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ASSESSMENT OF PROPERTIES OF ALGOMA PLATE SAMPLES

by

R. F. KNIGHT

PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

Chemical analyses of the three plates confirmed the analyses supplied by Algoma Steel Corporation Limited. Tensile testing confirmed that the desired 90,000 psi yield strength was not obtained. The optimum tensile properties for this material were apparently achieved at the 1 in. thickness. Microscopical examination revealed the presence of some free ferrite. This phase decreased in quantity, and some grain refinement was apparent, as the plate thickness decreased. This material exhibited an extremely abrupt transition from ductile to brittle failure in impact testing in the range -20°F to -40°F.

* Scientific Officer, Ferrous Metals Section, Physical Metallurgy Division, Mines Branch, Department of Mines and Technical Surveys, Ottawa, Canada.

INTRODUCTION

In an attempt to make available, from Canadian sources, a steel to be used as a substitute for USS-T-1 and HY-80 steels, Algoma Steel Corporation Limited, Sault Ste. Marie, Ontario, has initiated production of a normalized and tempered lower bainitic steel, "Algoma 90Y".

The results on a number of experimental heats were in general accord with those of Irvine and Pickering[1]. With carbon contents ranging from 0.04% to 0.08% and with manganese at the 0.5% level, at least 3.5% chromium, and probably 4.5% at the lowest carbon contents, was required to lower the transformation temperature sufficiently so that yield strengths of 90,000 psi could be retained after tempering at 1100°F.

The initial production run of this material was reported to be at the 4.3% chromium level. Initial indications were that the yield strength was lower than the desired 90,000 psi. It should be pointed out that in subsequent production the manganese content is being raised to 1.25%, the chromium content dropped to 3.5%, and 0.04% to 0.07% vanadium is being added to provide increased resistance to tempering.

Three plates of the initial production run, of 1/2 in., 1 in., and 1-1/2 in. thicknesses, were supplied to the Mines Branch for an investigation of the mechanical properties and welding characteristics. This report is concerned with the mechanical properties, composition and microstructure.

REPORTED HEAT TREATMENT AND PROPERTIES

Algoma reported that all three plates had been normalized from 1650°F and tempered at 1175°F. Their tensile test results for this material were as follows: ultimate tensile strength - 90,000 psi; yield strength (0.2% offset proof stress) - 75,000 psi; per cent elongation in 2 in. - 23%.

CHEMICAL COMPOSITION

Drillings were obtained from the three plates for chemical analysis, and samples were obtained for quantitative spectrographic analyses. The composition reported by Algoma, and the results of Mines Branch analyses are shown in Table 1.

TABLE 1

Chemical Composition of Plate Samples

Sample	Percentage of Element											
	C	Mn	Si	S	P	Ni	Cr	Mo	N	Al	B*	Cu*
Algoma report	0.06	0.49	0.26	0.022	0.019	0.02	4.29	0.27	-	-	0.005	-
1/2 in. plate	0.07	0.56	0.24	0.024	0.026	0.02	4.35	0.33	0.007	0.09	0.010	0.02
1 in. plate	0.07	0.55	0.23	0.023	0.023	0.02	4.35	0.33	0.006	0.10	0.011	0.03
1-1/2 in. plate	0.07	0.55	0.23	0.022	0.024	0.02	4.33	0.33	0.006	0.09	0.010	0.03

* - Quantitative spectrographic determination.

TENSILE PROPERTIES

Two transverse and two longitudinal tensile specimens were machined from each of the three plate samples. Standard 1/2 in. diameter tensile specimens were used for the 1-1/2 in. and 1 in. plates, and 5/16 in. diameter specimens for the 1/2 in. plate.

The individual test results are reported in Table 2, and Figure 1 shows the change in the average tensile properties with section size.

TABLE 2

Tensile Test Results

Plate Size, in.	Direction	Specimen	UTS kpsi	YS (0.2% offset) kpsi	% El in 2 in.	% RA
1/2	Trans.	1	95.0	81.2	14.0	53.2
		2	96.4	80.6	14.0	53.6
	Long.	1	93.6	78.4	17.0	75.1
		2	94.6	83.2	17.5	74.0
1	Trans.	1	94.0	82.2	19.5	58.2
		2	94.8	81.2	19.5	56.1
	Long.	1	95.0	83.0	23.5	74.0
		2	94.6	82.8	23.0	73.6
1-1/2	Trans.	1	90.9	77.4	20.5	60.0
		2	90.8	76.8	20.5	61.4
	Long.	1	89.3	74.6	24.0	76.0
		2	90.0	75.4	24.5	75.1

