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EXAMINATION OF PORTIONS OF THREE STEEL PLATES FROM THE M. S. "EAGLESCLIFFE HALL"

by

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PHYSICAL METALLURGY DIVISION

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SUMMARY OF RESULTS

The chemical analyses and microstructures were normal for as-rolled semi-killed mild structural steel. The mechanical properties were in line with the chemistry and microstructure, the tensile properties averaging 35,700 psi yield and 61,500 psi ultimate strength, with 38.7% elongation and 60.9% reduction of area. The Charpy V-notch transition temperatures were -10°F for the strake below the sheer strake, 7°F for the sheer strake, and 19°F for the deck stringer plate.

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(5 tables, 6 illus.)

INTRODUCTION

On January 2, 1958, Mr. Alan Cumyn, Director, Steamship Inspection Service, Board of Steamship Inspection, Department of Transport, Ottawa, Ontario, submitted two samples of steel plates from the M.S. "EAGLESCLIFFE HALL" to the Physical Metallurgy Division of the Mines Branch, with a request (letter of that date, File No. 9562-6523) that a series of Charpy V-notch impact tests with a temperature range of 50°F to 0°F be carried out so as to obtain the notch brittle characteristics. Room temperature tensile tests and chemical analyses were also requested.

The following information was supplied with the samples:

> The M.S. "EAGLESCLIFFE HALL" suffered a structural failure when crossing Lake Ontario in ballast in stormy weather. The failure consisted of a crack on the port side which would appear to have originated in a welded butt of the hatch girder stiffener located between No. 2 and No. 3 hatches and to have spread to the adjacent hatch girder butt (welded) located four inches aft of the stiffener butt, thence across the deck stringer plate through a welded butt in the riveted deck stringer angle, and then down the full depth of the sheer strake, through the strake below the sheer strake, and halfway down the second strake below the sheer strake, a total depth of about 10 ft. 6 in. (see Figure 1).

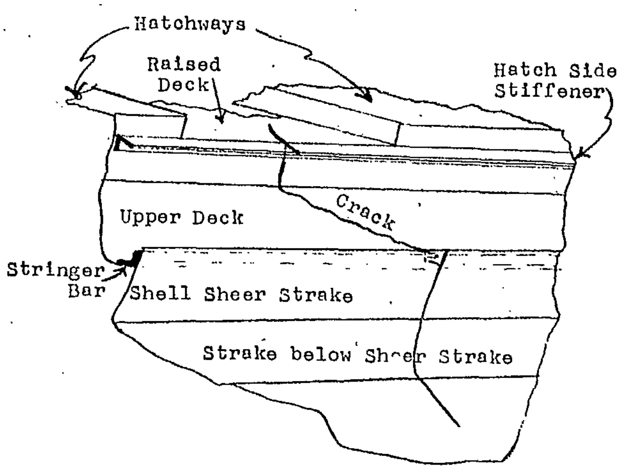


Fig. 1. - Sketch showing location and extent of crack.

Examination showed that the welding of the deck stringer angle butt had penetrated the sheer strake, thus forming a continuous path through the deck stringer angle butt. At the time of the failure air temperature was 20°F and water temperature was 34°F. Samples of the deck stringer plate, sheer strake and strake below the sheer strake were forwarded for examination; these samples are shown in Figures 2 and 3.

