studied when the transition temperature was considered to be the temperature corresponding to equal probabilities for ductile or for brittle fracture. The use of the Kahn definition suggested that the transition temperatures of steels, Types II and IV shown in Fig. 5(b), were not improved by increasing amounts of silicon. These two exceptions were not considered important because the apparent changes in transition temperature were either too small or based on too few data to be significant.

TABLE 8. FORMULAS FOR CALCULATING TEAR-TEST TRANSITION TEMPERATURES FOR HOT-ROLLED STEELS WITH DIFFERENT SILICON CONTENTS

Type of Steel	Silicon Range, per cent	Formula
		Kahn Tear-Test Transition Temperature
Type I	0.02 - 0.54	Trans. Temp, F = 94.25 - 83 x % Si + 155 x (% Si)^2 Standard Error of Estimate = 11.35 F
Type II	0.10 - 0.39	Trans. Temp, F = 68.42 + 17 x % Si Standard Error of Estimate = 17.51 F
Type III	0.01 - 0.20	Trans. Temp, F = 83.85 - 191 x % Si Standard Error of Estimate = 10.71 F
Type III	0.16 - 0.52	Trans. Temp, F = 33.82 + 112 x % Si Standard Error of Estimate = 9.80 F
Type IV	0.06 - 0.34	Trans. Temp, F = 31.70 + 171 x % Si Standard Error of Estimate = 6.92 F
Type V	0.02 - 0.57	Trans. Temp, F = 79.34 - 123 % Si + 249 x (% Si)^2 Standard Error of Estimate = 10.25 F
Fifty Per Cent Probability of Brittle Specimens Transition Temperature		
Type I	0.02 - 0.54	Trans. Temp, F = 87.50 - 93 x % Si + 189 x (% Si)^2 Standard Error of Estimate = 7.69 F
Type II	0.10 - 0.39	Trans. Temp, F = 94.69 - 356 x % Si + 717 x (% Si)^2 Standard Error of Estimate = 9.66 F
Type III	0.01 - 0.20	Trans. Temp, F = 71.14 - 178 x % Si Standard Error of Estimate = 9.88 F

TABLE 8. FORMULAS FOR CALCULATING TEAR-TEST TRANSITION TEMPERATURES FOR HOT-ROLLED STEELS WITH DIFFERENT SILICON CONTENTS (Continued)

Type of Steel	Silicon Range, per cent	Formula
Fifty Per Cent Probability of Brittle Specimens Transition Temperature		
Type III	0.16 - 0.52	Trans. Temp, F = $23.22 + 119 \times \%\,Si$ Standard Error of Estimate = 6.04 F
Type IV	0.06 - 0.34	Trans. Temp, F = $50.34 - 196 \times \%\,Si + 916 \times (\%\,Si)^2$ Standard Error of Estimate = 12.27 F
Type V	0.02 - 0.57	Trans. Temp, F = $73.96 - 154 \times \%\,Si + 286 \times (\%\,Si)^2$ Standard Error of Estimate = 7.73 F

TABLE 9. FORMULAS FOR CALCULATING TEAR-TEST TRANSITION TEMPERATURES FOR HOT-ROLLED STEELS WITH DIFFERENT ALUMINUM CONTENTS

Type of Steel	Range of Aluminum, per cent	Formula
		Kahn Tear-Test Transition Temperature
Type VI	0.001 - 0.127	Trans. Temp, F = 113.47-416 x % Al Standard Error of Estimate = 12.34 F
Type VII	0.000 - 0.211	Trans. Temp, F = 88.38-159 x % Al Standard Error of Estimate = 27.73 F
Type VIII	0.000 - 0.260	Trans. Temp, F = 98.93-230 x % Al Standard Error of Estimate = 12.80 F
Type IX	0.001 - 0.064	Trans. Temp, F = 85.86-207 x % Al Standard Error of Estimate = 9.85 F
Type X	0.000 - 0.192	Trans. Temp, F = 65.56+241 x % Al Standard Error of Estimate = 11.11 F
Type XI	0.000 - 0.200	Trans. Temp, F = 74.71-258 x % Al Standard Error of Estimate = 14.33 F
Fifty Per Cent Probability of Brittle Specimens Transition Temperature		
Type VI	0.001 - 0.127	Trans. Temp, F = 108.19-377 x % Al Standard Error of Estimate = 8.43 F
Type VII	0.000 - 0.211	Trans. Temp, F = 86.50-222 x % Al Standard Error of Estimate = 6.93 F
Type VIII	0.000 - 0.260	Trans. Temp, F = 82.31-156 x % Al Standard Error of Estimate = 5.81 F
Type IX	0.001 - 0.064	Trans. Temp, F = 81.15-203 x % Al Standard Error of Estimate = 7.67 F
Type X	0.000 - 0.192	Trans. Temp, F = 63.56-196 x % Al Standard Error of Estimate = 8.55 F
Type XI	0.000 - 0.200	Trans. Temp, F = 60.79-189 x % Al Standard Error of Estimate = 10.35 F

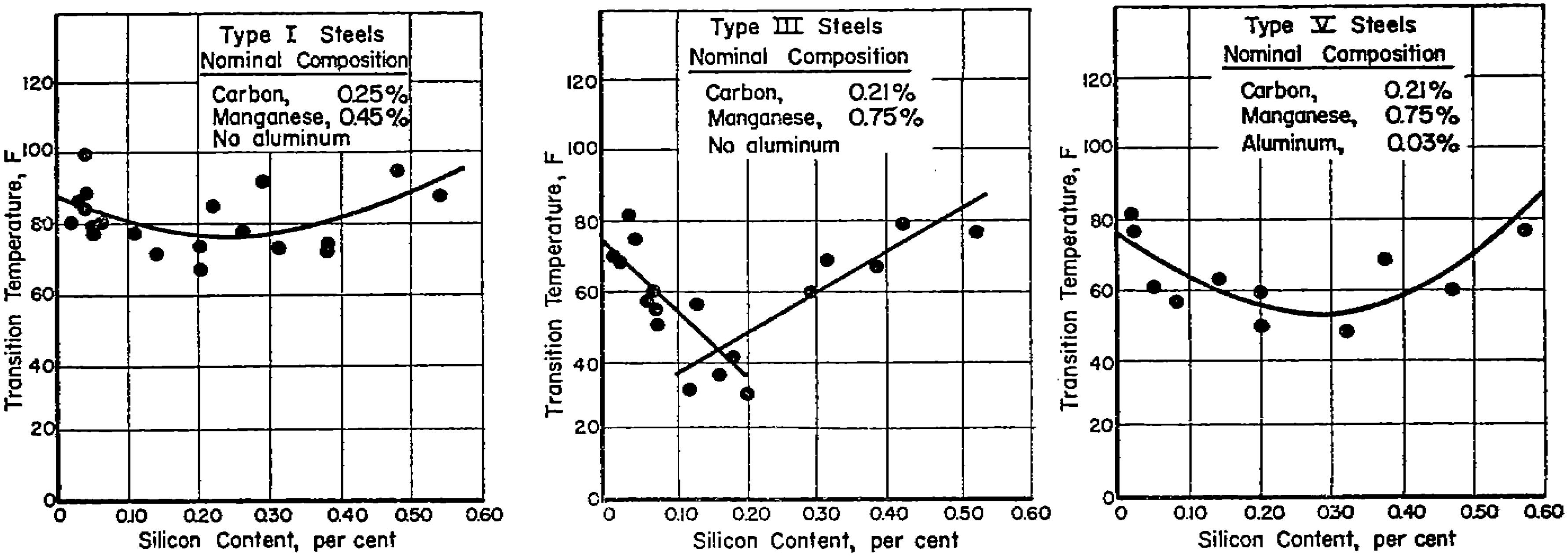

FIGURE 5(a) INFLUENCE OF SILICON ON P=0.5 TEAR-TEST TRANSITION TEMPERATURES OF THREE TYPES OF STEEL
All transition temperatures corrected to correspond to the nominal composition of each steel.

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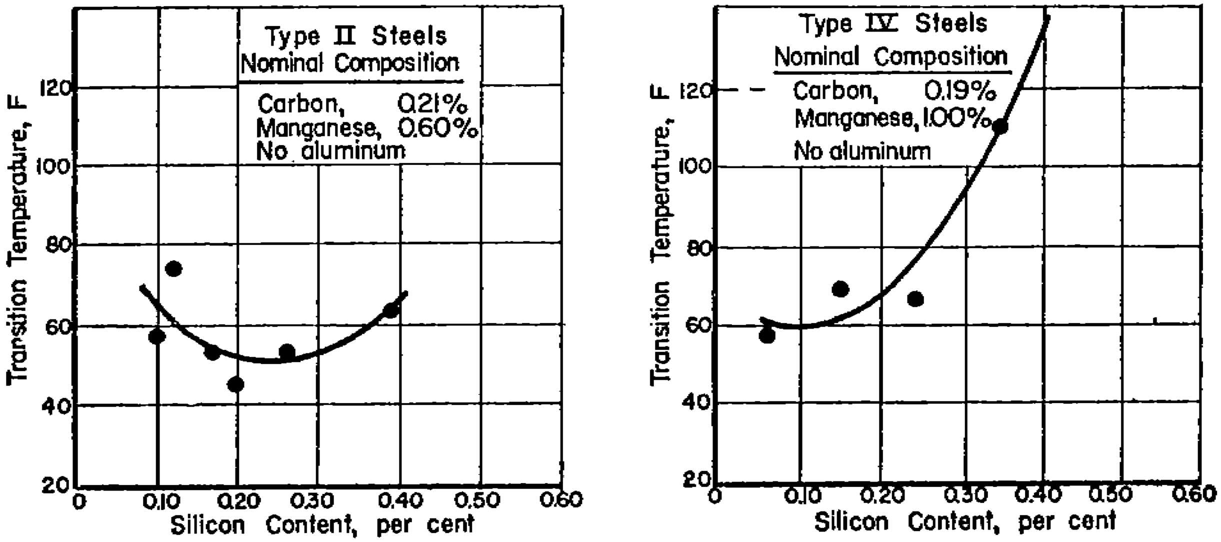

FIGURE 5(b) EFFECT OF SILICON ON p = 0.5 TEAR TEST TRANSITION TEMPERATURES OF TWO KINDS OF ALUMINUM-FREE STEEL

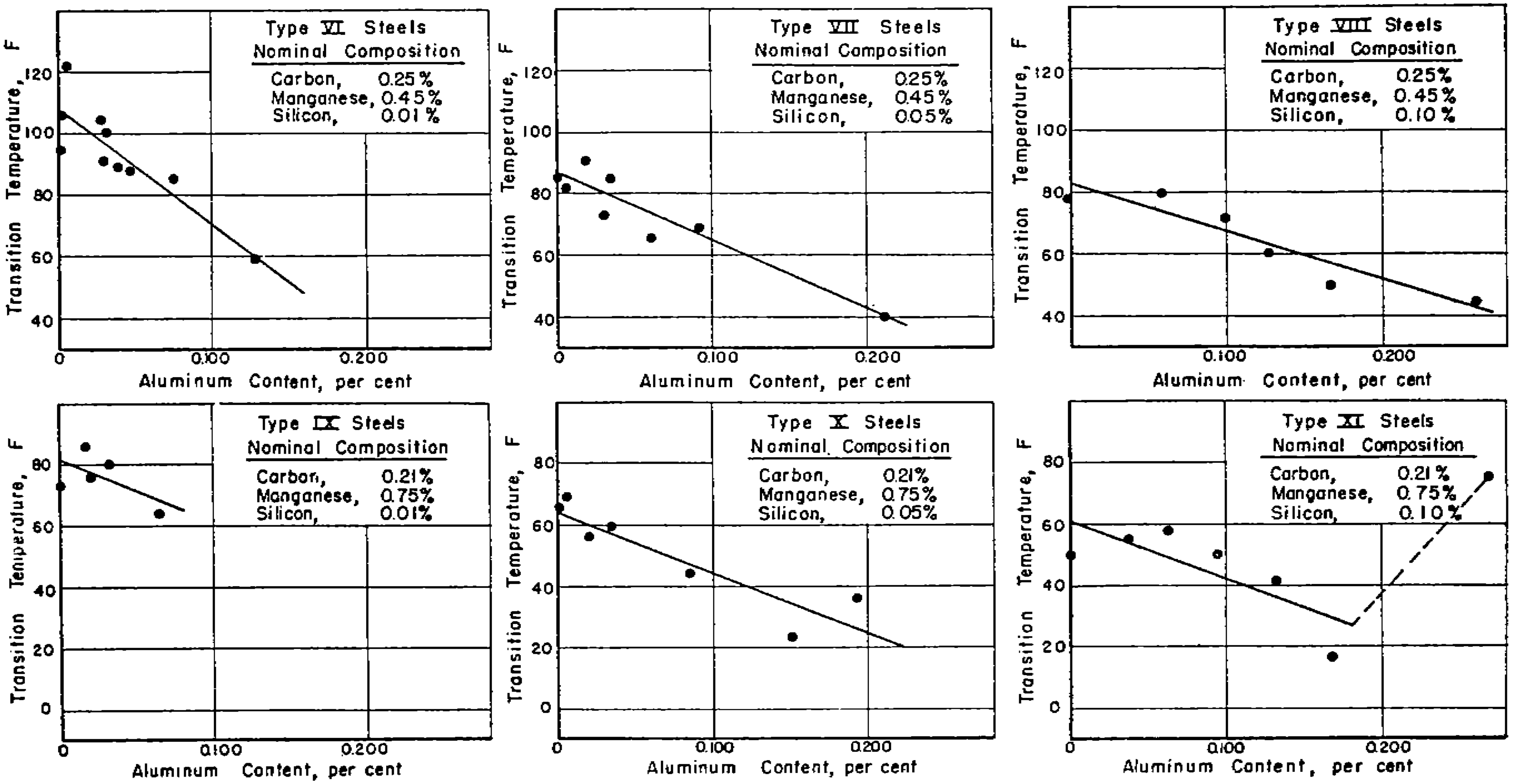

FIGURE 6 **INFLUENCE OF ALUMINUM ON THE P = 0.5 TEAR-TEST TRANSITION TEMPERATURES OF SIX TYPES OF STEEL**

All transition temperatures corrected to correspond to the nominal composition of each type of steel.

