O T T A W A February 11th, 1942.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1162.

(Subsequent to Investigation No. 1094, dated September 20th, 1941.)

Examination of Superheater Tubes.

(Copy No. 15.)

BUREAU OF MINES
DIVISION OF METALLIC MINERALS
ORE DRESSING AND
METALLURGICAL LABORATORIES

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

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Origin of Work and Object of Investigation:

The superheater tubing on which the work reported below was done was submitted by Lieut. Commander C. E. Olive, of the Department of National Defence (Naval Service), Ottawa, Ontario. This investigation is a continuation of work reported previously in Investigation No. 1094 (September, 1941) and in a letter dated October 9th, 1941, to Lieut. Commander C. E. Olive.

Previous work showed that tubing steel submitted

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

had to be drawn after forming if it was to have the specified tensile strength. It was shown that if the recommended heat treatment, i.e., close annealing after cold forming, were followed the tensile strength of the steel would be below the required minimum. A failure of one of the tubes in the flattening test was attributed to a scaling of the specimen. The steel was found to be low in carbon and practically free from silicon. It was pointed out that such low silicon low carbon steel was likely to be subject to strain embrittlement. Tests made on the material showed that it was subject to quench aging, a definite indication that it would also be subject to strain aging.

It is generally considered that the main cause of strain aging is the precipitation of oxygen or nitrogen constituents from the iron and that quench aging is due to carbide precipitate. As low carbon steels are especially likely to contain these gaseous constituents they are very subject to aging effects. There are two methods of preventing aging. The first consists in the controlling of the deoxidation practice (by the addition of fairly large amounts of aluminium, etc.) so that the gaseous products leave the solution as deoxidation products. The second consists in slowly cooling from a temperature high enough to effect solution of the troublesome constituents. In this slow cooling the constituents come out of solution as large particles which do not affect the steel ductility. Too fast a cooling results in the precipitation of fine embrittling particles.

(Continued on next page)

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

As the steel was made nothing could be done about the deoxidation practice. Close annealing will correct for many aging effects. The steels submitted, however, were too low in carbon to permit of close annealing, as this treatment lowered the ultimate strength below the specified value. The object of the following work was to determine whether a draw at 1250° F. followed by a furnace cool produced a stabilized material.

Material:

On January 15th, 1942, Lieut. Commander C. E. Olive sent in six sample pieces of superheater tubes for further tests and examination.

In a letter from Mr. G. W. Flack, of the Sales Department, PAGE-HERSEY TUBES, LIMITED, 100 Church Street, Toronto, Ontario, the following information was given:

1. The tubes were manufactured by the Push Bench process from a hot billet reheated and reduced in rolls to 2" O.D. x 11 B.W.G. Afterwards cold drawn in 3 passes to 1-1/8" O.D. x 0.116" wall.

2. Close annealed in boxes at a temperature of 1250° F. for 1 to 1-1/2 hours.

3.

Carbon, per cent	Manganese, per cent	Sulphur, per cent	Phosphorus, per cent
0.13	0.43	0.028	0.018

EXPERIMENTAL TEST WORK.

Chemical Analysis:

One of the tubes, in the "as received" condition, was sampled in a milling cutter for chemical analysis and the following results were obtained:

Carbon, per cent	Manganese, per cent	Sulphur, per cent	Phosphorus, per cent
0.05	0.40	0.005	0.009

Temper Tests:

The specification requires that strips cut from the tubes, after heating to 730° C. and quenching in water at 80° C., must withstand being doubled over a radius of ½ inch. Temper tests were carried out on strips from two different tubes and the material passed this test.

Hardness Tests:

The hardness tests were determined by the Vickers method on a section of tubing immediately after quenching in water at 80° C. from a temperature of 730° C. and also after standing at room temperature for 48 hours. The following results were obtained:

Time	Vickers Hardness Number
After quench	135
48 hours after quench	160

Tensile Tests:

Tensile tests were carried out on full-sized tubes of 12-inch length in the "as received," annealed, and drawn conditions and also in the quenched and quenched-and-aged state. The following results were obtained:

(Continued on next page)

(Tensile Tests, cont'd) -

Condition of tubes	Ultimate strength, p.s.i.	Yield strength, p.s.i.@@@@	Elongation, per cent in 2 inches
As received	44,700	27,000	66.0
Annealed 1600° F.	42,600	27,000	60.0
@Drawn 1250° F.	41,300	24,200	72.0
@@Quenched	61,500	32,700	46.0
@@@Quenched and aged	77,800	52,200	33.0

(Notes:)

@ Cooled in furnace.

@@ Tested 1 hour after quench.

@@@ Tested 6 days after quench.

@@@@ Yield strengths determined by extensometer method.

Other Tests:

Flattening tests: Passed.

Bell mouthing tests: Passed.

Water test: Passed (ruptured 4,000 p.s.i.).

Examination: Polished specimens were examined under the microscope and the steel was found to be fairly clean. The surfaces of the six tubes were also found to be fairly free from scale and other surface imperfections.

Discussion of Results:

Chemical Analysis -

Values obtained do not check with the figures given by Mr. G. W. Flack, the steel being lower in carbon. Such a low carbon low silicon steel is very susceptible to aging effects.

Physical Tests -

The steel in the "as received" condition fails to meet the specification requirements for the ultimate tensile strength. It passes all other tests. It is of note that hardness and tensile tests made on the freshly quenched and the quenched-and-aged steels show that they are subject to quench aging. The A.S.M. Handbook, 1939, p. 603, states: "In general a material which is subject to quench aging is also subject to strain aging." Bain and Davenport, on page 1089 of the 1935 Transactions of the A.S.M., show that the impact strengths at room temperature of ordinary soft steel are around 25 Kg.-M. per Cm.^{2} in the normalized condition and only around 4 in the aged condition.

The aging embrittlement occurs as a result of a precipitation from the iron constituent. Quench aging, of course, can be prevented by a slow cooling such as the steel would receive when close annealed, that is, slowly cooled from a high draw temperature. Strain aging, however, is not so easy to prevent. Working of a metal, followed by a heating of the steel to a high draw temperature, followed by a slow cool, causes a coalescence of the oxide and nitride particles and consequently removes the embrittling effect induced by the aging. Subsequent working, however, may embrittle the steel as strain aging, unlike quench aging, does not require a high degree of supersaturation of the

(Discussion of Results, cont'd) -

solute, precipitation apparently occurring along the slip planes. The first reheating process, however, will reduce the susceptibility of the steel to strain hardening.

Fairly crude impact tests indicate that the material is not brittle, an indication that it has been cooled sufficiently slowly after the drawing operation.

Conclusions:

1. The tests show that the "as received" material fails to meet the ultimate strength requirements but has all the other required physical properties.

2. The work definitely indicates that the material is subject to quench aging, a strong indication that it is also subject to strain aging.

3. Crude impact tests indicated that the "as received" material was not brittle, an indication that it had been cooled sufficiently slowly in the drawing operation to eliminate quench aging and any strain aging that would occur as a result of the forming of the tubes prior to drawing.

4. It was pointed out that if the tubes were subsequently strained in service they might possibly become embrittled. If there is no danger of straining occurring in service, and if the tensile strength is sufficiently high, the material "as received" is satisfactory.

5. If a higher strength is required the carbon content of the tubing must be increased.

6. If strain is likely to occur in service, a

(Conclusions, cont'd) -

non-aging steel (i.e., steel that has been well deoxidized with aluminium, etc.) should be specified.

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