O T T A W A December 30th, 1941.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1137.

Examination of Two Stainless Steel
Weld Tensile Test Specimens.

(Copy No. 9.)

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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Source of Material and Nature of Investigation:

On December 1st, 1941, Squadron Leader A. J. Horner, of the Department of National Defence (Air Services), No. 14 (Technical) Detachment, R.C.A.F., 304 Sparks Street, Ottawa, submitted two welded stainless steel specimens which had been pulled between grips in a tensile machine. The specimens were delivered by Flight Lieutenant L. Taylor.

The fracture had occurred near the weld in both specimens and it was requested that the weld be examined in order to find the reasons why the material had broken at this particular place.

Macro-Examination:

Figure 1 (natural size) shows a portion of the two broken tensile test pieces. The surface of Sample No. 1 appears greyish while that of Sample No. 2 is brighter. The welds, made by oxy-acetylene flame, had a regular, sound appearance. Figure 2 (X5) shows how the welds are made; the base metal is slightly curved near the weld in order to make a better joint, and the weld bead is on one side only. The fracture can be seen to have taken place in the "intermediate zone," i.e., the zone adjacent to the weld. On the other side of the weld, just at the point where the base metal is curved, a slight reduction in the thickness is noticeable.

Hardness Test:

The hardnesses were determined by the Vickers method, using a 10-kilogram load.

	Sample No. 1.	Sample No. 2.
At the weld --	225	249
Base metal under the weld --	197	224
Intermediate zone, immediately adjacent to weld -	216	238
1/16 inch from intermediate zone -	243	306
1/8 " " " " -	336	306
$\frac{1}{4}$ " " " " -	354	297
3/8 " " " " -	314	294
$\frac{1}{2}$ " " " " -	299	304
End of tensile piece --	264	212

Magnetic Test:

The response to a magnet was studied by means of

(Magnetic Test, cont'd) -

an Aminco-Brenner Magne-Gauge (which is essentially a torsional balance used to measure the attractive force of a calibrated magnet).[*] The units used in the following table are arbitrary and correspond to the actual force of attraction of the magnet as measured by the Aminco-Brenner instrument:

	Sample No. 1	Sample No. 2
Weld metal --	2	3
Base metal and intermediate zone adjacent to weld --	34	34
1/16 inch from intermediate zone -	54	81
1/8 " " " " -	169	164
¼ " " " " -	157	181
3/8 " " " " -	158	151
½ " " " " -	108	129
1 " " " " -	15	133
End of test piece --	13	134

Chemical Composition:

Samples milled from the test pieces analysed as follows:

	Sample No. 1	Sample No. 2
Carbon, per cent -	0.14	0.11
Manganese, " -	0.79	0.31
Silicon, " -	0.86	0.66
Phosphorus, " -	0.010	0.014
Nickel, " -	7.80	7.68
Chromium, " -	17.97	16.43

Microscopical Examination:

Figure 3 (magnification X250, etched with ferric chloride and hydrochloric acid) shows the structure at the weld of Sample No. 1. Fusion between the welding material and the base metal is good. In the zone immediately adjacent

[*] This instrument was recently acquired by the Metallic Minerals Division of the Bureau of Mines, at Ottawa.

(Microscopical Examination, cont'd) -

to the weld (upper part of the microphotograph) carbide precipitation is seen to have occurred at the grain boundaries but it becomes gradually more pronounced farther into the base metal (lower part of the microphotograph) where it acquires a definite orientation, as is shown in Figure 4 (magnification X250, etched with ferric chloride in dilute hydrochloric acid) which was taken approximately $\frac{1}{4}$ inch from the weld. Sample No. 2 shows a similar structure at the weld although the carbide precipitation in this case seems to be less abundant, as is indicated in Figure 5, magnification X250.

Figure 6 (magnification X250) shows the preferred orientation along slip planes of the precipitated carbide particles. As in Sample No. 1, this carbide precipitation and slip bands are due mainly to the heavy cold work set while pulling the tensile specimens.