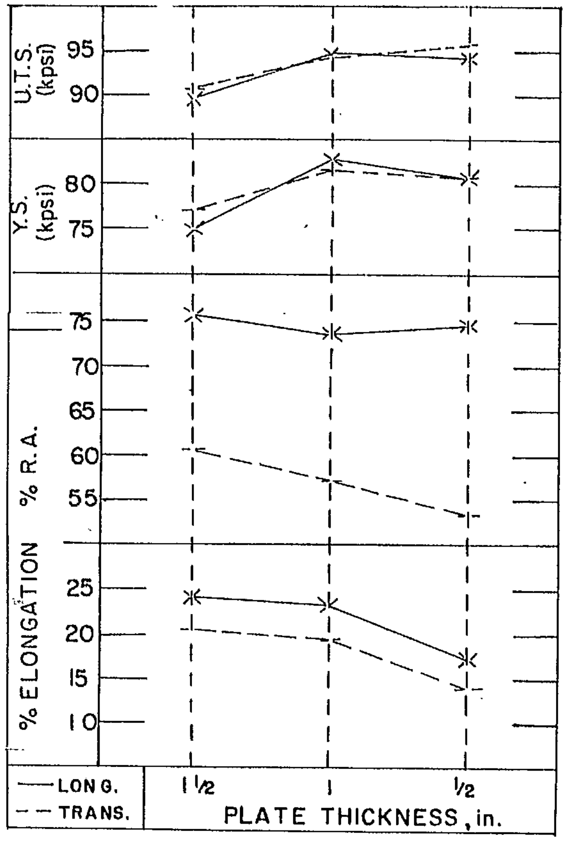


Figure 1. Change in Average Tensile Properties with Section Size.

IMPACT PROPERTIES

Longitudinal Charpy-V notch impact specimens were machined from each of the plates (with the notch oriented perpendicular to the plate surface). These were tested at various temperatures and the individual values are reported in Table 3, and a plot of the variation of average impact energy absorbed versus testing temperature is shown in Figure 2. A photograph of selected fractured bars is shown in Figure 3 to illustrate the change in fracture appearance with testing temperature.

In the case of the 1-1/2 in. thick plate, one set of Charpy bars was inadvertently obtained in the transverse direction with the notch cut parallel to the plate surface. For purpose of record the values obtained for these bars are also shown.

TABLE 3

Impact Test Results

Testing Temperature °F	Charpy V-notch Impact Energy Absorbed, ft-lb			
	1/2 in. plate	1 in. plate	1-1/2 in. plate	
	longitudinal	longitudinal	longitudinal	transverse
-80	8, 12	6, 6	6, 4	10, 11
-60	6, 18	10, 16	10, 10	-
-40	16, 34, 16, 36	12, 21, 18, 14	-	20, 13, 17, 12
-30	70, 16, 10, 136, 144	60	39, 68, 17	-
-20	9, 60, 108, 128	36, 14, 34, 30	39, 56, 10	18, 17, 14, 14
- 5	-	156, 160	124, 80, 55	-
10	240*	166, 178	108, 117	19, 22, 16, 22
40	-	148, 182	134, 132	38, 20
60	-	-	-	32, 28, 28
75	212, 212, 242*	174, 195, 166	134, 156, 138	30, 44, 42, 36, 32

* - incomplete fracture.