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Increasing the silicon content over 0.2 per cent seemed to raise the transition temperature in the tear test.

Fig. 6 shows that the tear test transition temperatures decreased as the aluminum contents of the experimental steels increased up to 0.20 per cent. On the average, an increase of 0.01 per cent aluminum lowered the transition temperature in tear tests about 2.2 F. This factor was slightly different for steels with different silicon contents, as shown by the variations between slopes of the trend lines in Fig. 6. Aluminum seems to have had the most pronounced effect in steels with 0.01 per cent silicon. These conclusions support those based on Charpy data obtained on the same materials.

It should be noted that considerable amounts of aluminum were required to produce appreciable changes in transition temperature. Aluminum contents of about 0.10 per cent seem to be necessary to lower the transition temperature about 20 F from the level for hot-rolled aluminum-free steel. This quantity of aluminum is considerably larger than that of most commercial steels. The normal aluminum content of "fine-grained" steels would not be expected to significantly improve the transition temperature of hot-rolled plates. In this regard, the data for the Type III and the Type V steels in Fig. 5(a) are important. The presence of 0.03 per cent aluminum in the Type V did not significantly affect the transition temperature of steels containing less than 0.2 per cent silicon. In fact, in this case, the tear test transition temperatures tended to be slightly higher for the steels containing aluminum.

The transition temperatures for the steels with 0.21 per cent carbon, 0.75 per cent manganese, and 0.10 per cent silicon (Type XI) are especially interesting. Fig. 6 shows that the transition temperature of this type of steel appears to have been significantly higher when the aluminum content was 0.269 per cent than when it was between 0.09 and 0.17 per cent. The trend line was drawn to indicate that the effect of aluminum on this type of steel reverses at about 0.2 per cent aluminum. The Charpy data for the same materials, shown in Fig. 2, lend some support to this interpretation. Perhaps there is an optimum aluminum content which produces the lowest transition temperature. This is consistent with the data showing the effect of silicon on transition temperature, but the data for aluminum are too scanty to justify a strong opinion on this point.

CONCLUSIONS

This study on the effects of variations in silicon and aluminum contents on the properties of steels made in an induction furnace and hot-rolled in the laboratory leads to the following conclusions:

1. Small amounts of silicon lowered the transition temperatures of the experimental steels in Charpy and tear tests. The keyhole Charpy data indicated that the 12 ft-lb transition temperature decreased about 1.5 F for each increase of 0.01 per cent

silicon up to the following silicon contents:

0.50% silicon in steels with 0.25% C, 0.45% Mn, no Al
0.40% silicon in steels with 0.21% C, 0.75% Mn, 0.03% Al
0.17% silicon in steels with 0.21% C, 0.75% Mn, no Al

Increasing the silicon content above 0.17% tended to raise the Charpy transition temperature of steels containing 0.21% C and 0.75% Mn.

The data suggest that variations in silicon content within the narrow range characteristic of semikilled steels have no significant effect on their notched-bar transition temperatures.

2. Increases in aluminum contents up to about 0.20 per cent lowered the Charpy and tear test transition temperatures of steels made and processed in the laboratory. In this range, each increase of 0.01 per cent aluminum lowered the transition temperature about 2.2 F in tear tests. The extent to which the Charpy transition temperature was lowered by adding aluminum depended on the silicon content of the experimental steels. In steels containing 0.03 per cent silicon or less, each increase of 0.01 per cent aluminum lowered the Charpy transition temperature about 3.7 F. Equal amounts of aluminum were only about half as effective in lowering the Charpy transition temperatures of steels containing 0.05 to 0.13 per cent silicon.

The quantity of aluminum normally present in steels made by fine-grained practice did not have a significant effect on the transition temperatures of the experimental steels tested in the hot-rolled condition.

3. For these hot-rolled steels, each increase of 0.01 per cent silicon raised the yield point approximately 130 psi and the tensile strength approximately 150 psi.

4. Variations in aluminum contents up to 0.27 per cent did not influence the tensile properties of the hot-rolled plates.

5. Neither silicon nor aluminum influenced the ferrite grain size of the hot-rolled experimental steels. Apparently, the ferrite grain size was controlled by the hot-rolling practice. All plates were finished at 1850 F.

6. Normalizing from 1650 F produced a finer ferrite grain size in Class C ship plate steels (containing aluminum) than in semikilled Class B steels.

7. Variations in silicon content up to 0.58 per cent had no effect on the austenite grain-coarsening temperature. Aluminum, on the other hand, had a pronounced effect on grain-growth characteristics. The presence of 0.01 per cent aluminum, or more, raised the coarsening temperature about 200 F. All of the experimental steels, however, had coarsening temperatures below 1850 F, the temperature of the plates during the final rolling reduction.

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APPENDIX

TABLE A-1. TENSILE-TEST DATA FOR TYPE I STEELS WITH VARIOUS SILICON CONTENTS

Heat	Specimen	Yield Strength, psi Upper	Yield Strength, psi Lower	Tensile Strength, psi	Elongation in 8 Inches, %
A8728	1	38,600	37,400	66,600	29.0
	2	40,000	39,400	66,600	28.5
A8922	1	37,000	35,600	65,900	27.5
	2	39,200	36,200	65,900	28.0
A8747	1	36,100	35,800	66,100	29.0
	2	38,100	35,900	66,100	28.0
B865	1	38,300	35,250	66,900	25.5
	2	38,100	37,200	66,800	26.5
A8729	1	39,900	38,600	72,900	27.5
	2	41,400	40,000	74,000	26.5
B866	1	39,500	37,500	68,500	27.0
	2	39,500	37,500	68,500	27.5
A8923	1	39,900	39,400	70,400	29.0
	2	39,800	39,200	70,400	28.5
B867	1	40,500	39,200	71,200	28.5
	2	40,100	39,200	70,000	24.5

TABLE A-2. TENSILE-TEST DATA FOR TYPE II STEELS WITH VARIOUS SILICON CONTENTS

Heat	Specimen	Yield Strength, psi Upper	Yield Strength, psi Lower	Tensile Strength, psi	Elongation in 8 Inches, %
A8151	1	35,500	34,600	60,500	30.0
	2	35,600	33,600	60,100	31.0
A9265	1	36,300	34,500	61,400	28.5
	2	35,200	34,000	61,000	29.0
A8375	1	37,200	35,600	62,300	28.0
	2	36,100	34,900	61,900	28.5
A9266	1	36,400	35,400	63,600	29.0
	2	37,000	35,400	63,600	29.0
A8376	1	37,500	36,500	64,400	28.0
	2	36,600	35,900	64,200	28.0
A9275	1	40,600	38,000	67,600	23.0
	2	39,600	39,000	67,100	26.0

TABLE A-3. TENSILE-TEST DATA FOR TYPE III STEELS WITH VARIOUS SILICON CONTENTS

Heat	Specimen	Yield Strength, psi Upper	Yield Strength, psi Lower	Tensile Strength, psi	Elongation in 8 Inches, %
A8378	1	38,400	34,800	61,800	33.0
	2	37,500	35,500	61,800	30.0
A9262	1	38,400	36,400	63,000	27.5
	2	39,600	36,100	63,100	27.5
B868	1	40,300	38,900	67,000	26.5
	2	40,100	39,400	66,400	28.0
A8730	1	39,000	38,100	67,400	29.0
	2	38,600	37,600	67,300	29.0
B869	1	40,400	39,100	67,400	26.0
	2	40,500	39,300	68,000	27.0
B870	1	43,000	42,400	69,500	27.0
	2	42,400	41,000	69,800	27.5

TABLE A-4. TENSILE-TEST DATA FOR TYPE IV STEELS WITH VARIOUS SILICON CONTENTS

Heat	Specimen	Yield Strength, psi		Tensile Strength, psi	Elongation in 8 Inches, %
		Upper	Lower		
A9271	1	36,700	36,300	63,500	30.0
	2	38,000	36,200	63,300	29.0
A9272	1	37,800	37,000	64,700	30.0
	2	37,200	37,100	64,700	30.0
A9273	1	39,700	37,100	66,800	29.0
	2	39,200	38,400	67,200	27.0
A9274	1	46,300	45,300	76,600	25.0
	2	46,200	45,000	75,200	24.0

TABLE A-5. TENSILE-TEST DATA FOR TYPE V STEELS WITH VARIOUS SILICON CONTENTS

Heat	Specimen	Yield Strength, psi		Tensile Strength, psi	Elongation in 8 Inches, %
		Upper	Lower		
A8904	1	36,200	35,200	63,200	30.5
	2	36,300	35,200	63,000	29.0
A8905	1	38,000	35,800	64,100	26.5
	2	37,500	36,100	63,900	30.5
A8906	1	38,600	35,800	64,900	30.0
	2	37,600	36,500	65,000	29.0
A8907	1	37,300	36,300	64,400	30.0
	2	37,900	36,400	64,800	28.5
A8908	1	38,600	37,000	65,100	31.0
	2	38,900	36,500	65,000	30.0
A8909	1	40,700	38,800	67,000	25.0
	2	40,800	38,900	66,200	22.5
B871	1	40,900	39,900	67,300	23.5
	2	41,100	40,000	68,100	24.0
B872	1	43,500	42,000	69,500	26.0
	2	42,600	41,600	69,400	26.5
B873	1	44,200	42,900	71,400	26.0
	2	43,500	42,500	70,600	24.5

TABLE A-6. TENSILE-TEST DATA FOR TYPE VI STEELS WITH VARIOUS ALUMINUM CONTENTS

Heat	Specimen	Yield Strength, psi		Tensile Strength, psi	Elongation in 8 Inches, %
		Upper	Lower		
A8736	1	33,800	32,500	58,200	25.0
	2	33,700	31,900	57,400	27.5
A8737	1	31,700	31,200	56,600	31.0
	2	33,400	31,900	57,600	28.5
A9263	1	33,600	32,700	58,600	32.5
	2	35,300	34,000	58,200	31.0
A9264	1	32,800	31,900	58,100	33.5
	2	33,800	31,400	58,300	32.8
A8142	1	34,400	32,800	58,500	29.0
	2	33,300	32,800	58,200	25.5
A8143	1	35,600	33,300	61,600	32.0
	2	34,700	33,800	61,300	31.5

TABLE A-7. TENSILE-TEST DATA FOR TYPE VII STEELS WITH VARIOUS ALUMINUM CONTENTS

Heat	Specimen	Yield Strength, psi Upper	Yield Strength, psi Lower	Tensile Strength, psi	Elongation in 8 Inches, %
A8136	1	35,800	34,100	63,400	30.5
	2	36,100	34,200	63,400	31.5
A7322	1	33,600	34,400	60,800	31.5
	2	34,000	35,900	61,500	30.5
A8137	1	35,700	33,700	60,800	31.0
	2	34,800	33,200	60,800	31.0
A8745	1	36,700	34,700	63,900	26.5
	2	36,900	34,700	63,600	29.5

TABLE A-8. TENSILE-TEST DATA FOR TYPE VIII STEELS WITH VARIOUS ALUMINUM CONTENTS

Heat	Specimen	Yield Strength, psi Upper	Yield Strength, psi Lower	Tensile Strength, psi	Elongation in 8 Inches, %
A8738	1	37,800	34,500	62,800	33.0
	2	36,700	34,900	64,300	29.5
A8350	1	36,100	34,900	62,700	32.0
	2	36,800	34,700	63,500	28.0
A8739	1	36,400	34,400	62,500	32.0
	2	37,000	34,700	62,500	32.5
A8351	1	36,800	35,100	63,700	31.0
	2	35,700	35,200	63,500	29.0
A8740	1	36,300	35,600	65,000	29.0
	2	36,400	34,900	63,600	29.5

TABLE A-9. TENSILE-TEST DATA FOR TYPE IX STEELS WITH VARIOUS ALUMINUM CONTENTS

Heat	Specimen	Yield Strength, psi Upper	Yield Strength, psi Lower	Tensile Strength, psi	Elongation in 8 Inches, %
A8145	1	34,600	32,900	59,500	33.0
	2	34,500	33,300	59,600	31.5
A7320	1	33,500	34,600	60,200	32.0
	2	33,300	34,200	59,700	31.5
A7319	1	33,900	35,100	58,900	30.0
	2	33,800	35,300	59,600	29.9
A8146	1	34,900	33,900	60,600	33.5
	2	34,600	34,100	60,600	30.0

