

File.

FILE COPY

O T T A W A

March 30th, 1943.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1378.

Examination of Boiler Tubes.



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

March 30th, 1943.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES,

Investigation No. 1378.

Examination of Boiler Tubes.

RECORDED IN THE OFFICE OF THE DIRECTOR OF DOCUMENTS

Origin of Sample:

On March 3rd, 1943, a number of samples of boiler tubes, some of which had cracked when the ends were being belled during installation, were submitted by A/Lt. Cdr. J. R. Millard, Senior Technician, Technical Division, Department of National Defence (Naval Service), Ottawa, Ontario. These tubes were in two sizes, outside diameters 1.012 and 1.138 inches.

Accompanying the above were four other lengths of tubing in a flattened condition and two unused tubes (about 15 inches long, outside diameters of 1.003 and 1.128 inches).

Object of Study:

Request was made (letter March 3rd, File No. N.S. 29-55-1 FD2276), for a metallurgical examination of these tubes in order to determine, if possible, a heat treatment which would render the tubes satisfactory for use.

Chemical Analysis:

An analysis of the unused tubes for carbon and silicon gave the following results:

	Small	Large
Carbon, per cent	= 0.31	0.31
Silicon, " "	= 0.006	0.006

The composition of one of the flattened tubes was found to be as follows:

	Per cent
Carbon	= 0.08
Manganese	= 0.27
Silicon	= Not detected.
Phosphorus	= 0.011
Sulphur	= 0.051
Nickel	= Trace.
Chromium, molybdenum, tungsten, and vanadium	= Not detected.

Macro-Examination:

The surface of the larger of the two unused tubes was rather severely scored; that of the smaller tube was very much better.

Physical Examination:

Hardness readings were taken, using the Vickers method with a 30-kilogram load, on the small and large unused tubes (designated Nos. 1 and 2 respectively):

Vickers Hardness Number
No. 1
No. 2

As received	=	130	117
-------------	---	-----	-----

Tube No. 2 passed a flattening test, while No. 1

(Physical Examination, cont'd) -

cracked when the external diameter was 0.725 inch.

Both tubes successfully withstood bellmouthing with a lathe centre having a 60° point. After standing for about 1½ weeks, neither shows any cracks.

Rings from both unused tubes were quenched in water from 1320° F.:

	Vickers Hardness Number No. 1	Vickers Hardness Number No. 2
Hardness as quenched	150	170
Hardness after air ageing for 95 hours	214	217

Both of these rings then failed a flattening test.

Hardness tests taken on one of the tubes received in a bellmouthed condition gave a reading of 177 Vickers on the bellmouthed part and a reading of 122 Vickers one inch away from it.

One-quarter-inch strips from one of the flattened tubes passed a temper test as quenched and after 89 hours in air. During this time the hardness increased from 122 Vickers, as quenched, to 195 Vickers.

Material with a Vickers hardness of about 120, such as Tube No. 2, would be normally expected to have a tensile strength of about 50,xxx pounds per square inch. There was not sufficient material to verify this.

Microstructure:

Tube No. 1 has its carbide constituent present predominantly as pearlite, while the carbide in the No. 2 sample is spheroidal. This is shown, at 1,000 diameters, in Figures 1 and 2.

(Continued on next page)

(Microstructure, cont'd) -

Figure 1.



X1000, picral etch.

SMALL TUBE (NO. 1).

Figure 2.



X1000, picral etch.

LARGE TUBE (NO. 2).

Discussion of Results:

Chemical analysis results show that the steel in these tubes is not of the strongly deoxidized type. Such a low carbon, low silicon steel is very prone to ageing.

The undesirable scoring on the surface of the larger of the unused tubes was probably caused by defects in the die.

Tube No. 1, as received, is much harder than No. 2. Since the dispersion of its visible carbide constituent, as compared to that of No. 2, cannot by any means explain its higher hardness, and since there is no evidence of serious cold work, it may be concluded that this tube hardened by ageing. This would explain its failure to pass the flattening test.