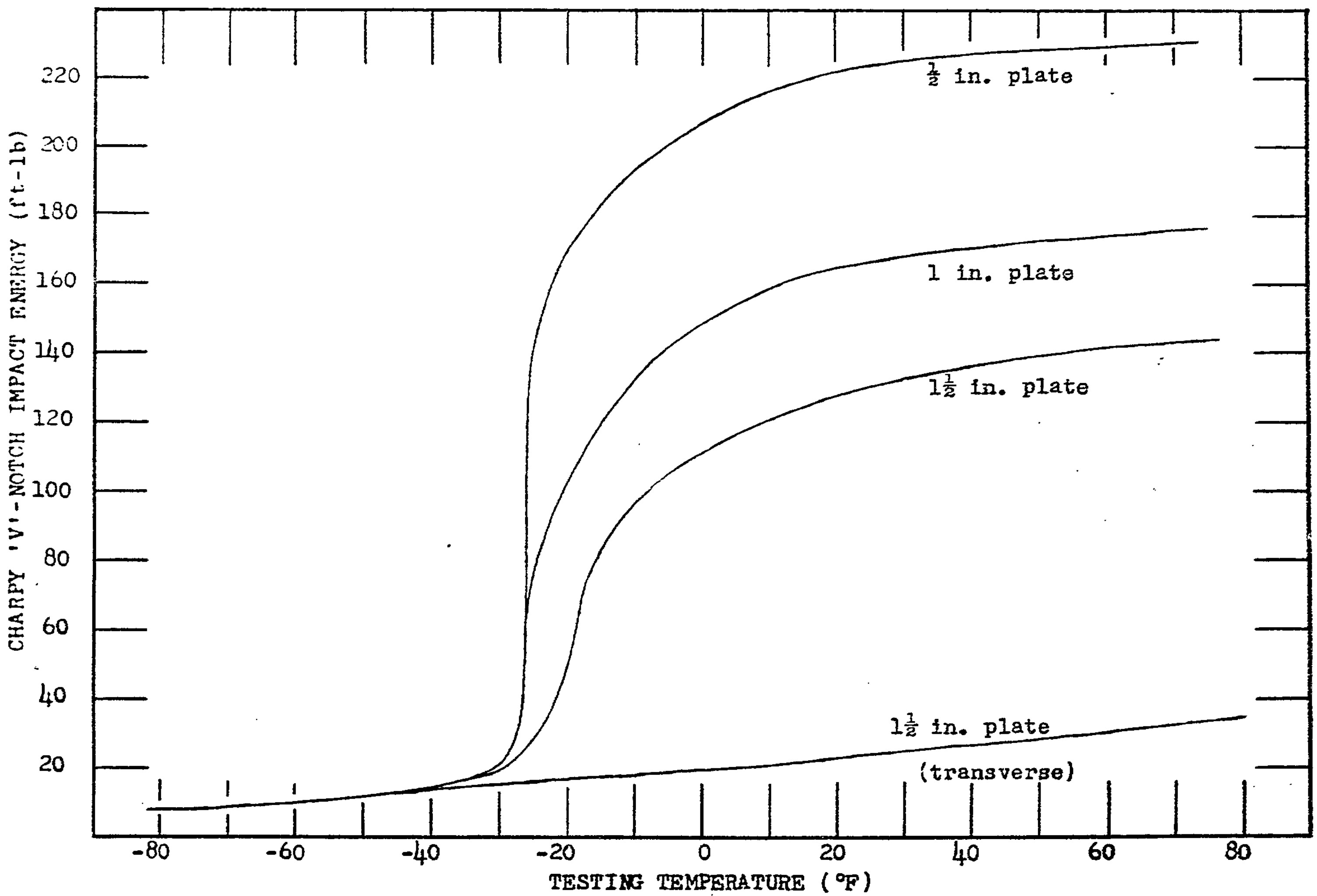


Figure 2. Impact Curves for Algoma Plate Samples. Average properties only are shown; individual points have been eliminated for the sake of clarity.