TABLE A-10. TENSILE-TEST DATA FOR TYPE X STEELS WITH VARIOUS ALUMINUM CONTENTS

Heat	Specimen	Yield Strength, psi		Tensile Strength, psi	Elongation in 8 Inches, %
		Upper	Lower		
A8144	1	36,100	33,900	61,600	24.0
	2	36,100	33,800	62,500	27.0
A8141	1	37,800	36,300	62,800	28.0
	2	38,100	36,000	62,500	29.5
A8746	1	33,100	32,500	58,000	34.0
	2	33,100	32,400	57,600	32.5

TABLE A-11. TENSILE-TEST DATA FOR TYPE XI STEELS WITH VARIOUS ALUMINUM CONTENTS

Heat	Specimen	Yield Strength, psi		Tensile Strength, psi	Elongation in 8 Inches, %
		Upper	Lower		
A8741	1	36,300	34,200	62,000	27.5
	2	35,400	34,200	62,400	27.5
A8352	1	37,700	35,800	63,300	32.5
	2	37,000	35,800	63,500	32.5
A8742	1	37,000	36,500	64,500	31.0
	2	37,100	36,300	64,100	30.0
A8353	1	36,500	35,600	63,200	32.0
	2	36,500	35,200	63,000	29.0
A8743	1	36,900	35,500	63,000	29.0
	2	36,400	35,200	64,100	31.0

TABLE A-12. NAVY TEAR-TEST DATA FOR TYPE I STEELS WITH VARIOUS SILICON CONTENTS

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A6602[a]	A2	60	36,950	842	58	2
	B1	60	36,850	833	33	3
	B2	60	36,700	750	117	7
	C1	70	37,000	866	67	5
	C2	80	36,350	850	125	10
A7663[b]	T1	90	36,350	700	633	100
	T2	90	36,450	690	92	15
A6650[a]	X2	60	37,400	824	450	45
	P2	70	36,100	790	642	100
	U2	70	37,650	800	75	3
	W1	70	35,950	815	642	87
	W2	70	35,950	766	808	100
	X1	70	36,750	800	824	100
	M1	70	36,250	725	42	2
	N2	80	36,550	800	609	100
	Q1	80	36,250	775	633	100
	R1	80	36,300	775	600	97
	R2	80	36,000	740	133	14
	S2	90	35,300	800	541	100
	T1	90	38,100	860	775	100
	T2	90	37,650	990	784	97
	U1	90	37,450	808	734	100
A7449	R1	60	37,400	808	92	5
	R2	60	37,350	824	167	5
	S1	60	36,650	725	50	3
	S2	60	36,650	784	83	5
	P2	70	36,700	790	67	5
	Q1	70	35,550	734	650	100
	Q2	70	35,850	740	616	95
	M1	70	37,650	709	117	10
	M2	80	36,700	791	715	100
	N1	80	36,000	692	600	95
	N2	80	36,000	725	616	90
	P1	80	36,100	715	600	100
A8132	K1	70	38,400	725	108	5
	K2	80	38,100	757	58	8
	B1	80	36,850	700	100	10
	B2	80	35,900	690	58	5
	C1	80	36,300	642	67	3
	A1	90	37,750	984	600	100
	A2	90	36,500	740	334	34
	L1	90	37,200	757	665	100
	L2	90	37,050	790	83	15
	M1	100	36,650	800	616	95
	M2	100	37,100	815	584	95
	N1	100	36,650	800	690	100
	N2	100	37,000	784	117	15
	P1	110	37,350	790	650	100
	P2	110	37,550	800	700	100
	Q1	110	36,850	757	600	100
	Q2	110	37,750	866	609	100
A6556[a]	A1	50	37,600	766	58	3
	A2	50	37,700	815	42	5
	B1	60	36,950	740	33	3
	B2	60	38,250	900	83	5
	T1	60	39,350	1050	508	92
	F1	60	37,400	734	83	3

TABLE A-12. (Continued)

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A6556[(a)]	G1	70	37,300	775	83	3
	L2	70	36,150	650	625	7
	M1	80	36,300	750	559	99
	S1	80	36,350	734	616	100
	S2	80	36,300	784	609	99
	T2	80	37,050	740	609	99
A6705[(a)]	W2	60	37,650	715	740	100
	L2	70	36,900	740	75	5
	W1	80	36,800	740	658	100
	M1	80	36,600	790	584	100
	N1	80	36,100	665	609	100
	N2	80	35,700	665	58	15
	E2	90	36,150	833	625	94
	V1	90	36,000	700	665	100
	V2	90	36,200	684	690	100
	P1	90	36,300	715	707	100
	Q1	90	36,100	684	234	49
	R2	100	36,300	725	625	100
	D1	100	37,500	700	565	95
	D2	100	38,350	757	559	100
	E1	100	38,400	766	492	60
A6555[(a)]	A1	50	36,800	775	83	5
	A2	50	36,800	700	234	7
	B1	50	37,250	775	83	5
	B2	60	37,300	866	600	90
	V2	60	37,500	833	600	85
	M1	60	37,500	707	600	70
	S1	60	37,900	808	66	4
	S2	70	39,100	935	616	98
	T1	70	37,200	734	150	16
	T2	80	36,250	690	650	100
	U1	80	37,050	975	642	100
	U2	80	37,050	885	690	100
	V1	80	36,800	757	675	100
A6594[(a)]	B1	50	37,450	790	600	88
	B2	60	37,900	866	684	95
	P1	60	37,550	800	584	75
	T1	60	38,600	824	584	100
	T2	70	37,900	842	575	100
	U1	80	38,150	850	609	100
	U2	80	37,700	775	625	100
	F2	80	37,850	824	633	100
A6657[(a)]	B1	50	39,400	842	142	5
	B2	50	39,900	875	150	7
	C1	50	39,150	815	100	5
	C2	50	39,600	850	58	3
	R2	60	39,150	815	117	5
	S2	60	38,050	766	484	67
	T1	70	38,000	815	600	100
A7526[(b)]	R2	50	39,800	715	83	15
	Q1	60	39,500	715	67	3
	Q2	60	39,050	675	117	2
	R2	60	39,500	715	142	12
	A1	60	40,800	800	283	25

TABLE A-12. (Continued)

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A7526[(b)]	A2	70	39,200	665	183	20
	B1	70	39,800	690	616	100
	B2	70	39,850	715	142	10
A8728	A1	60	39,750	757	158	10
	A2	60	39,800	707	133	10
	T1	60	39,900	715	75	3
	J1	60	39,500	815	50	7
	K2	70	38,850	775	193	18
	R1	70	38,550	707	575	100
	T2	70	39,300	725	550	98
	J2	70	39,150	750	117	10
	K1	80	37,950	684	117	15
	R2	80	38,100	707	584	100
	S1	80	38,600	725	658	100
	S2	80	38,550	707	609	100
	P1	90	38,000	715	642	100
	P2	90	37,700	700	642	100
	Q1	90	38,200	775	559	90
	Q2	90	39,200	950	650	100
A8922	M1	70	37,600	690	417	62
	T1	70	40,000	757	67	10
	T2	70	39,400	725	600	100
	U1	70	39,650	725	158	15
	M2	80	37,850	675	584	98
	N1	80	38,150	650	108	35
	U2	80	38,000	642	50	12
	V1	80	38,450	700	225	23
	N2	90	38,300	675	616	100
	B2	90	37,500	684	584	100
	P1	90	38,100	700	200	23
	V2	90	38,600	766	725	100
	P2	100	37,850	665	550	100
	Q1	100	37,100	642	575	100
	Q2	100	38,050	665	633	100
	R1	100	37,700	665	250	45
	R2	110	37,250	616	642	100
	S1	110	37,300	642	642	100
	S2	110	37,900	700	575	100
	B1	110	38,250	757	665	100
A8747	U1	60	38,850	665	466	83
	U2	60	39,000	690	58	3
	V1	60	39,100	675	250	15
	V2	60	38,850	690	133	10
	B1	70	38,700	675	150	10
	B2	70	38,100	665	684	100
	C1	70	38,150	707	75	7
	M1	70	37,200	684	300	45
	C2	80	38,750	725	633	100
	M2	80	37,550	650	565	95
	N1	80	37,650	684	600	100
	N2	80	38,900	757	150	25
	P1	90	37,900	700	584	100
	P2	90	37,500	690	575	100
	Q1	90	37,050	690	258	37
	T2	90	36,950	665	200	33
	Q2	100	37,600	707	633	100
	R1	100	37,500	700	633	100
	R2	100	37,400	650	525	100
	T1	100	37,050	642	600	100

TABLE A-12. (Continued)

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
B865	A1	60	40,250	790	216	18
	Q1	60	41,050	910	92	3
	Q2	60	40,900	860	83	7
	R1	60	40,850	842	100	3
	A2	70	39,550	750	750	100
	E1	70	40,100	784	92	8
	P1	70	42,150	915	150	10
	P2	70	39,850	815	75	7
	E2	80	39,700	790	600	100
	F1	80	40,200	808	150	10
	N1	80	40,650	800	715	100
	N2	80	40,400	875	625	85
	F2	90	39,200	757	575	100
	H1	90	39,950	775	584	100
	H2	90	40,400	800	609	100
	J1	90	39,900	800	208	20
	J2	100	39,800	766	600	100
	K1	100	38,950	757	600	100
	K2	100	39,750	790	616	100
	R2	100	39,850	842	665	100
A6696(a)	C1	50	41,550	833	100	2
	C2	50	41,500	815	100	3
	D1	50	41,450	961	83	3
	S2	60	40,350	790	125	4
	B1	60	41,500	875	616	100
	B2	60	40,450	757	609	100
	P2	70	39,750	815	575	100
	Q2	70	39,150	725	83	10
	T2	70	39,400	750	142	15
A8729	A1	70	41,000	625	83	10
	A2	70	42,000	675	183	15
	V1	70	40,450	633	375	45
	V2	70	41,200	616	150	10
	Q2	80	40,350	690	541	100
	R1	80	39,600	625	100	15
	R2	80	39,950	658	258	31
	J1	80	40,550	740	158	15
	J2	90	40,400	665	158	15
	Q1	90	40,500	690	584	100
	S1	90	40,200	675	650	100
	S2	90	40,400	665	541	100
	K1	100	39,500	684	616	100
	K2	100	39,900	684	665	100
	M1	100	39,400	642	534	100
	M2	100	39,800	658	508	100
B866	E1	50	41,500	790	108	3
	H2	50	40,600	800	67	5
	J1	50	41,150	750	117	8
	J2	50	40,600	784	83	5
	A2	60	41,600	824	559	98
	E2	60	41,550	850	650	100
	F1	60	41,950	800	367	43
	F2	60	42,000	875	100	3
	A1	70	40,300	784	584	100
	G1	70	41,250	750	665	100
	G2	70	40,750	740	625	100
	H1	70	40,350	734	609	100

TABLE A-12. (Continued)

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A8923	S2	80	38,000	690	83	13
	K1	80	40,200	757	42	10
	K2	80	40,950	707	292	20
	N1	80	41,050	658	225	28
	S1	90	38,650	725	108	18
	M1	90	39,950	690	650	100
	M2	90	40,000	658	650	100
	N2	90	40,800	743	250	25
	P1	100	39,600	675	633	100
	S1	100	39,750	775	576	100
	S2	100	39,150	675	565	100
	P2	100	40,000	684	316	42
	Q1	110	39,100	575	584	100
	Q2	110	39,150	684	690	100
	R1	110	39,600	658	616	97
	R2	110	39,150	650	600	100
B867	A1	60	41,350	815	117	7
	A2	60	42,200	833	83	7
	B1	60	42,750	850	108	5
	B2	60	41,800	790	67	7
	L2	70	42,050	775	117	8
	T1	70	41,400	740	133	10
	T2	70	41,300	750	208	25
	K1	70	42,300	815	590	100
	L1	80	40,950	750	565	100
	Q1	80	41,200	808	225	25
	S1	80	41,850	775	750	100
	S2	80	42,050	824	715	100
	K2	90	41,050	757	534	100
	Q2	90	41,750	740	575	100
	R1	90	41,450	734	734	100
	R2	90	41,700	734	625	100

(a) Test data for other specimens from this steel were reported in the Appendix of the First Progress Report on "An Investigation of the Influence of Deoxidation and Chemical Composition on Notched-Bar Properties of Semikilled Steel", Ship Structure Report No. 49.

(b) Test data for other specimens from this steel were reported in the Appendix of the Second Progress Report on " An Investigation of the Influence of Deoxidation and Chemical Composition on Notched-Bar Properties of Semikilled Steel", Ship Structure Report No. 53.