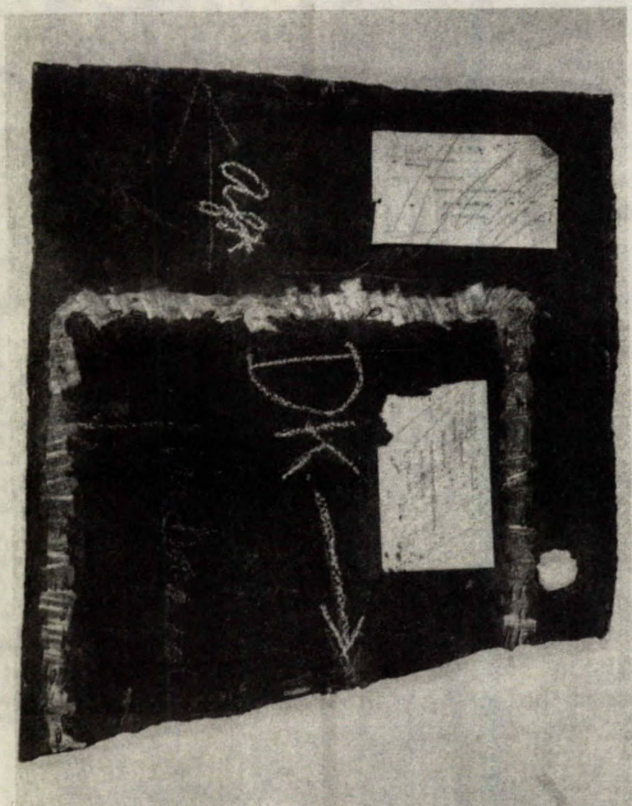


Fig. 2. - Deck stringer plate.

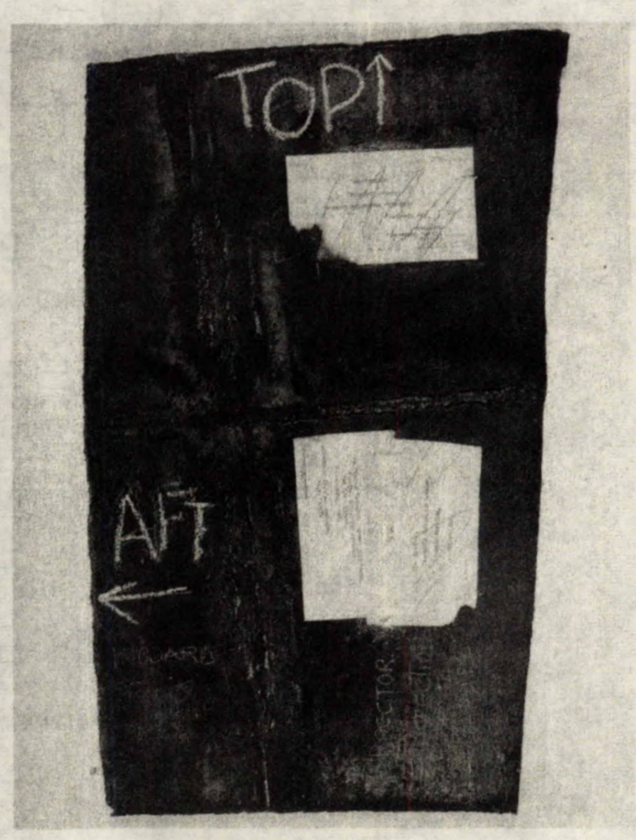


Fig. 3. - Port side shell plate. The portion above the weld is part of the sheer strake, and the portion below the weld is part of the strake below the sheer strake.

For ease of identification, letters were assigned to the various portions of plate as follows:

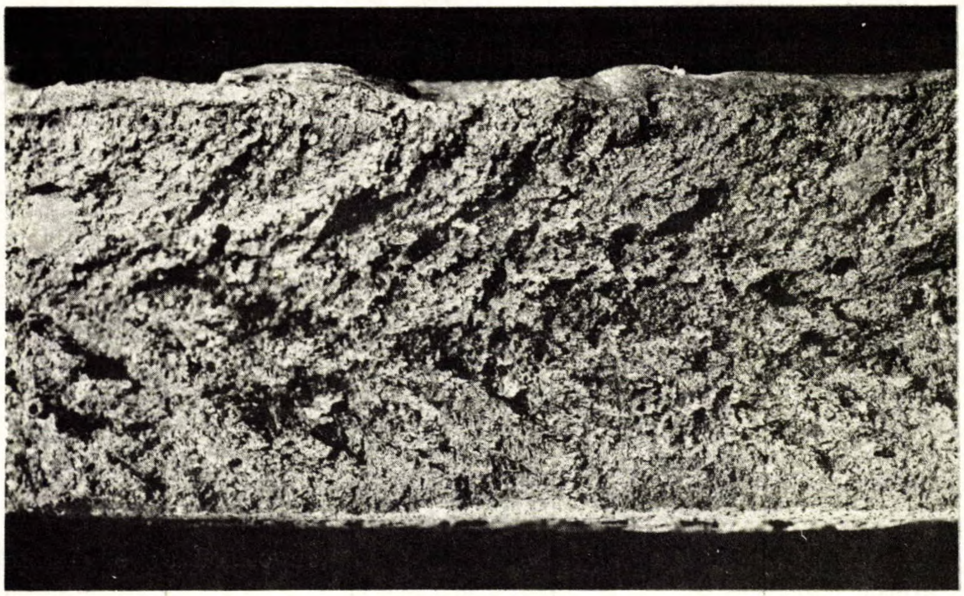
TABLE 1

Plate Identification

Strake below the sheer strake	-	Plate "A"
Sheer strake	-	Plate "B"
Deck stringer plate	-	Plate "C"