Discussion and Conclusions:

The chemical compositions of Samples Nos. 1 and 2 fall within the specified requirements for DTD 171A, which are as follows:

Carbon,	per cent	-	0.20 maximum;
Silicon,	"	-	0.20 minimum;
Manganese,	"	-	1.00 maximum;
Sulphur,	"	-	0.05 maximum;
Phosphorus,	"	-	0.05 maximum;
Nickel,	"	-	6.00 minimum; 20.0 maximum.
Chromium,	"	-	12.00 minimum.

The carbon content in both samples is seen to be on the high side although it falls well within the

(Discussion and Conclusions, cont'd) -

specified limit.

For the composition of the samples submitted, the ultimate strength of the material in the "as welded" condition will average 75,000 pounds per square inch. Its Vickers hardness numbers will be, in the "as welded" condition, from 165 to about 220, which values are slightly lowered by annealing. The hardness found on the base metal adjacent to the weld of Sample No. 1 falls within the specified figures while in Sample No. 2 it is slightly higher, probably due to the higher stressed condition of the material at the point where the reading was taken.

The survey of hardness of both samples shows that there exists a zone near the weld where its value reaches a maximum. This zone is corresponding exactly to that where the magnetic phase appears to be most abundant. This maximum in hardness and magnetic permeability indicates that the above-mentioned zone was heavily work-hardened during the tensile test, as is seen also by the carbide precipitation along slip planes (Figures 4 and 6).

It is known that the metastable austenitic steels in the low-carbon range work-harden more readily than similar steels of higher carbon content, and, also, that the low-carbon austenitic steels require less cold work to become magnetic. This fact, together with a slight surface decarburization observed on Sample No. 2, would explain why this specimen is more magnetic than Sample No. 1; the carbon content in this latter being higher, the amount of magnetic phase formed by the cold work introduced while pulling the tensile specimens is less abundant.

(Discussion and Conclusions, cont'd) -

The carbide precipitation in the zone adjacent to the weld has taken place before cold work was introduced in the tensile specimen, as can be seen by the lack of orientation of the carbide particles visible in the grain boundaries just adjacent to the weld (see Figure 3 and, especially, Figure 5). This accumulation of carbide at the grain boundaries would result in less resistance to corrosion but would likely tend to increase the tensile strength of the material. However, close examination of Figures 3 and 5 reveals the presence, near the weld, of a zone where very little precipitation of carbide has taken place, due possibly to partial decarburization by the oxy-acetylene flame. This zone, as indicated by hardness and magnetic tests, would be soft and would represent an area of partially transformed austenite having a lower tensile strength than the surrounding material. The break on the test specimens has therefore taken place in that zone, which, moreover, coincides with that portion of the metal sheet which was bent in order to receive the weld, which operation would have produced a decrease in the thickness at the curved part (see Figure 2).

Recommendations:

It is recommended:

(1) that chill blocks be used during the welding, to reduce the distribution of the heat from the oxy-acetylene flame;

(2) that the welded parts be heat-treated if possible,

(Recommendations, cont'd) -

quenching in water from 1950° F.; and

(3) that the oxy-acetylene welding technique be replaced by an arc welding (with the proper equipment[⊕] for thin metal welding), which will improve the quality of the weld by reducing decarburization or carburization which may occur in the oxy-acetylene welding.

