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OTTAWA January 22nd, 1942.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1151.

Examination of Weld Between Mild Steel Base and Tubular Body of 75 mm. Smoke Shell Cases.

(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

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Origin of Material and Object of Examination:

On January 10th, 1942, under Requisition No. O.T. 7, Mr. H. H. Scotland of the Inspection Board of the United Kingdom and Canada, 58 Lyon Street, Ottawa, Ontario, submitted three 75 mm. smoke shell cases for examination. One case was not marked and had received no heat treatment after welding. Another case (marked "A") had been heated to 734° F., held there for half an hour, and then removed from the furnace and cooled in still air. The third case (marked "N") had been heated to 1650° F., held there for 20 minutes, and then removed from the furnace and cooled in still air.

It was requested that the case in the best metal-

(Origin of Material and Object of Examination, cont'd) -

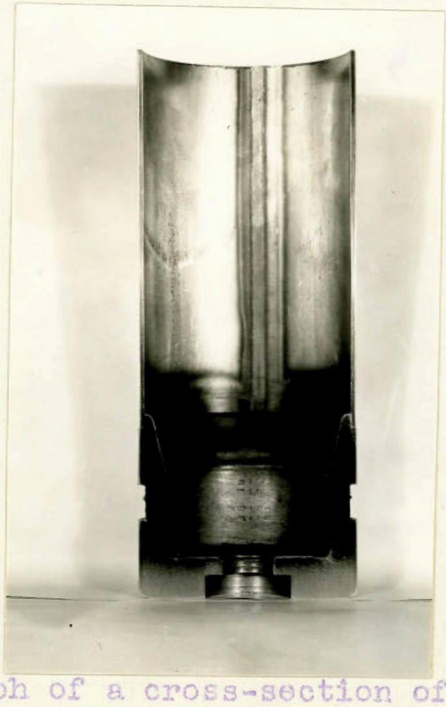
lurgical condition be determined.

Macro-Examination:

Figure 1.

Photograph showing three cases submitted.
(Approximately 1/3 size).

Figure 2.



Photograph of a cross-section of a smoke shell case, showing method of construction.
(Approximately 1/3 size).

(Continued on next page)

(Macro-Examination, cont'd) -

Figure 3.

A close-up of the welded joint, showing the extent of the weld, dimension "W".

(Approximately X4 magnification).

On four specimens examined, this dimension "W" was found to vary, as follows:

No. 1,	taken from Specimen "N",	0.036 in.
No. 2,	" " Specimen "A",	0.019 in.
No. 3,	" " Specimen "A",	0.012 in.
No. 4,	" " untreated specimen,	0.009 in.

Physical Tests:

The metal in the neighbourhood of the weld was examined for variations in hardness. The Vickers hardness tester was employed, using a 10-kilogram load. The results of this examination are shown in Figure 4.

(Continued on next page)

(Physical Tests, cont'd) -

Figure 4.

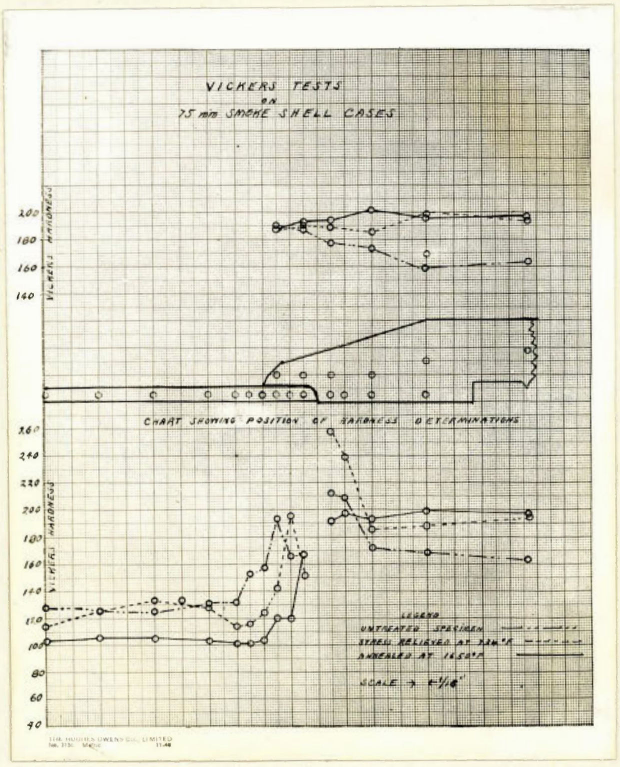


Chart showing variations in Vickers hardness in the neighbourhood of the welded joint.

Figure 5.

Photograph of tensile specimen used. (Approximately 1/2 size).