TABLE A-13. NAVY TEAR-TEST DATA FOR TYPE II STEELS WITH VARIOUS SILICON CONTENTS

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
AB151	C1	30	39,400	925	83	5
	C2	30	38,900	935	67	3
	D1	30	39,000	940	108	3
	D2	30	40,000	961	108	5
	E1	40	39,150	940	108	5
	B2	40	37,600	850	75	2
	T1	40	39,750	915	83	3
	T2	40	40,150	1000	590	98
	A1	50	38,100	915	100	10
	A2	50	37,750	815	684	100
	B1	50	36,700	790	75	5
	R2	50	38,800	935	325	33
	S1	60	38,750	900	790	100
	S2	60	38,250	860	100	5
	U1	60	40,000	975	665	100
	V1	60	38,700	842	325	25
	L1	70	38,900	910	208	20
	V2	70	39,600	935	900	100
	W1	70	38,050	875	707	100
	W2	70	38,950	866	700	100
	L2	80	38,050	885	684	100
	M1	80	38,000	842	790	100
	M2	80	37,100	790	700	100
	R1	80	39,250	1067	784	100
A9265	J1	40	37,100	808	67	5
	T1	50	39,000	860	92	3
	T2	50	38,200	842	100	4
	U1	50	38,500	875	167	5
	J2	50	38,550	990	158	18
	K1	60	37,400	842	292	32
	A2	60	38,400	824	50	5
	E1	60	38,300	866	625	100
	E2	60	38,450	808	700	100
	K2	70	37,200	808	642	100
	L1	70	36,800	824	658	100
	L2	70	36,550	824	667	100
	M1	70	37,900	866	75	12
	M2	80	37,500	935	17	12
	B1	80	37,450	891	600	98
	B2	80	38,050	850	658	100
	C1	80	39,050	961	715	100
	R1	90	37,350	815	725	100
	R2	90	37,450	860	325	38
	C2	90	38,750	935	790	100
	D1	90	38,300	961	757	100
	S1	100	37,250	824	665	100
	S2	100	37,000	815	633	100
	A1	100	37,350	833	757	100
	D2	100	36,500	790	700	100
A8375	A1	40	38,600	940	25	2
	A2	40	38,700	1080	150	10
	V1	40	38,550	824	400	43
	V2	40	39,450	1060	133	5
	W1	50	39,350	875	616	100
	L2	50	39,800	950	92	2
	T1	50	39,350	900	133	7
	T2	50	37,750	766	616	100
	U1	60	38,700	833	642	96
	U2	60	38,500	860	408	62
	L1	60	39,000	910	58	10
	M1	60	39,250	891	642	100

TABLE A-13. (Continued)

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A8375	M2	70	38,900	590	650	100
	R1	70	39,700	1020	690	100
	S1	70	40,050	1020	665	100
	S2	70	39,400	915	665	100
A9266	E1	20	42,750	935	158	3
	E2	30	42,300	958	83	3
	U1	30	42,350	950	100	3
	U2	30	41,600	866	125	3
	V1	30	42,250	975	258	20
	S2	40	40,900	910	675	99
	T1	40	40,400	891	275	20
	L1	40	40,250	842	83	5
	S1	40	40,350	900	75	2
	V2	50	40,850	885	200	21
	T2	50	40,700	925	684	100
	L2	50	40,900	925	600	100
	M1	50	40,200	850	225	17
	K2	60	40,550	891	665	100
	M2	60	40,350	875	650	100
	N1	60	40,000	860	534	77
	N2	60	39,800	860	534	85
	K1	70	40,400	900	790	100
A8376	D2	40	39,550	950	83	5
	E1	40	40,150	891	117	5
	E2	40	40,650	885	242	13
	F1	40	40,150	850	216	10
	C1	50	38,900	935	175	8
	C2	50	39,000	950	117	5
	D1	50	40,750	935	725	100
	M1	50	40,150	875	408	50
	L2	60	41,350	958	690	100
	M2	60	40,300	891	625	100
	R2	60	41,200	975	108	11
	V1	60	40,550	866	575	90
	S1	70	39,700	915	216	25
	V2	70	40,300	875	675	100
	W1	70	40,150	891	633	100
	W2	70	40,450	875	658	100
	S2	80	39,900	925	684	100
	T1	80	39,650	940	633	100
	T2	80	39,200	950	658	100
	U1	80	39,400	860	665	100
A9275	E1	40	43,800	1080	142	5
	E2	40	43,450	958	125	7
	F1	40	43,000	1010	200	7
	K1	40	42,250	800	58	2
	J2	50	42,700	885	525	72
	K2	50	42,400	958	400	37
	F2	50	42,600	940	142	5
	T1	50	42,250	866	83	3
	T2	60	42,100	860	800	100
	J1	60	41,100	775	690	100
	L1	60	40,550	842	658	96
	L2	60	41,300	915	100	3
	M1	70	41,400	925	700	100
	M2	70	40,500	800	824	100
	R1	70	41,050	860	690	100
	R2	70	41,500	910	167	7
	S1	80	40,250	833	408	45
	S2	80	41,150	910	824	100
A9275	N1	90	42,100	842	800	100
	N2	90	40,550	775	658	100
	P1	90	42,600	958	690	100
	P2	90	42,700	866	700	100

TABLE A-14. NAVY TEAR-TEST DATA FOR TYPE III STEELS WITH VARIOUS SILICON CONTENTS

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A6651(a)	S1	50	39,250	935	565	85
	X2	60	39,600	715	740	100
	Q1	60	38,700	866	891	100
	W1	70	39,100	1000	766	100
	W2	70	39,200	958	725	100
	X1	70	38,150	860	734	100
	M2	70	38,950	910	83	8
A6603(a)	T1	40	40,550	875	167	7
	T2	40	40,700	915	100	5
	U1	40	42,750	1150	142	10
	U2	40	42,400	1080	167	12
	B1	50	39,750	885	183	9
	B2	50	40,400	950	92	4
	C1	50	39,100	1000	590	78
	C2	60	37,900	800	766	97
	D1	60	38,950	1010	175	7
	D2	80	38,500	833	690	100
	E1	80	38,500	935	750	100
	E2	80	38,200	950	824	100
A7664(b)	U1	70	37,500	824	725	100
	S2	80	37,700	824	734	100
	T1	80	36,900	790	715	100
	T2	80	38,300	866	740	100
A6641(a)	X2	80	39,850	1077	665	100
A6588(a)	C2	40	40,200	984	308	25
	L1	40	38,050	815	133	5
	L2	40	38,750	935	250	23
	N2	40	38,650	915	475	49
	B2	50	38,450	900	133	5
	C1	50	39,750	1020	658	92
	A1	60	38,500	815	910	100
	A2	60	38,650	990	400	35
	B1	60	39,950	990	250	20
A6557(a)	B2	50	38,500	975	58	3
	K2	50	38,900	850	1358	100
	S1	50	41,200	1025	808	100
	A2	60	39,750	860	818	95
	B1	60	40,300	950	650	95
	A1	70	40,600	1077	158	12
A6584(a)	X1	50	40,150	950	125	5
	X2	50	40,450	1025	675	100
	W1	70	39,800	1040	715	100
	W2	70	39,100	984	707	100
A7450	U2	40	38,300	790	408	30
	N2	40	38,650	825	725	100
	P1	40	40,350	950	192	20
	U1	40	39,350	866	242	20
	N1	50	38,950	850	675	100
	P2	50	40,250	940	117	10
	V1	50	37,400	725	734	100
	V2	50	39,500	815	258	20
	Q1	60	38,400	833	833	100
	Q2	60	39,550	875	900	100
	R1	60	38,250	791	692	100
	R2	60	39,250	868	125	10

TABLE A-14. (Continued)

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A7450	M2	70	37,650	809	709	100
	T1	70	40,300	900	692	100
	S1	70	40,000	915	650	100
	S2	70	39,800	850	766	100
A6595[(a)]	U1	10	41,550	1020	133	3
	U2	10	41,850	1000	225	15
	V1	10	41,950	1000	715	100
	V2	10	42,550	1077	92	3
	B1	20	42,800	1077	550	68
	L2	20	40,650	958	584	77
	P1	20	41,450	990	117	3
	R1	20	41,450	1025	142	5
	Q2	30	40,600	935	158	2
	T1	40	41,350	1025	158	9
	T2	40	41,850	1060	833	100
	B2	40	42,350	1080	715	100
A8378	E1	20	41,350	1033	67	2
	E2	20	40,950	1025	92	4
	F1	20	41,750	990	108	3
	M1	20	41,600	1010	100	5
	L2	30	41,800	1140	815	100
	M2	30	39,500	958	283	20
	F2	30	41,950	1067	158	4
	G1	30	40,550	1020	83	3
	L1	40	41,150	1033	833	100
	R1	40	41,300	1125	800	100
	R2	40	40,300	1067	642	95
	S1	40	40,200	1067	383	35
	S1	50	40,850	1100	715	100
	T1	50	41,600	1175	757	100
	T2	50	40,750	1110	625	95
	U1	50	40,250	1077	167	10
	U2	60	40,000	990	83	5
	G2	60	40,700	1033	1915	100
	X1	60	40,800	1040	67	5
	X2	60	39,600	1080	740	100
	V1	70	41,250	1220	392	99
	V2	70	39,350	1033	940	100
	W1	70	40,000	1033	734	100
	W2	70	39,400	1020	675	100
A6695[(a)]	Q1	10	42,000	940	125	5
	N1	10	42,000	900	258	8
	Q2	10	41,850	935	175	12
	P1	10	41,500	935	142	3
	S1	20	41,850	975	125	2
	T1	20	42,850	1040	442	50
	T2	30	42,600	1020	117	2
	U1	30	42,200	1025	675	98
	U2	30	42,800	1033	133	3
A9262	G2	10	42,000	1077	158	5
	H1	10	42,650	1033	83	1
	H2	10	41,750	1025	910	100
	F1	20	41,600	1025	258	25
	F2	20	41,400	1033	75	2
	G1	20	40,800	1077	584	95
	E1	20	41,500	990	108	4
	K1	30	40,100	900	100	8
	E2	30	40,300	961	650	100
	U1	30	40,300	975	658	100
	U2	30	40,000	975	625	88

TABLE A-14. (Continued)

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A9262	V1	40	40,900	935	183	9
	V2	40	41,350	1033	734	100
	T2	40	39,650	885	650	86
	K2	40	39,300	833	408	45
	L1	50	38,800	875	658	100
	S1	50	39,100	891	740	100
	S2	50	39,150	925	658	100
	L2	50	39,500	910	83	5
	M1	60	39,300	891	725	100
	M2	60	39,300	950	684	100
	N1	60	39,500	915	725	100
	N2	60	39,200	950	675	100
A7528[(b)]	B2	20	42,700	1040	167	7
	A1	30	42,400	950	1150	100
	A2	30	44,000	1025	208	10
	B1	30	42,450	984	83	3
	R1	30	41,200	866	475	57
	R2	40	41,350	950	658	100
	S1	40	41,600	875	757	100
	S2	40	40,750	833	559	97
A6697[(a)]	T1	30	44,750	1080	142	5
	U1	30	44,750	1090	150	3
	T2	30	45,300	1077	175	15
	B1	40	43,150	961	690	100
	B2	40	42,900	984	158	5
	C1	40	44,000	1067	133	9
	C2	50	43,800	1110	658	100
	D1	60	43,250	1077	675	100
	D2	60	43,000	1067	715	100
	S2	60	41,250	975	300	22
B868	P1	40	42,000	1033	92	3
	P2	40	41,650	1010	108	3
	Q1	40	42,550	1120	208	12
	Q2	40	41,900	1050	665	95
	M1	50	42,900	975	117	5
	M2	50	43,100	1040	117	5
	N1	50	43,100	1010	175	13
	N2	50	43,250	1010	642	90
	A1	60	40,850	1040	684	99
	A2	60	43,250	1020	75	5
	J2	60	42,000	940	142	5
	H1	60	44,800	1250	700	100
	E1	70	42,150	1010	675	100
	E2	70	41,200	900	183	10
	H2	70	41,000	910	633	97
	J1	70	42,500	1010	575	93
	F1	80	41,400	975	642	98
	F2	80	41,650	961	715	100
	G1	80	41,500	958	625	100
	G2	80	41,700	950	707	100
A8730	U1	50	42,600	891	408	47
	U2	50	43,150	940	234	17
	V1	50	42,100	850	292	28
	V2	50	42,500	925	193	15
	Q2	60	41,500	900	707	99
	S2	60	41,350	885	800	100
	T1	60	42,000	885	92	4
	T2	60	42,600	950	625	95

TABLE A-14. (Continued)

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A8730	R1	70	41,900	935	750	100
	S1	70	41,200	950	734	100
	K2	70	41,950	875	665	83
	L1	70	41,200	875	400	49
	K1	80	41,150	900	684	100
	L2	80	41,050	885	600	100
	Q1	80	40,850	860	665	100
	R1	80	40,850	800	584	99
B869	H1	50	43,300	915	108	2
	H2	50	43,650	1025	200	10
	J1	50	44,050	984	108	3
	J2	50	43,950	1060	133	5
	F1	60	43,600	1050	658	93
	F2	60	43,600	1160	625	98
	G1	60	43,050	990	83	3
	G2	60	43,350	1077	400	45
	V1	70	42,500	940	707	100
	V2	70	41,900	900	258	25
	W1	70	43,000	1060	150	10
	W2	70	42,100	935	690	100
	M1	80	42,450	950	83	8
	S2	80	42,900	950	740	100
	U1	80	42,850	915	740	100
	U2	80	42,750	915	665	100
	M2	90	41,900	915	584	97
	R1	90	41,000	850	616	97
	R2	90	42,100	961	658	100
	S1	90	41,400	900	675	100
B870	M2	50	44,000	1040	92	3
	N1	50	44,300	940	75	3
	N2	50	44,600	1033	175	3
	P1	50	45,000	1090	125	1
	M1	60	44,400	975	107	98
	H2	60	43,600	1010	658	100
	J1	60	43,550	935	784	100
	J2	60	43,900	915	83	3
	E1	70	42,150	891	208	15
	G1	70	43,900	1000	600	100
	G2	70	45,000	1100	650	100
	H1	70	43,350	958	292	15
	A2	80	42,300	784	734	100
	E2	80	42,800	940	609	98
	F1	80	42,300	891	684	100
	F2	80	43,350	940	757	100
	A1	90	43,700	940	658	100

(a) Test data for other specimens from this steel were reported in the Appendix of the First Progress Report on "An Investigation of the Influence of Deoxidation and Chemical Composition on Notched-Bar Properties of Semikilled Steel", Ship Structure Report No. 49.