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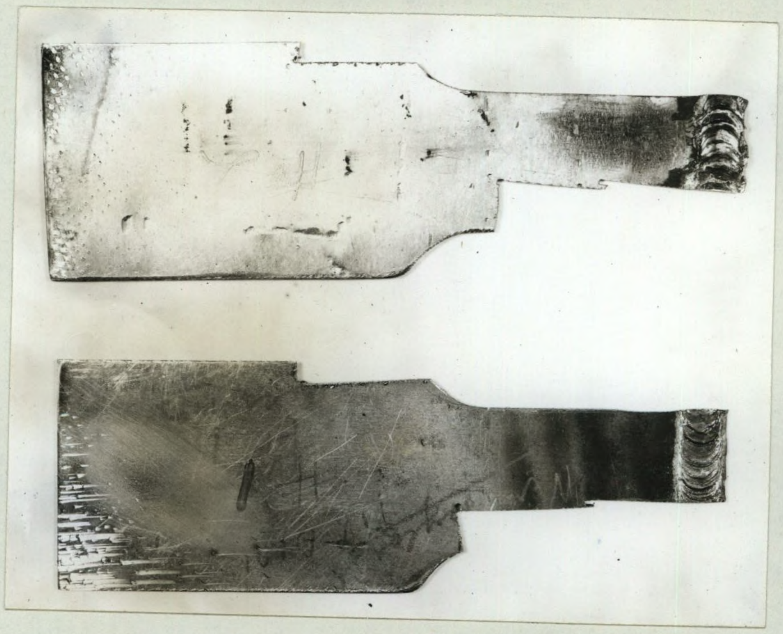
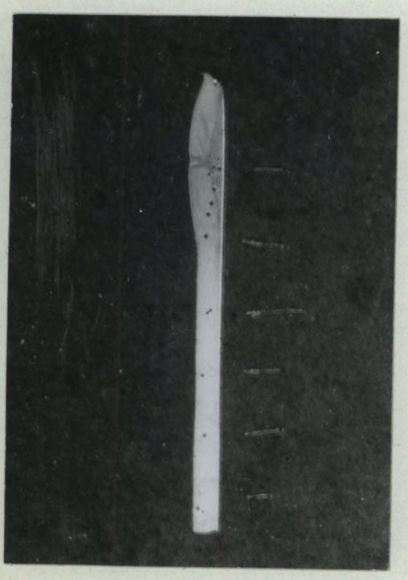
[⊕] A new low-current electronic welder for thin metal (equipped with an automatic voltage adjustment) is sold under the name of Weld-O-Tron, by Allis-Chalmers, Milwaukee, Wisconsin.

Figure 1.



SHOWING TEST SPECIMENS.

Figure 2.



Sample No. 1. Sample No. 2.

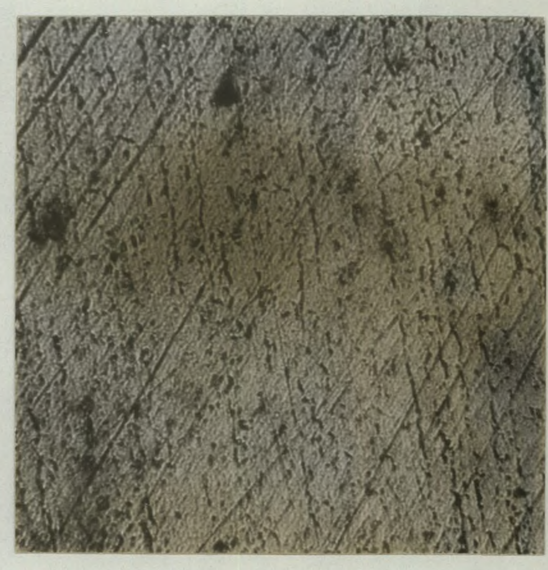
SHOWING DETAILS OF WELD.

(Magnification, X3).

Figure 3.

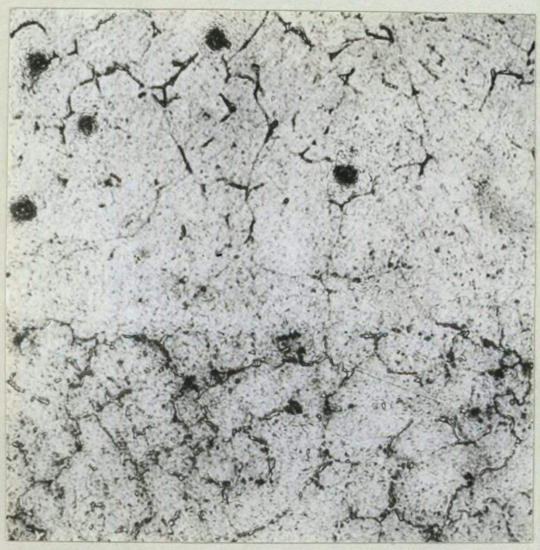
At weld, Sample No. 1.

Figure 4.



$\frac{1}{4}$ inch from weld, Sample No. 1.

Figure 5.



At weld, Sample No. 2.

Figure 6.

$\frac{1}{4}$ inch from weld, Sample No. 2.

ALL ABOVE MICROPHOTOGRAPHS ARE ETCHED WITH FERRIC CHLORIDE IN DILUTE HYDROCHLORIC ACID.

Magnification: X250.

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