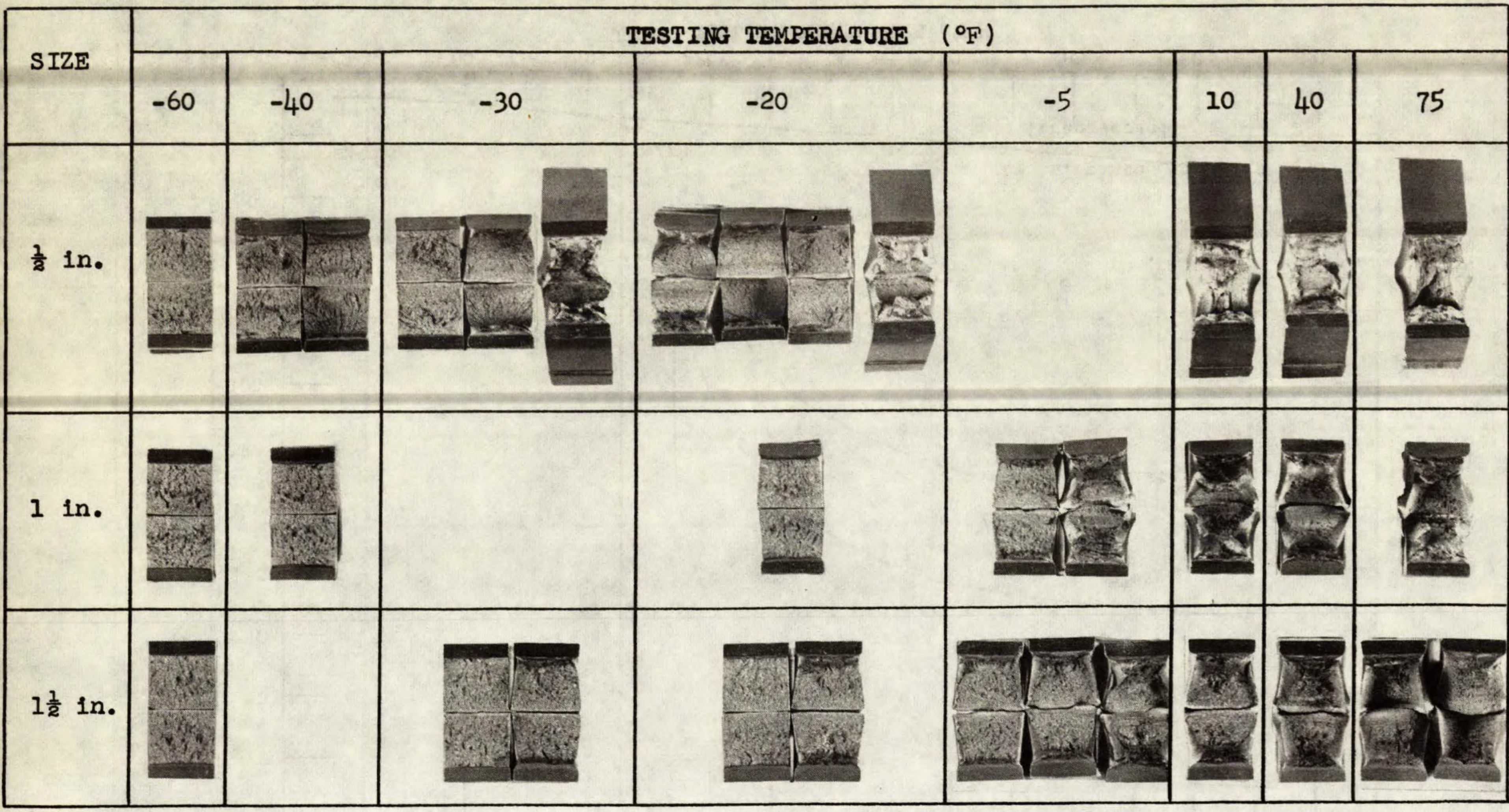


Figure 3 . Change in fracture appearance with testing temperature.

There was considerable scatter of impact results, particularly in the transition range. However, from the curves showing average properties two estimates of transition temperature were made. The temperature corresponding to the average of the maximum and minimum impact strengths (T.T.1) and the temperature corresponding to the upper inflection point of the impact energy curve (T.T.2) are shown in Table 4. The range of experimental variation shown in the table is a measure of the width of the experimental scatter band.