(b) Test data for other specimens from this steel were reported in the Appendix of the Second Progress Report on "An Investigation of the Influence of Deoxidation and Chemical Composition on Notched-Bar Properties of Semikilled Steel", Ship Structure Report No. 53.

TABLE A-15. NAVY TEAR-TEST DATA FOR TYPE IV STEELS WITH VARIOUS SILICON CONTENTS

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A9271	W2	10	44,650	1125	442	40
	E1	10	45,600	1180	75	2
	E2	10	45,500	1150	175	7
	F1	10	45,600	1175	108	2
	V2	20	43,600	1170	766	100
	U2	20	44,050	1120	92	2
	V1	20	43,500	1067	300	28
	W1	20	43,800	1080	150	3
	M2	30	43,250	1110	142	2
	N1	30	42,400	1040	815	100
	N2	30	42,600	1060	67	5
	S1	30	43,200	1077	125	5
	S2	40	42,800	1080	815	100
	T1	40	42,300	1020	350	12
	T2	40	42,700	1080	534	49
	K1	40	42,250	950	334	27
	K2	50	42,050	1020	860	100
	L1	50	42,000	1010	824	100
	L2	50	40,500	885	842	100
	M1	50	40,700	860	833	100
A9272	H1	20	45,250	1175	125	1
	H2	20	44,800	1150	117	2
	J1	20	46,350	1258	150	2
	E1	20	45,900	1433	167	5
	E2	30	44,200	1033	125	2
	F1	30	44,150	1080	183	3
	F2	30	43,400	1033	740	100
	K2	30	43,900	1125	442	49
	J2	40	44,750	1240	117	5
	K1	40	42,750	984	750	95
	L1	40	43,350	1060	150	5
	T2	40	42,750	925	150	2
	S2	50	42,500	961	824	100
	T1	50	43,250	1110	757	100
	L2	50	42,850	1025	790	100
	M1	50	42,450	1033	316	28
	M2	60	43,200	1080	850	100
	N1	60	43,050	1040	757	100
	N2	60	43,450	1125	766	100
	S1	60	42,750	1025	734	100
A9273	S2	20	44,600	900	142	3
	T1	20	45,900	1150	150	11
	U1	20	44,800	–	–	3
	G2	20	46,800	1175	183	8
	J2	30	44,600	1033	860	100
	S1	30	45,100	1100	283	12
	J1	40	44,750	1025	715	98
	M2	40	43,700	935	125	4
	R1	40	44,650	1067	784	100
	R2	40	42,850	891	750	100
	K1	50	43,850	1025	175	8
	E2	50	44,550	1100	775	100
	F2	50	45,500	1150	392	40
	G1	50	44,950	1067	842	100
	F1	60	43,700	1020	800	100
	U2	60	43,700	1000	442	42
	T2	60	44,500	1100	800	100
	K2	60	44,600	1067	167	10

TABLE A-15. (Continued)

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear In Fracture
A9273	L1	70	43,300	935	815	100
	L2	70	43,300	961	860	100
	M1	70	43,050	958	808	100
	E1	70	43,950	1050	833	100
A9274	K2	50	49,600	1120	67	5
	L1	60	49,800	1130	216	13
	L2	70	49,350	1120	125	10
	M1	80	48,450	1000	425	35
	A1	80	48,950	707	167	20
	A2	80	52,400	1067	50	15
	B1	80	50,250	1100	100	15
	B2	90	49,450	1220	833	100
	M2	90	48,850	935	790	100
	N1	90	47,750	940	815	100
	N2	90	49,150	1000	325	20
	S1	100	49,700	1080	833	100
	S2	100	47,300	910	800	100
	T1	100	49,050	1060	750	100
	T2	100	49,150	1090	740	100

TABLE A-16. NAVY TEAR-TEST DATA FOR TYPE V STEELS WITH VARIOUS SILICON CONTENTS

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A8904	Q2	60	40,300	961	158	15
	R2	60	38,400	824	500	49
	S1	60	38,900	866	308	25
	K1	60	39,500	915	125	10
	J2	70	40,200	1067	83	10
	J1	70	39,200	975	142	10
	R1	70	40,150	958	75	5
	S2	70	39,500	866	675	100
	K2	80	39,200	885	600	90
	L1	80	39,500	984	600	90
	L2	80	38,400	900	650	96
	Q1	80	39,300	925	675	100
A8905	A1	30	42,800	1067	200	15
	A2	30	41,700	925	183	7
	V1	30	42,500	1020	258	30
	V2	30	41,400	935	117	2
	T1	40	41,650	1033	590	80
	T2	40	41,700	940	117	5
	U1	40	41,400	1000	108	4
	U2	40	41,600	1020	125	5
	R1	50	40,500	875	658	95
	R2	50	41,200	925	67	3
	S1	50	40,500	910	609	91
	J1	50	40,300	990	133	15
	J2	60	39,700	984	665	100
	K1	60	40,700	1080	675	100
	K2	60	41,250	1060	117	12
	S2	60	40,150	915	750	100
	L1	70	40,400	910	658	100
	L2	70	41,050	975	642	100
	M1	70	40,200	935	625	98
	M2	70	40,300	900	675	100
A8906	L1	30	41,000	950	300	26
	L2	40	40,850	891	392	46
	B1	50	41,300	961	665	100
	B2	50	41,850	1000	142	5
	U1	50	42,000	1050	125	5
	U2	50	41,150	940	665	100
	A1	60	41,500	1077	66	5
	A2	60	40,250	875	1220	100
	T2	60	41,000	935	665	100
	K1	60	40,650	891	234	32
	Q1	70	41,000	958	658	100
	Q2	70	40,200	915	690	100
	K2	70	40,900	925	158	21
	T1	70	40,450	885	725	100
	R1	80	38,600	842	616	100
	R2	80	40,750	915	616	100
	S1	80	39,800	925	675	100
	S2	80	39,550	915	625	100
A8907	J2	20	41,950	958	250	20
	J1	30	42,800	915	675	100
	L1	30	42,700	875	275	26
	K1	40	42,250	975	700	100
	L2	40	42,350	961	100	7
	B1	40	43,300	1050	208	20

TABLE A-16. (Continued)

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A8907	K2	50	41,850	915	665	90
	Q1	50	41,750	915	665	100
	Q2	50	42,000	900	833	100
	R1	50	41,450	900	142	15
	R2	60	41,650	958	283	38
	T1	60	41,500	925	715	100
	T2	60	41,400	940	625	98
	B2	60	42,100	1025	1225	100
	A1	70	41,350	1010	648	100
	A2	70	41,300	935	1410	100
	S1	70	41,750	958	750	100
	S2	70	40,900	961	650	100
A8908	K2	30	42,850	975	142	10
	K1	40	42,250	1077	808	100
	Q1	40	41,950	885	125	7
	A1	40	42,200	1020	1090	100
	R1	50	41,150	875	734	98
	L1	50	42,200	915	866	95
	L2	50	42,200	915	541	76
	Q2	50	43,000	1020	234	7
	T1	60	41,900	900	242	20
	A2	60	40,900	910	150	8
	B1	60	41,500	935	425	47
	B2	60	42,400	1000	725	100
	R2	70	41,650	961	690	100
	S1	70	41,450	990	609	80
	S2	70	42,000	1020	824	100
	T2	70	40,750	885	400	36
	U1	80	41,100	866	775	100
	U2	80	41,900	990	900	100
	V1	80	41,450	900	633	97
	V2	80	41,250	900	757	100
A8909	V1	20	45,250	961	193	10
	V2	20	45,000	1000	308	23
	W1	20	44,950	984	216	7
	W2	20	45,050	950	234	18
	T1	30	44,350	910	584	85
	T2	30	43,350	1010	133	10
	U1	30	44,900	1077	75	3
	U2	30	45,000	1040	266	20
	L2	40	43,750	990	700	98
	M1	40	42,650	866	142	5
	M2	40	43,150	958	125	6
	R1	40	44,400	1080	125	3
	H1	50	42,650	940	316	27
	R2	50	43,100	984	92	15
	S1	50	42,850	935	757	95
	S2	50	42,650	940	675	93
	H2	60	43,500	1060	658	100
	K1	60	44,900	1125	707	100
	K2	60	43,850	1033	715	100
	L1	60	42,700	984	508	100
B871	J1	40	45,200	1100	584	90
	J2	40	44,200	1000	266	15
	K1	40	42,850	925	408	37
	K2	40	42,550	1050	133	5
	G2	50	43,500	1040	216	20
	H1	50	43,950	1077	700	97
	H2	50	42,900	1170	757	100
	M1	50	44,100	1067	193	10

TABLE A-16. (Continued)

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
B871	G1	60	44,450	1077	242	25
	M2	60	43,750	990	67	10
	V1	60	43,500	1020	984	100
	V2	60	42,750	984	75	7
	U1	70	43,150	1025	740	100
	U2	70	42,700	961	108	10
	R1	70	42,000	958	715	100
	R2	70	43,100	984	193	15
	S1	80	42,700	1040	885	100
	S2	80	42,650	990	961	100
	T1	80	43,000	940	725	100
	T2	80	43,650	1033	658	100
B872	L1	50	43,700	1000	175	17
	T2	50	44,950	1110	67	2
	U2	50	45,050	1067	117	5
	U1	50	44,750	1100	200	12
	L2	60	43,400	950	815	100
	M1	60	43,700	1020	740	100
	M2	60	42,700	940	915	100
	R1	60	44,400	1033	425	42
	R2	70	43,750	990	707	100
	S1	70	44,300	1000	690	100
	S2	70	44,000	975	700	100
	T1	70	43,150	990	684	100
B873	L2	30	44,900	860	133	5
	V2	30	45,200	950	108	2
	W1	30	44,800	1160	117	3
	W2	30	45,900	1170	325	27
	L1	40	46,400	1025	650	99
	M1	40	45,200	990	83	5
	V1	40	45,450	1010	258	7
	M2	50	46,100	1077	642	100
	R1	50	45,350	1050	292	33
	J2	50	45,000	958	100	3
	R2	60	44,800	1020	650	100
	S1	60	45,550	1050	158	15
	J1	60	43,850	860	283	30
	S2	70	45,700	1050	534	80
	T1	70	45,550	1050	642	100
	T2	70	44,650	961	940	100
	U1	70	45,100	935	158	15
	U2	80	45,400	1000	200	20
	H1	80	44,050	842	234	15
	H2	80	44,050	935	707	100
	F1	90	44,300	990	725	100
	F2	90	44,350	940	808	100
	G1	90	43,750	891	775	100
	G2	90	43,750	935	725	100

TABLE A-17. NAVY TEAR-TEST DATA FOR TYPE VI STEELS CONTAINING VARIOUS AMOUNTS OF ALUMINUM

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A6648(a)	P1	90	38,100	824	92	12
	Q2	90	37,650	815	92	10
	T1	90	37,600	707	42	15
	T2	100	36,950	675	559	95
	U1	100	36,950	658	590	100
	U2	100	36,250	734	42	10
A8736	D2	70	35,650	715	42	1
	E1	70	36,350	775	50	2
	E2	70	36,850	824	92	3
	A1	80	33,650	684	609	70
	A2	80	34,600	707	83	10
	B2	80	34,650	790	250	15
	C1	80	35,000	757	67	3
	C2	90	35,150	757	50	5
	L1	90	36,750	961	75	10
	V1	90	36,600	1210	690	75
	L2	100	35,350	891	75	15
	V2	100	34,400	925	824	92
	W1	100	34,150	1033	975	100
	W2	100	35,600	1125	833	100
	M1	110	35,950	940	183	26
	T1	110	33,900	950	824	90
	T2	110	34,450	958	775	100
	V2	110	34,600	1020	925	100
	M2	120	34,750	915	684	100
	R1	120	33,750	940	866	100
	S1	120	34,700	1067	757	100
	S2	120	34,950	1060	775	100
A8737	B1	80	33,950	707	58	8
	B2	80	35,700	766	50	3
	C1	80	35,700	775	100	5
	K1	80	36,400	775	33	8
	J1	90	35,700	1060	609	98
	J2	90	35,150	910	42	11
	A1	90	31,950	633	658	85
	C2	90	35,950	808	83	8
	A2	100	32,150	541	242	25
	U1	100	34,350	885	842	97
	U2	100	35,150	1067	885	100
	K2	100	34,750	915	417	49
	V1	110	34,050	975	815	99
	V2	110	33,300	891	925	100
	L1	110	35,150	900	633	87
	L2	110	34,800	900	216	20
	M1	120	35,100	990	650	100
	M2	120	34,350	940	690	96
	R1	120	34,950	975	750	96
	R2	120	33,800	885	475	49
	S1	130	33,450	866	784	94
	S2	130	33,400	850	875	100
	T1	130	33,000	891	833	100
	T2	130	35,150	1150	715	95
A6707(a)	B1	70	36,000	850	83	10
	C1	70	37,750	940	308	25
	C2	70	37,050	961	275	25
	B2	80	37,500	1000	100	8
	P2	80	37,750	950	1350	100
	R2	80	35,850	885	700	100

