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OTTAWA June 7th, 1943.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1424.

Examination of Samples of English, American
and Page Hersey (Canadian) Steel Tubing.

(Copy No. 10.)

Bureau of Mines
Division of Metallic
Minerals
-
Ore Dressing
and Metallurgical
Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch
O T T A W A June 7th, 1943.

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Examination of Samples of English, American and Page Hersey (Canadian) Steel Tubing.

Origin of Samples and Object of Investigation:

On May 25th, 1943, Mr. H. H. Scotland, of the Inspection Board of the United Kingdom and Canada, Ottawa, Ontario, submitted samples of solid drawn tubes which were said to have been made in England, the United States, and the Canadian Page Hersey plant.

Request was made (letter May 24th, 1943, File No. 4/4/10/P.H./6) for a determination of the grain size, micro-structure, cleanliness, and susceptibility to ageing of the Page Hersey tubes. It was reported that on going into corvette boilers some Page Hersey tubes were splitting when they were expanded on the interior face of the crown sheet prior to "rolling" the tube in the crown sheet itself. Whether

(Origin of Samples and Object of Investigation, cont'd) -

or not trouble was being experienced with British and American tubes was not stated.

The steel in the tubes was supposed to conform to Specification N466, copy of which was submitted. Page Hersey tubing was said to have met the required mechanical tests though the tensile strength was near the top limit of 26 tons per square inch. The tubes were reported to have been given their final bright anneal around 1400° F.

A portion of a Page Hersey tube which cracked in a flattening test and was said to be not exactly representative of the failures encountered was also submitted. There was not enough of this tube to conduct a full investigation of it. Consequently, unless this cracked sample is referred to specifically the Page Hersey tubes discussed must be considered as those mentioned in the first paragraph.

Chemical Analysis:

Turnings taken from the tubes after the surface had been removed were chemically analysed. The results follow:

		English	American	Page Hersey	Page Hersey Cracked
		- Per cent -			
Carbon	-	0.09	0.20	0.14	0.09
Manganese	-	0.44	0.56	0.39	0.34
Silicon	-	N.D.	0.26	0.11	0.006
Sulphur	-	0.032	0.026	0.033	
Phosphorus	-	0.005	0.005	0.005	
Nickel	-	Trace.	Trace.	N.D.	
Chromium	-	0.01	0.01	N.D.	
Molybdenum	-	N.D.			

(N.D. = Not detected)

Macro-Examination:

The American and Page Hersey tubes had a rather bright surface while the English one was coloured a deep blue.

The Page Hersey tube which cracked in a flattening test did so with a duplex type fracture. Apparently, part of

(Macro-Examination, cont'd) -

the fracture was a longitudinal defect extending inward about 0.022 inch from the outside surface of the tube.

A cross-section from each of the four types of tubing submitted was etched in a hot 50 per cent aqueous solution of hydrochloric acid. The Page Hersey tube which had cracked in a flattening test was seen to be made from rimming steel. This is shown in Figure 1. The other American, British, and Page Hersey tubes were evidently made from killed steel.

Physical Examination:

Hardness readings were taken, using the Vickers method with a 10-kilogram load, on the tubes as received:

	Vickers Hardness Numbers.			
	British	American	Page Hersey	Page Hersey Cracked
As Received -	91.2-95.3	120-139	114-123	95.8-100

Since the tubes were not long enough to permit a standard tube tensile test, bars with a nominal diameter of 0.5 inch (curvature in bar disregarded) and a 2-inch gauge length were removed. These gave the following values at test:

	British	American	Page Hersey
Ultimate stress, p.s.i. -	50,300	65,300	63,000
Yield point, p.s.i. -	30,000	41,800	45,400
Elongation in 2 inches, per cent -	39	33	30

Rings from English and American tubes passed a flattening test while two Page Hersey samples opened up slightly.

A ring from a Page Hersey tube passed a flattening

(Physical Examination, cont'd) -

test, with no sign of opening up, after it had been annealed in lead at 1400° F. and slow-cooled.

Tests for Ageing Susceptibility:

Rings from each of the three types of tubes submitted were water-quenched from 1260° F. The following hardness readings were then obtained:

	Vickers Hardness Number		
	British	American	Page Hersey
Hardness as quenched -	134-139	147-151	151
After air-ageing 160 hours -	188-192	179-180	194-198

Microstructures:

English and Page Hersey tubes have their carbide constituent present as pearlite, while that of the American one is pearlite that has been partially spheroidized. The ferrite in all samples has been recrystallized. While the carbide constituent of the American tube is elongated, the pearlite in the English and Page Hersey tubes shows no preferred orientation. These points are illustrated in Figures 2 to 5 which are photomicrographs, at 250 magnifications, of etched longitudinal sections from each of the tubes.

The steel in all of these tubes was found to be fairly clean.

The grain sizes of the steel in these three types of tubing, as determined by a McQuaid-Ehn test (pack-carburized 8 hours at 1700° F. and slow-cool), were British 7-8, American 7-8, and Page Hersey 3-5.

