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O T T A W A November 8th, 1944.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1734.

Examination of Welded and Unwelded Compressed-Air Bottles for Lancaster Aircraft.

(Copy No. 10.)

Bureau of Mines
Division of Metallic
Minerals
-
Physical Metallurgy
Research Laboratories

CANADA
DEPARTMENT
OF
MINES AND RESOURCES
Mines and Geology Branch

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Source of Material and Object of Investigation:

On November 2nd, 1944, samples of welded and unwelded British Standard Specification 3S-3 sheet steel (0.081-inch gauge) were submitted by the O.C., No. 14 A.I.D., Royal Canadian Air Force, Department of National Defence for Air, Ottawa, Ontario. It was stated that this sheet steel was being fabricated by oxy-acetylene welding with a No. 7 welding rod (a low-carbon steel containing approximately 0.05 per cent carbon) into compressed-air bottles for Lancaster aircraft. Three of these bottles were also submitted, for heat treatment and hydraulic tests.

It was reported that the specification required that these bottles be heat-treated after welding. However, the heat treatment was not specified.

It was also stated that a large number of these bottles had given good service without any heat treatment after welding. Because of this it was contended that heat treatment was not

(Source of Material and Object of Investigation, cont'd) -

necessary. "As welded" bottles withstood test pressures up to 800 pounds per square inch. However, welded bottles which had been given a subsequent normalizing heat treatment at 1400° F. bulged in testing at 800 pounds per square inch (gauge).

The problem to be decided, therefore, is whether or not heat treatment is necessary after welding and to determine, if heat treatment is decided upon, what heat treatment should be used.

Hardness Tests:

(a) Welded Samples -

A hardness survey was carried out on two samples of welded material in the "as received" condition. The survey was started in the centre of the weld metal, and its readings, taken along the edge of the sheet at the indicated distances from the weld centre, are given in the following table:

LOCATION: Centre of weld metal zone, all readings being approximately 1/16 inch apart.

VICKERS HARDNESS NUMBERS		VICKERS HARDNESS NUMBERS	
Sample No. 1	Sample No. 2	Sample No. 1	Sample No. 2
152	138	124	134
155	142	138	125
153	139	131	129
151	155	130	135
143	149	131	139
144	146	136	138
141	148	134	136
141	143	133	138
139	142	135	135
136	138	136	138
136	139	138	136
134	136	138	139
131	137	140⊕	134⊕
125	127	138⊕	138⊕
126	127	136⊕	140⊕
131	130		

⊕ Note: Last three readings 1 inch apart.

(Continued on next page)

(Hardness Tests, cont'd) -

(b) Unwelded Samples -

Hardness tests were carried out on unwelded samples in the "as received" condition and also after heat treatment. The following Vickers hardness values were obtained:

Sample		Vickers Hardness Number
As received	-	160
Draw, 800° F.	-	152
As received	-	212
Draw, 1000° F.	-	189
As received	-	186
Draw, 1100° F.	-	142
As received	-	197
Draw, 1200° F.	-	132
As received	-	157
Normalized	-	156
Weld Sample No. 2:		
Weld	-	138
Parent metal	-	138
Draw, 1000° F.:		
Weld	-	127
Parent metal	-	123

Welded Bottles:

Welded bottles subjected to hydraulic tests withstood the following pressures after the indicated heat treatment:

Heat Treatment	Atmosphere	Cooling Medium	Hydraulic Test
1650° F.	No control.	Air.	725 p.s.i. (gauge)*
1650° F.	Controlled.	Air.	825 p.s.i. (gauge)*
1000° F.	No control.	Air.	950 p.s.i. (gauge)

* Plastic deformation occurred at these pressures.

Discussion of Results:

The welded specimens examined showed no serious variations in hardness and indicated that, for this particular material, there would be no point in following the welding with a normalizing heat treatment unless the presence of high internal stresses is suspected. These internal stresses can be removed by a simple draw heat treatment. Tests carried out at 1000° F. showed scarcely any change in hardness at the weakest point in the "as welded" material.

It is of note that the hardness of the various pieces of sheet steel submitted varied considerably. Carbon determinations made on the "As Welded" Sample No. 2 and the 186 Vickers specimen showed respective values of 0.22 and 0.26 per cent. This carbon variation, rather than variation in rates of cooling, is thought to account for the hardness differences obtained.

The results of heat treatment experiments on the 197 Vickers specimen would indicate that a 1200° F. draw is too high for low-carbon material. Another point of interest is that one of the samples shows exactly the same hardness in the "as received" condition and after normalizing at 1650° F., and it should be noted that both hardnesses are above that of the "as welded" specimens. This indicates that, in this particular case, the normalized steel has the same hardness as the "as rolled" material. Subsequent tests, however, proved that due to the differences in cooling rates this is not always the case. Failure in pressure tests of bottles normalized at 1400° F. may be accounted for by the presence of low-strength ferrite areas in the metal. These areas would not be present in material normalized at 1650° F., at least not to the same extent.

Further tests were carried out on the three welded bottles. Two of these were heated to 1650° F., one in a controlled atmosphere and the other without, and then cooled

(Discussion of Results, cont'd) -

in still air, while the third bottle was stress-relieved at 1000° F. The bottle normalized under controlled atmosphere conditions was practically free from scale and withstood without bulging a hydraulic pressure of 825 pounds per square inch, while the other bottle was badly scaled and bulged slightly under 800 pounds per square inch (gauge). The bottle that was drawn at 1000° F. was free from scale and showed no signs of bulging under a hydraulic pressure of 950 p.s.i. (gauge).

The results of hardness tests on a cross-section of the weld metal (see results of tests on Samples Nos. 1 and 2) would indicate that the use of No. 7 welding rod in welding these bottles was quite satisfactory.

Summary and Conclusions:

The results of this investigation have shown that the welded material is fairly uniform in hardness. This, and the fact that "as welded" bottles have given good service in the past, would indicate that heat treatment probably is not necessary. However, there is always the possibility of internal stresses in a bottle unheat-treated after welding. These stresses can be removed either by a normalizing or a draw heat-treatment.

The results of tests carried out on normalized bottles show that it is necessary to use a controlled-atmosphere furnace in order to prevent scaling and decarburization of the thin sheet steel. A bottle drawn at 1000° F. was able to withstand a higher hydraulic pressure than the normalized bottles. This indicates, provided the samples are identical, that the cooling rate after rolling probably was faster than cooling after normalizing. From the results of these tests, it is recommended that a draw of 1000° F. follow the welding. Such a heat treatment

(Summary and Conclusions, cont'd) -

has the following advantages:

1. It does not require a controlled-atmosphere furnace.

2. The steel is not oxidized or decarburized at this atmosphere.

3. There is also no danger of distortion of the bottles.

4. Results should be quite uniform while with normalized bottles the results depend largely on the rate of cooling. (Large numbers of bottles would not cool at the same rate in a room as an individual bottle. Changes in room temperatures would also alter the results. Care must be exercised to see that the bottles are not subjected to a cold blast of air.)

5. It is easier to operate a draw furnace, and the cost is appreciably lower.

6. By this treatment, over 90 per cent of the stresses are removed. (This is an approximate figure. The actual stress retained is limited by the yield point at draw temperature.)

7. The strength as shown by hydraulic tests is higher than after a normalizing heat-treatment and well above specifications.

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