TABLE A-17. (Continued)

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A6707[(a)]	S2	90	35,900	866	675	100
	U2	90	35,400	815	690	85
A9263	U1	60	37,500	915	83	4
	U2	60	36,750	940	25	3
	V1	60	37,100	891	417	43
	V2	60	36,500	885	75	5
	S2	70	36,200	860	525	67
	N2	70	35,600	815	50	8
	S1	70	37,000	990	92	10
	T1	70	35,800	842	92	8
	L1	80	36,050	860	600	93
	L2	80	36,100	885	625	100
	M1	80	36,300	866	175	15
	T2	80	36,100	940	100	10
	K1	90	36,500	910	766	92
	K2	90	36,600	915	1100	100
	M2	90	36,000	866	700	100
	M1	90	36,550	915	590	100
A9264	S1	70	36,800	900	75	6
	S2	70	36,800	860	92	5
	T1	70	36,650	940	58	8
	T2	70	37,300	940	75	15
	U1	80	36,650	958	725	100
	U2	80	37,350	1050	600	100
	L1	80	36,000	910	433	47
	Q1	80	36,650	900	100	10
	L2	90	35,150	815	725	100
	Q2	90	36,350	860	1125	100
	R1	90	36,850	975	658	98
	R2	90	36,600	891	625	100
A6708[(a)]	T1	50	36,600	790	83	5
	T2	50	37,600	950	92	7
	U1	50	39,000	940	193	5
	U2	50	38,900	900	75	3
	B1	60	37,650	866	100	7
	B2	60	40,100	1140	665	100
	C1	60	38,150	900	92	8
	C2	70	38,300	915	92	12
	V1	70	37,100	875	92	6
	V2	80	36,900	784	1160	100
A8142	T1	50	38,650	925	117	6
	K1	50	36,500	842	358	43
	K2	60	38,000	900	67	5
	P1	60	37,050	833	75	4
	T2	60	37,750	940	100	6
	P2	60	36,750	850	100	8
	J2	70	37,400	815	725	100
	L1	70	37,250	850	766	100
	L2	70	37,250	891	715	100
	M1	70	37,550	935	292	45
	J1	80	35,000	850	690	100
	M2	80	37,600	900	775	100
	N1	80	37,850	940	650	98
	N2	80	38,350	961	690	100
A8143	L2	70	36,750	757	58	3
	M1	70	36,950	734	417	5
	M2	70	36,600	725	75	3
	N1	70	36,300	784	75	4

TABLE A-17. (Continued)

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A8143	N2	80	36,200	766	283	30
	P1	80	36,650	734	83	15
	P2	80	38,000	891	142	15
	J2	80	35,800	815	92	10
	J1	90	37,700	842	690	100
	K1	90	37,250	860	516	73
	K2	90	38,200	800	658	86
	L1	90	37,250	824	508	100
A6709(a)	B1	20	39,850	950	108	3
	B2	30	39,150	925	83	2
	C1	30	39,500	940	75	3
	C2	30	38,800	900	100	4

(a) Test data for other specimens from this steel were reported in the Appendix of the Second Progress Report on "An Investigation of the Influence of Deoxidation and Chemical Composition on Notched-Bar Properties of Semikilled Steel", Ship Structure Report No. 53.

TABLE A-18. NAVY TEAR-TEST DATA FOR TYPE VII STEELS CONTAINING VARIOUS AMOUNTS OF ALUMINUM

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A7531[a]	S2	50	38,750	842	108	5
	B1	50	39,450	850	100	5
	B2	50	39,350	850	92	5
	C1	50	39,100	935	83	5
	N2	60	37,800	790	167	15
	P1	60	38,000	850	33	3
	S1	60	38,500	850	67	2
	C2	70	38,150	808	1140	100
	T1	70	37,750	790	690	96
	T2	70	38,150	815	67	5
	U1	70	37,900	815	108	5
A8136	M1	80	38,750	650	58	10
	R1	80	38,000	734	108	7
	R2	80	38,250	766	208	12
	S1	80	37,500	700	50	10
	M2	90	38,000	766	17	15
	S2	90	37,250	734	633	100
	Q1	90	37,350	734	67	15
	Q2	90	37,500	766	83	12
	N1	100	38,500	850	935	100
	N2	100	39,000	940	800	100
	P1	100	37,800	790	665	100
	P2	100	38,200	910	650	100
A7322	H1	40	39,050	984	100	5
	H2	50	38,850	915	150	10
	J1	60	38,550	875	108	5
	S1	60	39,600	891	58	8
	S2	60	38,200	815	58	3
	C2	70	41,100	1077	684	100
	J2	70	38,350	868	990	100
	K1	70	38,450	934	167	10
	K2	80	38,500	940	1010	100
	L1	80	37,300	833	659	100
	L2	80	38,500	910	709	100
	M1	80	38,050	833	75	10
	M2	90	37,700	833	641	85
	M1	90	38,200	860	691	100
	N1	90	37,500	809	250	12
	C2	90	38,400	950	707	100
	A1	100	37,850	868	709	100
	A2	100	38,350	915	725	100
	B1	100	38,050	875	675	100
	B2	100	39,700	950	875	100
A7661[a]	U1	50	39,150	940	83	4
	U2	50	38,700	915	83	5
	V1	50	38,750	950	83	5
	V2	50	38,200	958	58	4
	A1	60	37,900	866	67	5
	A2	60	37,550	750	67	15
	B1	60	37,800	866	642	97
	B2	70	38,200	885	734	100
	S1	70	38,500	866	675	100
	S2	80	37,800	866	1210	100
	T1	80	37,850	885	690	100
	T2	80	38,600	958	92	12
A8137	K2	50	39,350	915	50	11
	Q1	50	38,100	824	42	3
	Q2	50	39,000	885	58	3
	U1	50	38,600	850	75	7

TABLE A-18. (Continued)

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A8137	K1	60	39,450	850	665	100
	M1	60	39,400	900	600	98
	M2	60	39,450	1077	58	4
	U2	60	38,400	808	609	92
	N1	70	38,900	808	642	100
	N2	70	38,500	875	200	20
	V1	70	39,050	910	92	15
	V2	70	38,150	824	193	20
	L1	80	38,450	885	625	100
	L2	80	38,100	866	690	100
	P1	80	38,400	900	575	100
	P2	80	37,450	850	616	100
A7529(a)	V1	50	39,200	885	58	3
	V2	50	39,400	815	108	5
	W1	50	39,400	784	92	5
	W2	50	39,350	740	158	5
	Q2	60	37,450	734	133	10
	U1	60	39,250	808	142	10
	U2	60	39,100	784	559	86
	R1	70	37,450	766	665	100
	R2	70	37,400	715	584	93
	S1	70	38,300	808	83	7
	S2	80	37,350	725	584	100
	T1	80	37,450	707	833	100
	T2	80	36,950	675	734	100
A8745	A1	20	39,900	750	316	37
	J1	20	39,750	740	75	3
	H2	30	39,500	833	609	100
	J2	30	39,500	734	292	25
	A2	30	40,900	833	83	3
	T1	30	40,000	815	283	33
	H1	40	40,050	824	584	100
	S2	40	39,600	800	575	90
	N1	40	39,950	860	175	16
	T2	40	39,750	860	665	100
	N2	50	39,000	750	565	99
	P1	50	37,950	800	616	100
	P2	50	39,750	915	158	20
	Q1	50	38,650	815	550	100
	Q2	60	38,900	850	508	100
	R1	60	38,550	784	650	97
	R2	60	38,650	808	541	100
	S1	60	37,600	850	690	100

(a) Test data for other specimens from this steel were reported in the Appendix of the Second Progress Report on "An Investigation of the Influence of Deoxidation and Chemical Composition on Notched-Bar Properties of Semikilled Steel", Ship Structure Report No. 53.

TABLE A-19. NAVY TEAR-TEST DATA FOR TYPE VIII STEELS CONTAINING VARIOUS AMOUNTS OF ALUMINUM

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A8738	A1	60	39,400	815	100	5
	A2	60	39,900	885	108	5
	B1	60	39,300	833	167	13
	B2	60	39,800	875	142	6
	M2	70	34,450	650	675	100
	N1	70	36,200	850	684	100
	N2	70	34,200	707	757	100
	P1	70	35,850	790	675	100
A8350	E1	50	38,050	750	308	32
	E2	50	38,050	775	92	4
	A1	50	39,600	800	650	100
	K1	50	39,900	824	10	2
	A2	60	38,800	850	616	100
	B1	60	38,500	790	866	100
	B2	60	38,500	790	100	10
	K2	60	39,950	860	117	4
	L1	70	38,450	850	92	12
	M1	70	38,000	790	616	100
	C1	70	38,250	775	625	98
	C2	70	38,700	808	650	100
	D1	80	38,000	750	915	100
	D2	80	37,500	750	633	100
	M2	80	38,550	775	392	48
	N1	80	38,700	842	625	100
	L2	90	38,050	800	675	100
	N2	90	38,400	800	722	100
	P1	90	38,500	800	665	100
	P2	90	37,850	784	234	25
	Q1	100	37,750	766	609	100
	Q2	100	38,100	790	616	100
	U1	100	39,200	–	–	100
	U2	100	38,150	–	–	100
A8739	D1	30	39,300	891	133	3
	D2	30	39,450	915	83	3
	X1	30	39,900	940	83	7
	X2	30	40,500	915	142	10
	A2	40	39,650	950	175	10
	B1	40	39,400	900	559	90
	B2	40	38,950	866	117	7
	C2	40	38,250	790	67	3
	C1	50	38,650	833	142	7
	R1	50	38,350	842	100	7
	R2	50	38,350	850	75	5
	S1	50	38,050	800	475	85
	S2	60	36,950	766	466	66
	T1	60	38,400	860	616	100
	T2	60	37,600	808	990	100
	K1	60	38,600	850	108	3
	K2	70	37,750	833	609	100
	L1	70	37,550	808	600	97
	L2	70	37,950	784	616	94
	Q1	70	36,900	715	658	100
A8351	K2	10	40,350	790	83	12
	K1	20	41,300	866	616	100
	L1	20	39,700	–	–	2
	P2	20	39,650	784	58	3

TABLE A-19. (Continued)

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A8351	Q1	30	39,800	800	150	4
	Q2	30	39,500	740	75	3
	U1	30	39,700	800	292	30
	L2	30	40,700	833	100	2
	M1	40	38,500	700	58	2
	U2	40	39,500	885	158	8
	V1	40	39,250	824	242	27
	V2	40	39,250	842	75	4
	M2	50	39,550	757	650	100
	N1	50	40,000	784	450	100
	N2	50	35,750	815	550	70
	P1	50	39,500	757	625	100
A8740	A1	30	41,650	984	117	3
	A2	30	39,900	800	150	5
	T2	30	38,600	734	100	3
	R2	30	39,550	790	283	28
	S1	40	39,000	775	334	42
	S2	40	39,200	750	584	100
	T1	40	39,750	790	675	100
	L1	40	40,100	775	50	4
	K2	50	39,400	833	665	100
	Q1	50	38,200	784	417	100
	Q2	50	39,100	766	633	100
	R1	50	39,150	559	565	100