VISUAL EXAMINATION

The chevron markings usually associated with brittle fracture of mild steel were observed on the fracture surfaces of all three plates. A typical area is shown in Figure 4.



(approx. X4)

Fig. 4. - Fracture surface of plate "C". Note obvious chevron markings.

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The coarseness of the chevron marking indicates that the fracture occurred at a temperature not far below the transition temperature of the plate. The plate thicknesses varied, plate "A" being 0.415 in., plate "B" 0.518 in. and plate "C" 0.607 in. thick.

CHEMICAL ANALYSIS

Drillings were taken along the transverse axis of the plates in order to obtain as representative a sample as possible for chemical analysis. It should be appreciated that considerable segregation is possible in a large plate, and, since the plate samples are small, the results reported below are strictly applicable to the samples only and cannot be considered to be truly representative of the full size plate.

TABLE 2

Chemical Analysis

Element	Percent		
	Plate "A"	Plate "B"	Plate "C"
Carbon	0.14	0.18	0.19
Manganese	0.54	0.56	0.53
Silicon	0.08	0.03	0.04
Sulphur	0.039	0.048	0.042
Phosphorus	0.034	0.032	0.015
Copper	0.09	0.09	0.09
Nitrogen	0.005	0.007	0.007
Mn/C ratio	3.86	3.11	2.79

MECHANICAL PROPERTIES

Insufficient material was available to prepare full-thickness standard plate tensile samples. Round tensile bars of the maximum diameter possible for each plate were prepared. The diameters are shown in Table 3 below. Full-size standard Charpy-V-notch bars were prepared, the notch being cut normal to the plate surface. Three Charpy bars were tested at each temperature, the average of the three being used as the representative value (shown in Table 4 below and used in the graph, Figure 5). Both tensile and Charpy bars were oriented in the longitudinal direction.

TABLE 3

Tensile Test Results

Plate	Diameter, in.	Strength, in psi		% Elong. in 4 x diam.	% Reduc. in Area
		Yield	Ultimate		
A	0.186	34,400	58,300	41.3	64.0
B	0.312	38,000	63,600	37.6	59.3
C	0.373	34,800	62,700	37.3	59.3

Charpy V-notch Test Results

Temp. °F.	Plate A	Plate B	Plate C
212 -	58 ft-lb	88 ft-lb	73 ft-lb
160 -	57 "	90 "	74 "
110 -	57 "	83 "	62 "
73 -	58 "	75 "	42 "
50 -	54 "	55 "	30 "
32 -	48 "	38 "	21 "
0 -	22 "	11 "	8 "
-40 -	3 "	3 "	3 "