(Continued on next page)

(Physical Tests, cont'd) -

Tensile test specimens were cut out of the cases. These strips were about 3/8 inch wide. The results are tabulated below:

Test No. --	1.	2.
Specimen No. --	"N"	"A"
Width of test piece -	0.328 in.	0.411 in.
Thickness of tube wall -	0.064 in.	0.064 in.
Area in tube wall -	0.021 sq. in.	0.026 sq. in.
Thickness of weld -	0.036 in.	0.019 in.
Area in weld -	0.012 sq. in.	0.008 sq. in.
Ultimate load -	1,028 pounds	1,106 pounds
Stress in tube wall -	48,952 p.s.i.	42,531 p.s.i.
Stress in weld -	85,667 p.s.i.	138,250 p.s.i.
Load on weld, per linear inch -	3,130 pounds	2,691 pounds
Position of fracture -	In tube wall.	In weld.

A tensile piece was also obtained from the untreated case but it broke at the weld, in handling. The weld was found to be only 0.009 in. thick.

Chemical Analysis:

	Mild Steel Base	Tubular Body
Carbon, per cent -	0.24-0.35	0.06-0.07
Manganese, per cent -	0.65-0.77	0.29-0.39
Phosphorus, " -	0.014-0.026	0.009-0.017
Sulphur, " -	0.026-0.034	0.020-0.038
Silicon, " -	0.18-0.24	None detected.

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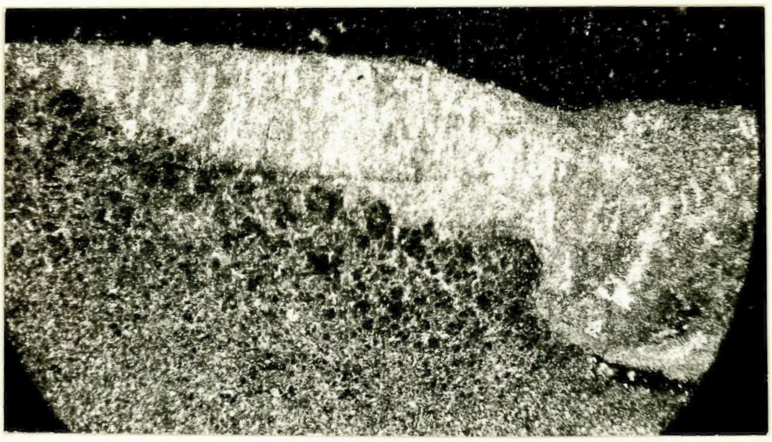
Microscopic Examination:

Figure 6.

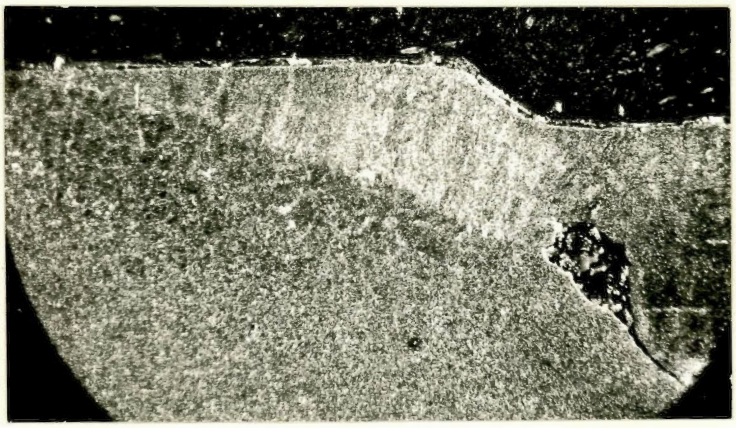


X22, HCl etch.

WELD WITHOUT ANY HEAT TREATMENT.

(Note dendritic structure in weld metal and enlarged grain size in base.)

Figure 7.



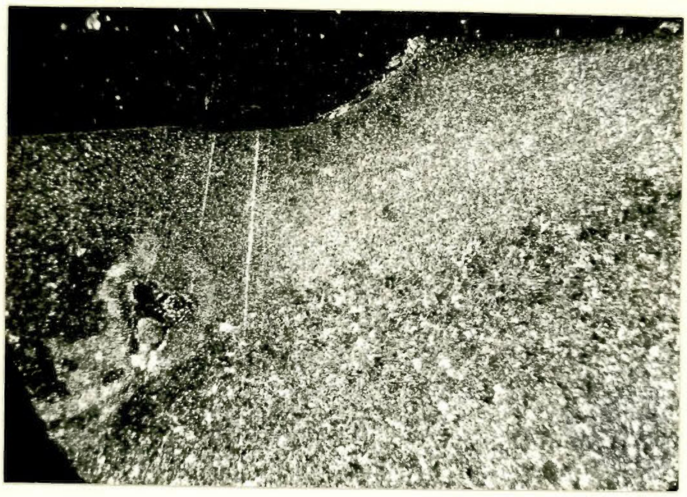
X22, HCl etch.

WELD HEAT-TREATED AT 734° F. FOR ½ HOUR AND AIR-COOLED.

(Note that the same structure as shown in Figure 6 still persists.)

(Continued on next page)

(Microscopic Examination, cont'd) -



X22, HCl etch.

WELD HEAT-TREATED AT 1650° F. FOR 20 MINUTES AND AIR-COOLED.

(Note that the dendritic structure in the weld metal has been broken down but that the structure of the metal in the base has been made coarser.)