TABLE A-20. NAVY TEAR-TEST DATA FOR TYPE IX STEELS WITH VARIOUS ALUMINUM CONTENTS

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A6649(a)	V1	60	38,450	700	58	2
	W1	60	37,900	715	75	3
	V2	60	38,650	725	75	3
	E1	70	40,400	885	650	100
	E2	70	39,650	842	75	10
	M2	70	39,450	833	133	12
	N1	80	40,350	1025	642	100
	R2	80	39,750	950	675	98
A8145	V1	60	38,450	975	42	3
	V2	60	39,200	1077	92	4
	W1	60	38,750	1010	83	2
	W2	60	39,450	1090	108	5
	L2	70	39,600	1025	117	10
	Q2	70	37,750	910	142	6
	Q1	70	37,950	1000	725	100
	R1	70	38,250	984	42	3
	L1	80	38,050	915	760	98
	M1	80	38,550	950	784	99
	M2	80	38,750	1070	133	15
	R2	80	37,250	940	707	99
	N1	90	37,900	935	750	100
	N2	90	38,400	915	808	100
	P1	90	38,050	990	790	100
	P2	90	38,500	950	833	100
A7320	T2	40	40,500	1040	125	5
	D1	40	41,500	1080	108	5
	D2	40	40,150	984	108	5
	T1	40	40,000	1060	150	7
	C2	50	40,750	1000	642	94
	B1	50	41,400	1125	234	20
	B2	50	41,400	1140	915	100
	C1	50	41,450	1160	83	8
	J2	60	40,000	1050	208	10
	N2	60	40,550	1080	92	5
	P1	60	41,200	1190	108	5
	P2	60	39,850	1025	67	5
	J1	70	40,350	1090	850	100
	K1	70	39,350	1000	715	85
	K2	70	40,050	1082	125	7
	N1	70	39,600	1080	117	10
	L1	80	39,100	990	775	95
	L2	80	38,600	965	875	100
	M1	80	38,350	990	800	98
	M2	80	38,600	934	784	95
A7319	E1	50	41,650	1225	100	5
	E2	50	41,200	1258	125	5
	D1	50	40,600	1180	83	3
	D2	50	40,200	1040	133	3
	B1	60	41,900	1400	1320	100
	B2	60	40,450	1210	117	7
	C1	60	40,150	1080	92	5
	C2	60	40,450	1200	183	12
	L2	70	39,750	1067	475	45
	M1	70	39,650	1080	766	90
	M2	70	39,000	1010	125	12
	N1	70	39,000	1033	750	100
	J1	80	38,800	940	1010	100
	N2	80	38,800	1110	860	98
	P1	80	39,100	1050	766	98
	P2	80	39,400	1077	961	100

TABLE A-20. (Continued)

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A8146	V1	40	39,750	1000	50	2
	V2	40	37,850	940	175	7
	W1	40	39,950	1040	167	5
	W2	40	39,400	1025	83	2
	N2	50	40,000	1020	100	5
	P1	50	39,250	940	408	40
	P2	50	39,300	885	367	25
	Q1	50	38,700	875	757	88
	L2	60	39,400	984	408	45
	Q2	60	39,050	1000	83	5
	R1	60	39,100	940	808	100
	R2	60	37,600	891	167	12
	L1	70	39,250	975	715	95
	M1	70	39,650	950	707	87
	M2	70	40,150	990	715	98
	N1	70	39,750	975	500	75

(a) Test data for other specimens from this steel were reported in the Appendix of the Second Progress Report on "An Investigation of the Influence of Deoxidation and Chemical Composition on Notched-Bar Properties of Semikilled Steel", Ship Structure Report No. 53.

TABLE A-21. NAVY TEAR-TEST DATA FOR TYPE X STEELS CONTAINING VARIOUS AMOUNTS OF ALUMINUM

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A7660[(a)]	T1	50	40,700	975	92	4
	B1	50	39,900	984	92	5
	B2	50	40,100	958	58	3
	C1	50	40,600	984	100	5
	T2	60	39,850	961	75	3
	U1	60	40,000	940	700	100
	U2	60	40,450	1033	117	6
	V1	60	40,200	990	167	10
	V2	70	40,100	940	850	100
	W1	70	40,500	990	750	100
	W2	70	40,950	1060	757	100
A8144	P1	40	41,100	950	100	3
	N2	40	40,850	910	266	22
	P2	40	40,150	891	242	14
	Q1	40	40,450	875	75	3
	Q2	50	40,550	940	125	4
	R1	50	40,350	935	367	29
	R2	50	39,750	850	334	30
	L2	50	42,100	1025	117	5
	L1	60	40,000	1000	633	92
	M1	60	40,850	984	565	80
	M2	60	42,000	1040	740	100
	N1	60	41,050	1010	915	100
A7662[(a)]	V1	40	40,050	990	425	30
	U2	40	40,000	1010	100	5
	V1	40	40,150	958	300	12
	V2	40	40,350	1025	175	10
	Q2	50	40,000	990	150	4
	R1	50	40,100	940	684	97
	R2	50	40,300	990	740	94
	S1	50	39,150	900	75	2
	S2	60	39,300	885	690	100
	T1	60	39,800	935	158	12
	T2	60	39,750	975	766	100
A7530[(a)]	P2	30	41,700	940	83	4
	Q1	30	41,300	925	167	3
	Q2	30	41,700	935	167	5
	R1	30	41,600	875	117	3
	V1	40	41,450	984	75	2
	V2	40	40,300	885	83	2
	B1	40	40,950	935	108	3
	B2	40	40,700	940	125	3
A8141	K1	10	42,500	1060	316	24
	N1	10	41,150	975	358	32
	N2	10	41,300	950	183	10
	L2	10	41,350	1000	58	3
	J1	20	41,900	1067	609	76
	J2	20	41,650	950	935	100
	K2	20	41,500	990	633	80
	L1	20	41,500	990	860	100
A8746	J1	20	41,350	1280	67	5
	S1	20	39,400	1100	383	41
	R2	20	38,500	1000	100	8
	S2	20	39,450	1125	425	34
	J2	30	39,600	1100	-	100
	K1	30	38,750	1077	800	100
	K2	30	39,200	1110	609	70
	P2	30	39,550	1170	500	49
A8746	P1	40	38,600	1090	784	100
	Q1	40	39,000	1080	790	100
	Q2	40	38,300	1090	790	100
	R1	40	38,350	1120	625	100

(a) Test data for other specimens from this steel were reported in the Appendix of the Second Progress Report on "An Investigation of the Influence of Deoxidation and Chemical Composition on Notched-Bar Properties of Semikilled Steel", Ship Structure Report No. 53.

TABLE A-22. NAVY TEAR-TEST DATA FOR TYPE XI STEELS CONTAINING VARIOUS AMOUNTS OF ALUMINUM

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A8741	A2	40	41,650	975	150	8
	B1	40	41,400	961	367	32
	B2	40	40,500	984	125	7
	C1	40	41,000	940	75	3
	J2	50	40,550	875	133	11
	Q2	50	40,050	900	642	100
	R1	50	40,050	900	684	87
	R2	50	40,150	–	–	95
	J1	60	39,100	860	675	92
	P1	60	39,850	940	125	10
	S1	60	39,650	915	600	90
	S2	60	39,100	833	707	98
	K1	70	38,400	824	650	100
	K2	70	38,900	833	690	100
	P2	70	39,850	975	625	100
	Q1	70	39,100	891	690	100
A8352	D1	30	41,000	950	790	100
	D2	30	41,050	915	525	80
	E1	30	40,900	891	260	20
	E2	30	41,250	1025	133	7
	C1	40	40,300	958	707	100
	C2	40	40,400	958	58	2
	K1	40	41,500	940	342	45
	A1	40	40,550	891	633	90
	L1	50	41,150	900	216	20
	A2	50	39,400	784	984	100
	B1	50	39,750	842	75	10
	B2	50	40,700	910	633	100
	K2	60	41,050	935	466	65
	L2	60	40,800	940	500	70
	M2	60	39,850	940	42	22
	U1	60	40,400	875	75	5
	M1	70	39,450	850	707	100
	M1	70	39,600	875	242	22
	N2	70	40,100	850	784	100
	U2	70	41,150	935	658	92
	P1	80	40,050	866	590	83
	P2	80	40,400	915	690	100
	Q1	80	40,100	866	750	100
	Q2	80	39,750	875	684	100
A8742	L2	30	39,200	915	92	2
	Q1	30	38,300	866	266	26
	Q2	30	39,550	900	283	28
	R1	30	39,550	891	133	3
	R2	40	39,700	900	175	8
	S1	40	40,750	885	616	100
	S2	40	38,850	800	484	49
	J2	40	39,150	910	17	5
	J1	50	39,650	910	590	97
	K1	50	39,600	940	625	98
	K2	50	40,150	940	633	93
	L1	50	39,400	925	725	88
A8353	E1	10	42,200	990	292	27
	E2	10	41,500	875	616	74
	R2	10	40,600	885	559	85
	S1	10	41,650	866	108	2
	S2	20	41,450	900	167	5
	T1	20	42,000	940	108	4
	T2	20	40,550	842	234	9
	P2	20	41,600	961	125	8

TABLE A-22. (Continued)

Heat	Specimen	Testing Temperature, F	Maximum Load, pounds	Energy to Start Fracture, ft-lb	Energy to Propagate Fracture, ft-lb	% Shear in Fracture
A8353	P1	30	41,350	850	757	100
	Q1	30	41,750	990	658	95
	Q2	30	40,650	850	725	100
	R1	30	41,200	885	757	100
	K2	40	41,800	915	784	100
	K1	50	41,500	866	784	100
A8743	J1	20	42,400	875	484	49
	J2	30	42,150	975	784	100
	K1	30	41,850	975	100	5
	K2	40	41,350	1025	642	100
	L1	40	41,400	950	684	100
	L2	40	40,600	935	417	48
	Q1	50	45,650	885	442	49
	Q2	60	40,450	900	358	46
	S1	70	40,450	885	175	32
	B1	70	39,500	833	117	20
	B2	70	39,900	875	158	20
	C1	70	39,700	850	200	23
	R1	80	39,500	800	675	97
	R2	80	40,050	833	392	36
	C2	80	38,500	757	700	96
	S2	80	38,450	784	325	30
	D1	90	38,700	833	584	96
	D2	90	39,000	824	642	95
	T1	90	39,750	940	590	95
	T2	90	39,700	833	600	97

TABLE A-23. KEYHOLE CHARPY IMPACT-TEST DATA FOR TYPE I STEELS WITH VARIOUS SILICON CONTENTS

Heat	Testing Temperature, F	Charpy Impact Strength, ft-lb			
		1st Test	2nd Test	3rd Test	4th Test
A6657[(a)]	-30	4	19	21	18
	-10	26	23	26	25
A8728	80	31	30	–	–
	0	24	20	23	21
	-10	17	22	20	20
	-20	18	21	21	19
	-30	17	17	15	17
	-40	15	16	4	17
	-50	4	6	3	10
	-60	3	5	3	2
A8922	80	32	28	–	–
	0	22	23	22	22
	-10	23	19	21	19
	-20	17	19	21	8
	-30	17	17	11	18
	-40	16	19	7	4
	-50	7	3	12	5
	-60	6	6	5	3
	-70	3	2	–	–
A8747	80	29	32	–	–
	10	24	–	–	–
	0	23	21	20	24
	-10	22	22	22	20
	-20	19	18	16	22
	-30	19	6	19	18
	-40	8	16	16	18
	-50	3	6	9	11
	-60	6	4	4	6
	-70	4	4	–	–
B865	80	30	30	–	–
	20	26	23	–	–
	0	18	22	23	23
	-10	21	22	19	5
	-20	19	4	19	4
	-30	5	16	4	4
	-40	17	4	4	3
	-50	16	3	3	3
A6696[(a)]	-50	17	8	18	–
	-60	20	8	5	–
A8729	80	26	25	–	–
	30	20	23	20	21
	20	19	21	22	20
	10	18	20	20	19
	0	19	20	19	20
	-10	17	19	19	19
	-20	20	18	–	–
	-40	18	6	20	18
	-50	12	–	–	–
	-60	4	10	9	3
B866	80	31	28	–	–
	20	24	25	–	–
	0	23	23	–	–
	-10	21	22	20	23
	-20	21	20	20	18
	-30	4	20	18	16
	-40	4	6	3	19
	-50	3	14	–	–
A8923	80	29	27	–	–
	0	22	22	20	21
	-10	21	20	22	20
	-20	20	20	18	19
	-30	20	20	22	20
	-40	9	20	18	19
	-50	20	18	7	17
	-60	16	6	14	15
	-70	5	10	7	6
	-80	4	–	–	–
B867	80	31	31	–	–
	-30	21	21	20	19
	-40	18	18	19	19
	-50	18	3	12	10
	-60	17	18	11	18
	-70	10	9	14	2
	-80	5	10	–	–

(a) Test data for other specimens from this steel were reported in the Appendix of the First Progress Report on "An Investigation of the Influence of Deoxidation and Chemical Composition on Notched-Bar Properties of Semikilled Steel", Ship Structure Report No. 49.