Discussion of Results:

Chemical analysis results show that the steel in the three types of tubing is of the normal low-to-medium-carbon type.

Since the cracked Page Hersey tube was made from rimming steel it does not conform to Clause 1 of the specification. No relation between this fact, however, and the cracking of the tube in a flattening test is seen. The defect present extended only partly into the outer rim of comparatively sound metal in the tube. Since this tube was already broken open when received, exact determination of the nature of the defect was not possible, but it would seem to have been caused by an ingot defect, lap, or deep score, which subsequent drawing had transformed into a tight-lipped defect extending longitudinally along the tube. It is felt that this tube cracked in flattening because of the notch effect of this defect.

Physical tests, while not very accurate, indicate that the American and Page Hersey tubes may have a higher tensile strength than the specification allows. This and the hardness of these two tubes reflects their higher carbon content as compared with that of the English tube.

The slight opening-up of a ring from the Page Hersey tube in a flattening test may have been caused by its high yield and tensile strengths. It is also possible, however, since our lead-annealed sample passed the test, that Page Hersey tubes are "picking up" some hydrogen either in their manufacture or, more probably, from the furnace atmosphere used in bright annealing, and thus, becoming slightly embrittled.

That the three types of tubing were subject to quench ageing and, by inference, to strain ageing was shown by the increase in hardness after the 1260° F. quench. Since, however, (Discussion of Results, cont'd) -

the tubes were not harder than would be expected and since splitting reportedly occurred when the expanding was taking place, the possibility that ageing was a big factor in the failure of the Page Hersey tubes is discounted.

Microstructure examination would seem to indicate that the 1400° F. anneal given the Page Hersey tube was as good as an anneal from above the upper critical point having the same rate of cooling, because, having been taken over the lower critical point the pearlite is equiaxed. Also, the tube was evidently cold-worked enough to make the recrystallization temperature of the ferrite be below 1400° F. The English tube was evidently given either the same heat treatment as the Page Hersey one or an anneal from a higher temperature. The American tube seems to have been given a high sub-critical draw.

CONCLUSIONS:

1. Longitudinal defects, such as found in the Page Hersey tube which cracked in a flattening test, may be fairly common. These would cause the tube to split when it is expanded. Tubing containing typical failures should be submitted for examination.

2. Canadian and American tubes may have higher tensile strengths than the specification allows. If this is so, it might explain the failure of some Page Hersey tubes. More material is needed in order that a check may be made of this point.

3. Page Hersey tubes may be "picking up" hydrogen from the furnace atmosphere and becoming slightly embrittled. Examination of typical failures would clarify this point also.

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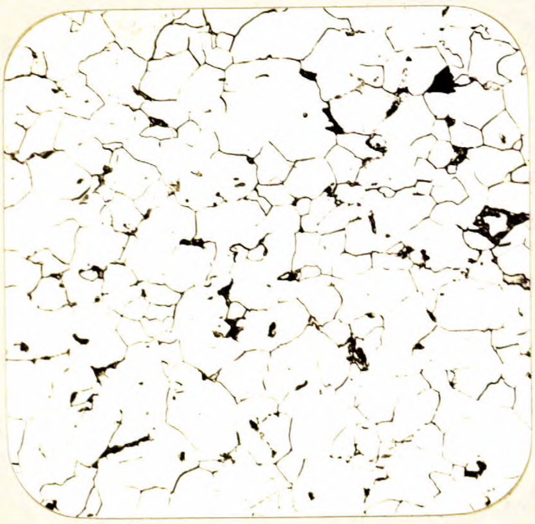
Figure 1.

PHOTOGRAPH OF MACRO-ETCHED SECTION FROM PAGE HERSEY TUBE WHICH CRACKED IN FLATTENING TESTS.
(Approximately twice actual size).

Figure 2.

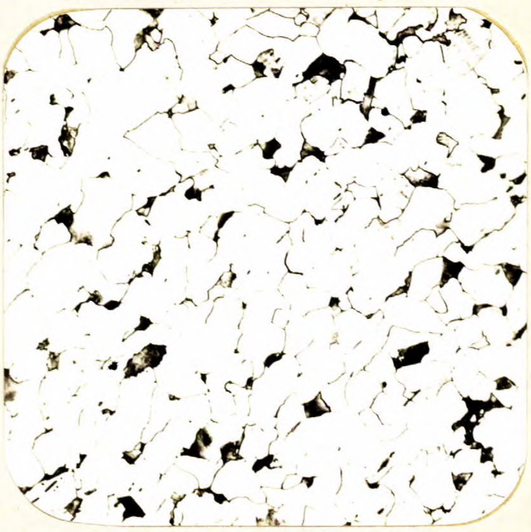


ENGLISH TUBE.

Figure 3.

AMERICAN TUBE.

Figure 4.



PAGE HERSEY TUBE.

ALL PHOTOMICROGRAPHS, X250, NITAL-ETCHED, TAKEN FROM LONGITUDINAL SECTION.

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