The brittleness of Tube No. 1 indicates that it was not cooled slowly enough in the final heat treatment to

(Discussion of Results, cont'd) =

effectively eliminate quench ageing. Another method, aside from slow cooling that would place this tube in a ductile condition, would be a subcritical quench-and-draw (e.g., water quenching from 1320° F. and drawing for 3½ hours at 400° F.). If facilities are available this latter treatment would reduce production time. Although neither of these heat treatments would remove the susceptibility of this tube to strain ageing they would eliminate any strain ageing that had been incurred in fabrication prior to heat treatment.

The heat treatment received by Tube No. 2 appears to be satisfactory. The spheroidal condition of its carbide indicates that it was either held for a long time at high subcritical temperature or else cooled very slowly through the spheroidizing range.

That the two unused tubes were subject to quench ageing and, by inference, to strain ageing, was shown by the increase in hardness after the 1320° F. quench.

Hardness readings taken on the tube received in a bellmouthed condition show that the strained portion of the tube is very much harder than the parent metal. For this reason, if cracking is to be avoided, tubes made from steel susceptible to ageing should be protected from severe impact stresses after bellmouthing, because the strained portion of the tube is then in a relatively brittle condition. The steel, however, may well not be brittle when at service temperature (which is said to be around 400° or 500° F.).

General Discussion:

Numerous investigators have demonstrated that there are two types of ageing, quench-ageing and strain ageing, and that, in general, a steel susceptible to one is

(General Discussion, cont'd.) -

susceptible to the other. Unfortunately, however, pre-ageing the steel with respect to the former does not eliminate the latter, because quench ageing is thought to be caused by a carbide precipitate, while strain ageing is believed to be the result of precipitation of minute oxide particles in the slip bands of the cold-worked grains of metal.

Quench ageing can be, to all practical extents, eliminated by either the slow-cool or the quench-and-draw heat treatment mentioned above. Strain ageing, however, under ordinary conditions, is not so easy to prevent. Discussing this, Davenport and Bain state⁹:

"The pre-aging for this type of aging is accomplished by working the metal cold and then heating to some temperature of rapid precipitation and coalescence. This treatment succeeds in putting away some portion of the dissolved oxygen in the form of a harmless particle distribution. The trouble, however, with this treatment is that the action is not complete; another succeeding cold working operation appears to recondition new metal for precipitation and there is unfortunately still some oxygen to be precipitated. Accordingly, the operation of cold-working and re-heating may have to be repeated several times to be effective. It is safe to predict, however, that sheet or strip which has been produced by means of a great deal of cold rolling, if re-heated to a suitable temperature (e.g., 650-700 degrees Fahr., 340-370 degrees Cent.) during process, will be noticeably superior to ordinary sheet metal with respect merely to the strain-aging phenomena."

CONCLUSIONS:

1. Efforts should be made to keep the dies used in forming these tubes in good condition, in order to insure against scoring.

2. If no severe straining followed later by impact is likely to occur, particularly in installation, a tube

⁹ The Aging of Steel, by E. S. Davenport and E. C. Bain - Trans. Amer. Soc. for Metals (Vol. 23) 1936, p. 1090.

(Conclusions, cont'd) -

heat-treated to a ductile pre-(quench)-aged condition, as was Tube No. 2, should be satisfactory. A very slow cool, or a quench-and-draw treatment, as discussed here, is recommended. If these severe installation strains followed by impacts cannot be avoided, a non-ageing type of steel (i.e., one strongly deoxidized with aluminium, etc.) should be specified.

3. If tubes of the ageing type can be installed without cracking, the high temperatures of service should remove the effects of strain ageing incurred in installation or in cold working after installation, by a process of pre-(strain)-ageing similar to that recommended above by Davenport and Bain. In effect, this means that there would appear to be little likelihood of strain ageing trouble being encountered in tubes which have reached the operation stage without cracking.

oooooooooooo
oooooo
.oo

LPT:GHB.