TABLE A-24. KEYHOLE CHARPY IMPACT-TEST DATA FOR TYPE II STEELS WITH VARIOUS SILICON CONTENTS

Heat	Testing Temperature, F	Charpy Impact Strength, ft-lb			
		1st Test	2nd Test	3rd Test	4th Test
A8151	80	33	33	–	–
	0	26	25	20	26
	–10	22	24	24	23
	–20	22	24	22	23
	–30	4	12	21	14
	–40	3	8	9	7
	–50	13	3	–	–
A9265	0	25	22	22	22
	–10	21	5	19	24
	–20	4	5	5	23
	–30	20	4	4	3
	–40	3	5	4	3
	–50	3	3	3	3
A8375	80	33	38	–	–
	0	25	24	25	28
	–10	24	23	23	27
	–20	22	17	17	20
	–30	24	17	22	19
	–40	5	4	3	3
A9266	0	23	26	24	16
	–10	24	25	24	20
	–20	21	26	6	5
	–30	5	22	22	20
	–40	4	5	4	22
	–50	3	3	4	10
A8376	80	38	34	–	–
	0	25	24	23	22
	–10	27	25	24	23
	–20	17	6	15	21
	–30	8	23	4	20
	–40	4	4	–	–
A9275	80	32	32	–	–
	0	23	22	–	–
	–20	21	20	22	23
	–30	5	22	18	22
	–40	16	18	9	19
	–50	3	19	11	18
	–60	3	4	3	3

TABLE A-25. KEYHOLE CHARPY IMPACT-TEST DATA FOR TYPE III STEELS WITH VARIOUS SILICON CONTENTS

Heat	Testing Temperature, F	Charpy Impact Strength, ft-lb			
		1st Test	2nd Test	3rd Test	4th Test
A8378	80	36	42	–	–
	0	28	32	30	30
	–10	25	24	26	24
	–20	26	26	30	26
	–30	4	23	21	28
	–40	4	24	25	4
	–50	25	26	5	26
	–60	3	3	23	–
A6695(a)	–60	7	25	25	24
	–70	25	9	2	14
	–90	17	2	–	–
A9262	0	27	29	–	–
	–40	27	27	16	28
	–50	4	23	14	4
	–60	19	3	4	3
	–70	8	3	16	23
	–80	2	3	2	2
	–90	2	2	–	–
A6697(a)	–50	6	8	25	–
	–60	24	7	27	–
B868	80	37	38	–	–
	20	29	26	–	–
	0	18	23	24	23
	–10	25	18	22	7
	–20	9	21	19	8
	–30	4	17	8	6
	–40	4	3	3	5
A8730	80	37	34	–	–
	10	26	30	29	31
	0	26	29	28	15
	–10	25	25	6	24
	–20	4	19	20	24
	–30	4	11	4	12
	–40	4	17	21	20
	–50	10	5	4	3
B869	80	40	36	–	–
	20	24	23	–	–
	10	17	21	27	22
	0	11	21	21	18
	–10	13	16	18	25
	–20	4	10	10	5
	–30	5	4	–	–
	–40	4	8	–	–
B870	80	33	33	–	–
	20	28	28	–	–
	0	23	24	22	22
	–10	21	14	23	14
	–20	24	12	6	6
	–30	5	14	19	24
	–40	4	3	6	5

(a) Test data for other specimens from this steel were reported in the Appendix of the First Progress Report on "An Investigation of the Influence of Deoxidation and Chemical Composition on Notched-Bar Properties of Semikilled Steel", Ship Structure Report No. 49.

TABLE A-26. KEYHOLE CHARPY IMPACT-TEST DATA FOR TYPE IV STEELS WITH VARIOUS SILICON CONTENTS

Heat	Testing Temperature, F	Charpy Impact Strength, ft-lb			
		1st Test	2nd Test	3rd Test	4th Test
A9271	10	42	42	-	-
	0	31	24	-	-
	-10	30	30	27	30
	-20	27	8	24	29
	-30	24	26	25	5
	-40	26	4	4	22
	-50	3	3	3	4
A9272	0	30	29	-	-
	-20	27	28	26	26
	-30	26	29	17	25
	-40	23	4	4	4
	-50	24	3	17	20
	-60	3	19	24	3
	-70	2	3	-	-
A9273	80	39	42	-	-
	0	25	31	-	-
	-20	31	23	28	18
	-30	24	5	25	20
	-40	4	24	21	4
	-50	5	3	4	24
	-60	8	6	3	5
A9274	0	29	26	-	-
	-20	28	26	30	30
	-30	28	20	29	5
	-40	26	3	24	26
	-50	5	23	13	6
	-60	29	3	17	17
	-70	3	3	-	-

TABLE A-27. KEYHOLE CHARPY IMPACT-TEST DATA FOR TYPE V STEELS WITH VARIOUS SILICON CONTENTS

Heat	Testing Temperature, F	Charpy Impact Strength, ft-lb 1st Test	2nd Test	3rd Test	4th Test
A8904	20	33	31	–	–
	0	26	29	–	–
	–10	24	22	24	5
	–20	14	18	16	25
	–30	5	19	17	5
	–40	14	22	6	12
	–50	3	3	3	3
A8905	80	37	36	–	–
	0	30	28	[illegible]	–
	–30	26	25	28	25
	–40	24	28	25	23
	–50	23	22	5	16
	–60	3	3	17	3
	–70	4	3	3	2
A8906	80	37	46	–	–
	0	31	33	–	–
	–30	23	25	27	25
	–40	14	23	24	22
	–50	8	23	7	19
	–60	8	20	13	3
	–70	3	6	14	11
A8907	80	38	43	–	–
	0	30	30	–	–
	–30	25	25	25	26
	–40	24	19	26	23
	–50	23	13	23	22
	–60	6	15	21	8
	–70	19	22	21	20
A8908	80	42	41	–	–
	0	28	28	–	–
	–40	22	25	–	–
	–50	25	24	13	21
	–60	20	21	21	21
	–70	5	18	19	21
	–80	17	3	2	3
	–90	4	7	8	–
A8909	80	38	41	–	–
	0	27	29	–	–
	–40	25	25	–	–
	–60	23	22	22	23
	–70	21	19	13	15
	–80	20	18	13	8
	–90	2	20	13	15
	–100	3	5	–	–
B871	80	40	43	–	–
	–40	23	25	27	25
	–70	24	23	22	23
	–80	21	19	20	22
	–90	5	3	16	9
	–100	3	15	5	5
	–110	8	4	5	9
	–120	2	2	–	–
B872	80	41	42	–	–
	–40	24	26	24	27
	–60	24	22	–	–
	–70	3	24	23	18
	–80	22	21	22	–
	–90	13	10	19	22
	–100	17	4	6	15
	–110	8	11	4	6
	–120	7	3	–	–
B873	80	38	42	–	–
	–40	26	19	26	24
	–60	22	24	–	–
	–70	21	6	20	–
	–80	19	7	21	21
	–90	18	8	6	8
	–100	5	12	22	8
	–110	8	8	19	5
	–120	14	2	–	–

TABLE A-28. KEYHOLE CHARPY IMPACT-TEST DATA FOR TYPE VI STEELS WITH VARIOUS ALUMINUM CONTENTS

Heat	Testing Temperature, F	Charpy Impact Strength, ft-lb			
		1st Test	2nd Test	3rd Test	4th Test
A8736	80	35	35	–	–
	40	30	28	–	–
	30	8	28	18	27
	20	23	31	19	29
	10	5	29	5	16
	0	5	23	5	5
	–10	4	6	4	7
A8737	80	32	32	–	–
	30	28	34	31	26
	20	13	23	23	27
	10	18	13	15	8
	0	15	12	4	9
	–10	4	9	16	5
	–40	3	3	–	–
A9263	80	35	33	–	–
	20	26	24	–	–
	10	25	23	6	24
	0	22	23	18	16
	–10	10	16	19	15
	–20	11	20	8	4
	–30	3	4	3	4
A9264	80	35	37	–	–
	20	25	26	–	–
	10	23	26	24	24
	0	22	22	20	21
	–10	7	7	12	9
	–20	4	4	7	9
	–30	6	5	3	10
A8142	80	38	35	–	–
	10	29	28	–	–
	0	23	24	24	25
	–10	4	6	5	20
	–20	6	21	16	21
	–30	16	4	17	5
	–40	3	7	4	4
A8143	80	31	30	–	–
	30	23	23	23	26
	20	23	19	22	17
	10	10	18	12	21
	0	21	7	10	11
	–10	7	8	6	11
	–20	8	19	–	–

TABLE A-29. KEYHOLE CHARPY IMPACT-TEST DATA FOR TYPE VII STEELS WITH VARIOUS ALUMINUM CONTENTS

Heat	Testing Temperature, F	Charpy Impact Strength, ft-lb			
		1st Test	2nd Test	3rd Test	4th Test
A8136	80	29	30	28	30
	40	26	27	–	–
	20	24	20	19	23
	10	21	22	22	21
	0	19	5	18	13
A7322	80	33	38	–	–
	10	28	28	27	27
	0	21	23	25	14
	–10	22	14	25	6
	–20	23	18	23	19
	–30	13	6	9	5
A8137	80	34	33	–	–
	20	28	26	–	–
	10	23	22	23	24
	0	23	18	13	5
	–10	20	15	20	21
	–20	19	5	12	8
	–30	3	6	4	5
A8745	80	33	35	–	–
	0	26	26	–	–
	–20	24	24	24	20
	–30	22	22	8	22
	–40	4	6	11	19
	–50	5	13	6	10
	–60	7	14	7	7

TABLE A-30. KEYHOLE CHARPY IMPACT-TEST DATA FOR TYPE VIII STEELS WITH VARIOUS ALUMINUM CONTENTS

Heat	Testing Temperature, F	Charpy Impact Strength, ft-lb			
		1st Test	2nd Test	3rd Test	4th Test
A8738	80	33	31	–	–
	10	26	24	–	–
	0	26	24	25	19
	–10	21	22	20	19
	–20	18	7	7	20
	–30	5	12	15	7
	–40	8	6	9	7
A8350	80	35	34	–	–
	0	24	23	25	23
	–10	25	21	25	23
	–20	19	18	19	20
	–30	20	18	18	21
	–40	8	16	9	14
	–50	7	–	–	–
A8739	80	33	33	–	–
	0	26	23	27	24
	–10	21	18	20	22
	–20	22	21	21	6
	–30	7	11	19	20
	–40	4	14	5	8
	–50	3	4	–	–
A8351	80	32	34	–	–
	40	30	30	31	–
	0	24	24	–	–
	–20	25	24	23	22
	–30	21	22	3	12
	–40	20	15	21	13
	–50	20	6	11	21
	–60	11	3	3	2
A8740	80	36	34	–	–
	0	28	24	–	–
	–20	23	23	23	23
	–30	21	22	20	22
	–40	10	21	19	20
	–50	15	17	14	18
	–60	3	7	20	12

TABLE A-31. KEYHOLE CHARPY IMPACT-TEST DATA FOR TYPE IX STEELS WITH VARIOUS ALUMINUM CONTENTS

Heat	Testing Temperature, F	Charpy Impact Strength, ft-lb			
		1st Test	2nd Test	3rd Test	4th Test
A8145	80	38	40	–	–
	10	32	29	31	21
	0	24	20	29	28
	–10	22	24	19	6
	–20	8	7	6	9
	–30	23	4	4	10
	–40	3	5	–	–
A7320	80	40	43	–	–
	0	32	24	–	–
	–10	33	8	–	–
	–20	7	27	31	25
	–30	6	24	11	26
	–40	28	20	7	4
	–50	10	22	3	3
	–60	3	3	–	–
A7319	80	42	41	–	–
	10	37	36	–	–
	0	14	35	34	36
	–	34	32	–	–
	–10	32	8	35	31
	–20	31	6	–	–
	–40	6	25	21	6
	–50	3	3	8	–
A8146	80	46	45	–	–
	0	32	30	–	–
	–20	27	–	–	–
	–30	27	27	24	12
	–40	12	28	20	24
	–50	4	6	4	5
	–60	8	5	6	5
	–80	2	3	–	–

TABLE A-32. KEYHOLE CHARPY IMPACT-TEST DATA FOR TYPE X STEELS WITH VARIOUS ALUMINUM CONTENTS

Heat	Testing Temperature, F	Charpy Impact Strength, ft-lb			
		1st Test	2nd Test	3rd Test	4th Test
A8144	80	39	38	–	–
	0	31	27	–	–
	–10	27	29	28	28
	–20	25	26	29	11
	–30	18	7	16	22
	–40	5	4	9	19
	–50	3	7	–	–
	–80	3	4	–	–
A8141	80	39	41	–	–
	0	29	32	–	–
	–40	25	26	24	20
	–50	24	22	5	25
	–60	20	9	23	13
	–70	3	23	4	3
	–80	3	3	9	–
A8746	80	43	46	–	–
	0	39	35	–	–
	–40	30	26	30	31
	–50	25	28	28	7
	–60	7	7	26	24
	–70	19	24	12	20
	–80	8	3	3	3

TABLE A-33. KEYHOLE CHARPY IMPACT-TEST DATA FOR TYPE XI STEELS WITH VARIOUS ALUMINUM CONTENTS

Heat	Testing Temperature, F	Charpy Impact Strength, ft-lb			
		1st Test	2nd Test	3rd Test	4th Test
A8741	80	39	41	–	–
	0	29	30	–	–
	–20	22	27	25	27
	–30	25	20	26	25
	–40	9	24	22	10
	–50	19	5	4	5
	–60	7	4	6	5
A8352	80	37	35	–	–
	0	28	27	–	–
	–20	27	23	21	25
	–30	24	25	5	21
	–40	4	4	24	5
	–50	3	21	16	20
	–60	23	10	11	13
A8742	80	38	35	–	–
	0	28	27	–	–
	–40	24	24	–	–
	–50	21	22	–	–
	–60	22	20	20	21
	–70	11	3	3	4
	–80	5	5	7	17
	–90	3	2	13	3
A8353	80	37	41	–	–
	0	31	31	–	–
	–40	23	26	–	–
	–60	21	24	25	24
	–70	19	5	21	14
	–80	21	19	11	11
	–90	12	2	8	3
A8743	80	35	37	–	–
	0	26	28	–	–
	–20	28	27	28	28
	–30	26	27	26	23
	–40	25	7	22	26
	–	25	2	–	–
	–50	24	24	24	23
	–60	22	14	4	15
	–70	3	20	4	20
	–80	3	3	5	–