TABLE 5

Charpy V-notch Transition Temperature

Plate		Transition Temp., 15 ft-lb.
A	-	-10°F
B	-	7°F
C	-	19°F

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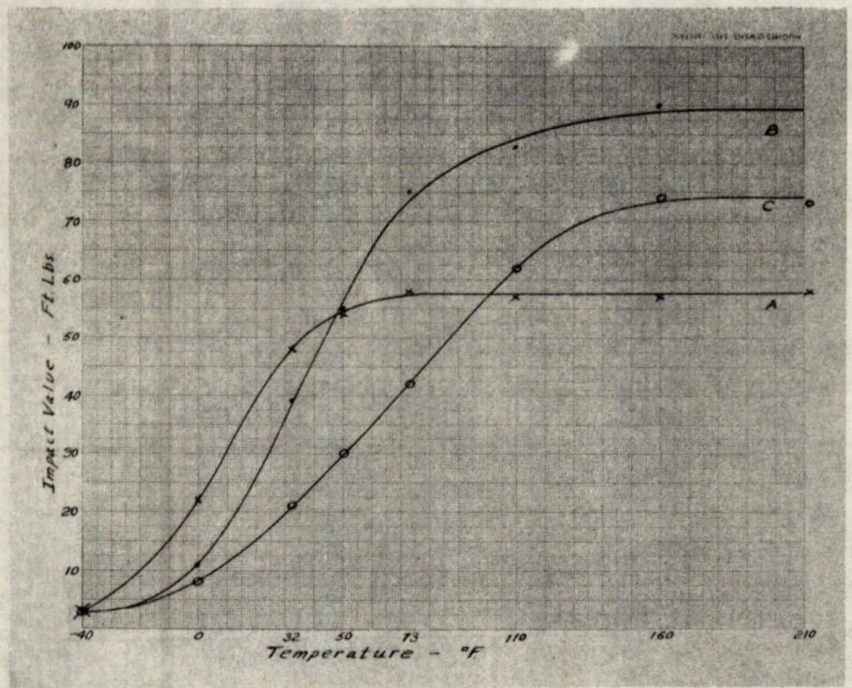

Fig. 5. - Charpy V-notch test results.

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DEEP ETCH

Sections of all plates were deep etched in 1:1 HCl and water at 165°F. There was no evidence of piping or excessive segregation.

MICROEXAMINATION

Sections of all plates were prepared for microexamination. Neither type nor quantity of non-metallic inclusions appeared abnormal for the grade of material. The microstructure of fine pearlite and ferrite was typical of as-rolled mild steel (Figure 6).

(a)

Plate A

(b)

Plate B

(c)

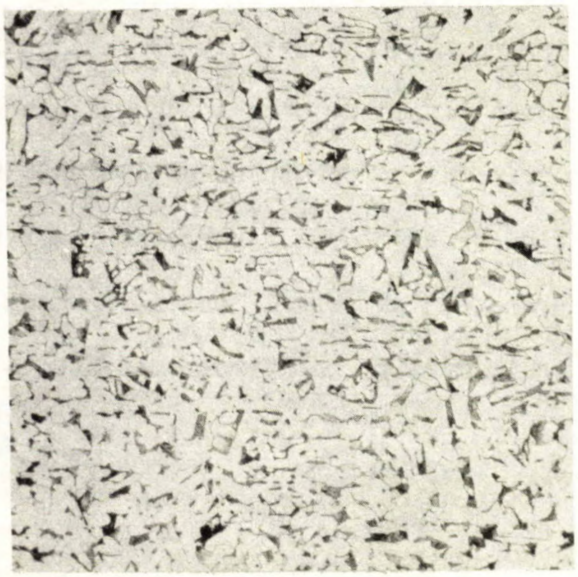

Plate C

Fig. 6. - Typical microstructures, Plates A, B and C. (X100; etched in 2% nital).

DISCUSSION

The chemical analysis of the plates is typical of semi-killed mild structural steel. The relatively low manganese contents indicate that they were probably not made to an improved notch toughness requirement. Microexamination revealed no abnormalities. The tensile properties appear normal in every respect. The 15 ft-lb transition temperatures fall in the range expected for the analyses and plate thicknesses. It is perhaps noteworthy that plate A, with the highest manganese-to-carbon ratio, had the lowest transition temperature despite a somewhat coarser ferrite grain size than plates B and C.

It seems reasonable to assume that the temperature of the plates at the time of failure was the same as the air temperature, i.e. 20°F. The 15 ft-lb transition temperature of plate C is essentially the same as the service temperature, and the transition temperatures of plates B and A are fairly well below the service temperature. The fact that the crack propagated in a brittle fashion through plates at a temperature above their 15 ft-lb transition is not unusual. On the contrary, it is well established that it is easier to propagate than to initiate a crack. It would be anticipated that plates A, B and C, when loaded within the elastic limit, could stop a running crack at temperatures of 13°F, 30°F and 35°F, respectively. While the crack-stopping temperature of plate A is below the service failure temperature, the actual load is unknown and, furthermore, the uncertainty of testing is most probably not accurate to ± 7°F.

CONCLUSIONS

1. All three plate samples examined were characteristic of semi-killed mild structural steel.

2. No defects or quality deficiencies were noted.

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