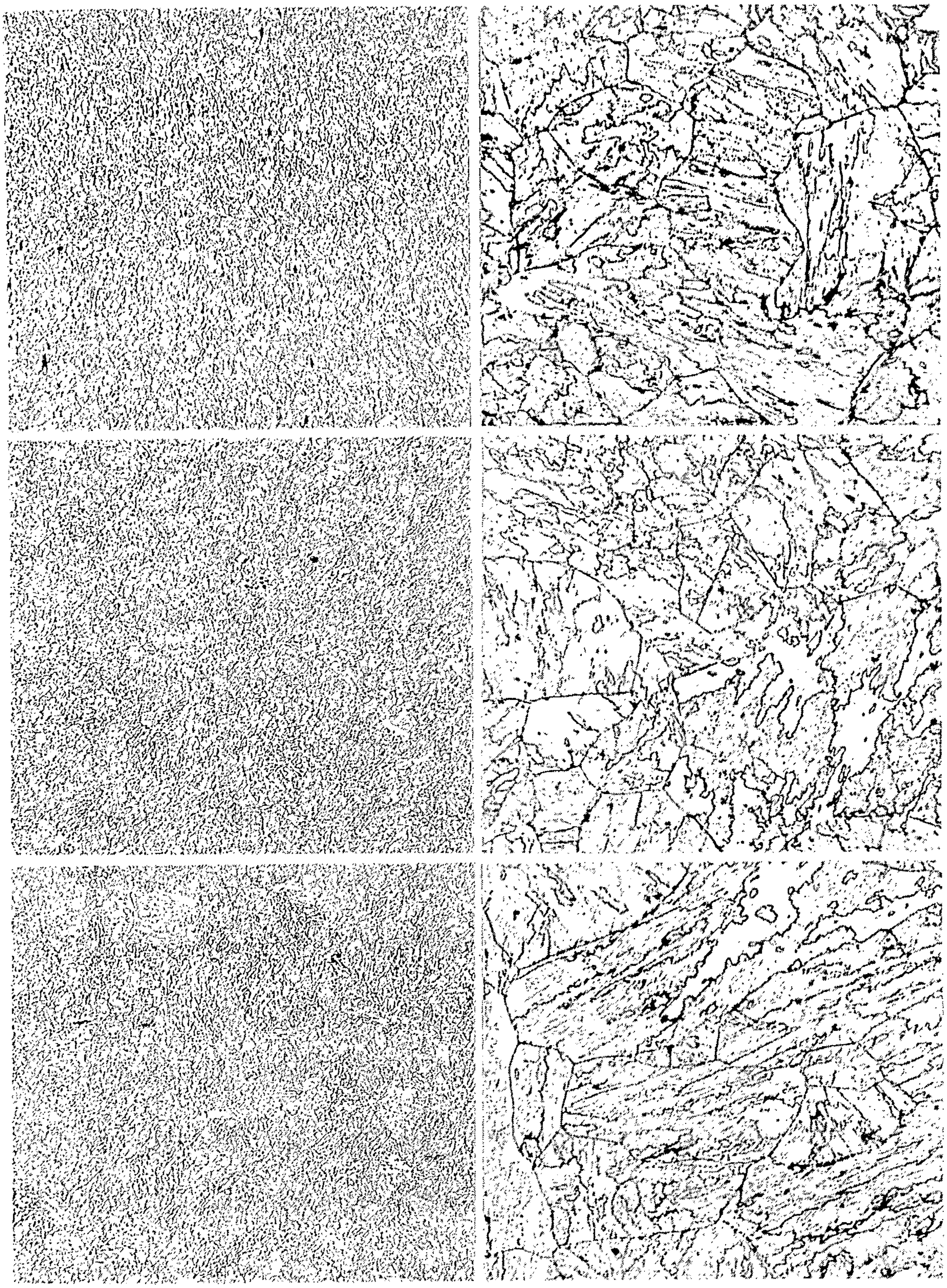
TABLE 4

Impact Transition Temperature of Algoma Plate

	T.T. 1			T.T. 2		
Plate Size, in.	Energy Level, ft-lb	Trans. Temp. °F	Experi. Varia. F°	Energy Level, ft-lb	Trans. Temp. °F	Experimental Variation F°
1/2	117	-26	± 6	84	-26	± 6
1	93	-22	± 10	50	-26	± 10
1-1/2	77	-16	± 14	50	-20	± 14

MICROSCOPICAL EXAMINATION

The microstructures of the three Algoma plates are shown in Figure 4. A slight grain refinement, and a decrease in the quantity of free ferrite, is apparent as the plate thickness decreases.



1/2 in. plate

1 in. plate

1-1/2 in. plate

X 100   X 1000

Figure 4. Microstructures of Algoma Steel Plates. (All etched in 2% nital).

DISCUSSION

The chemical composition reported by Algoma checked closely with the Mines Branch analyses of all three plates. The molybdenum content used by Algoma is significantly lower than that of Irvine and Pickering. It is possible that the proposed increase in the manganese content may result in a mixed martensite - lower bainite structure, particularly at this lower molybdenum content. The proposed level of vanadium is significantly lower than the 0.2% level recommended by Irvine and Pickering for increasing the resistance to tempering.

The tensile test results reported by Algoma corresponded to the Mines Branch results for longitudinal specimens from the 1-1/2 in. thick plate. Other samples showed higher strengths, but in no case did the yield strength reach the desired 90,000 psi level.

It is apparent that the optimum tensile properties for this steel occur at the 1 in. thickness, where the yield strength is at a maximum. As the thickness decreases the rate of loss of ductility apparently increases.

This steel has an extremely sharp transition from ductile to brittle fracture, and extreme variability in impact test results in the testing temperature range from -20 °F to -40 °F, making it undesirable for applications where winter exposures are required.

The slight reduction of grain size and the reduced quantity of free ferrite as the plate thickness decreases, are probably partially responsible for the higher room temperature impact properties of the thinner plates.

CONCLUSIONS

The results confirm that the desired level of yield strength was not obtained in this material. Abrupt transitions from ductile to brittle fracture, unless they occur at extremely low temperatures, are obviously undesirable. The extremely abrupt transition of this material in the range -20 °F to -40 °F would make it unsatisfactory for applications where shock loading and low temperature may be factors.

REFERENCE

1. K. J. Irvine and F. B. Pickering - "The Impact Properties of Low Carbon Bainitic Steels" - JISI 201, 518-531 (June 1963).

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