Figure 9.

X100, nital etch.

Junction of weld metal and steel base.

NO HEAT TREATMENT.

(Note dendritic structure of weld metal and enlarged grains in base.)

(Continued on next page)

(Microscopic Examination, cont'd) -

Figure 10.

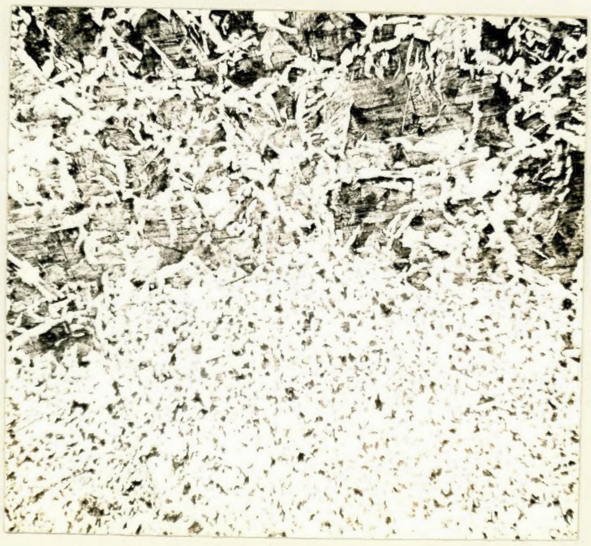
X100, nital etch.

Junction of weld metal and steel base.

HEAT-TREATED AT 734° F. FOR ½ HOUR AND AIR-COOLED.

(Note dendritic structure of weld metal and enlarged grains in base, similar to Figure 9.)

Figure 11.



X100, nital etch.

Junction of weld metal and steel base.

HEAT-TREATED FOR 20 MINUTES AT 1650° F. AND AIR-COOLED.

(Note normalized structure of weld metal and refined structure of metal in base.)

(Continued on next page)

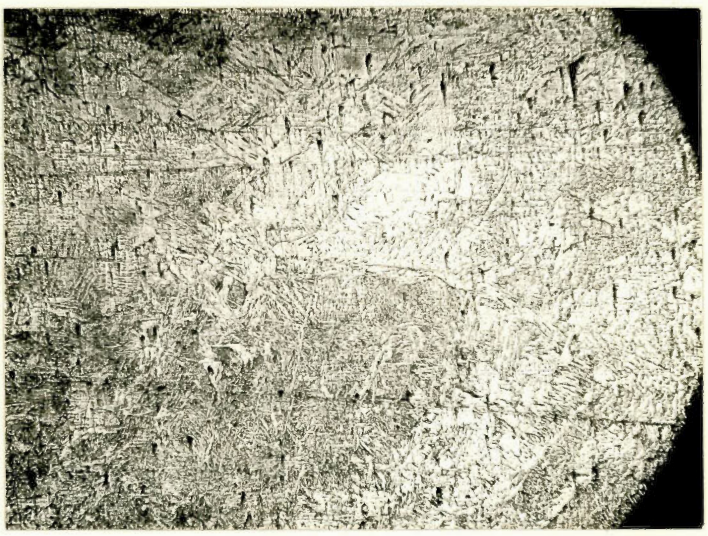
(Microscopic Examination, cont'd) -

Figure 12.

X100, nital etch.

Structure of metal in forged steel base before normalizing, in an area not affected by welding.

Figure 13.



X100, nital etch.

Junction of weld metal with tubular body.

NO HEAT TREATMENT.

(Note the dendritic structure of the weld metal and enlarged grains in tubular body.)

(Continued on next page)

(Microscopic Examination, cont'd) -

Figure 14.

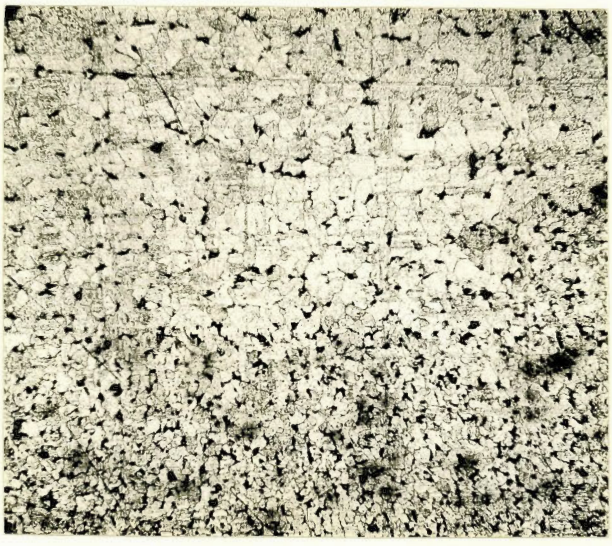
X100, nital etch.

Junction of weld metal with tubular body.

HEAT-TREATED FOR ½ HOUR AT 734° F. AND AIR-COOLED.

(Note persistence of dendritic structure of the weld metal and enlarged grains in tubular body.)

Figure 15.



X100, nital etch.

Junction of weld metal and tubular body.

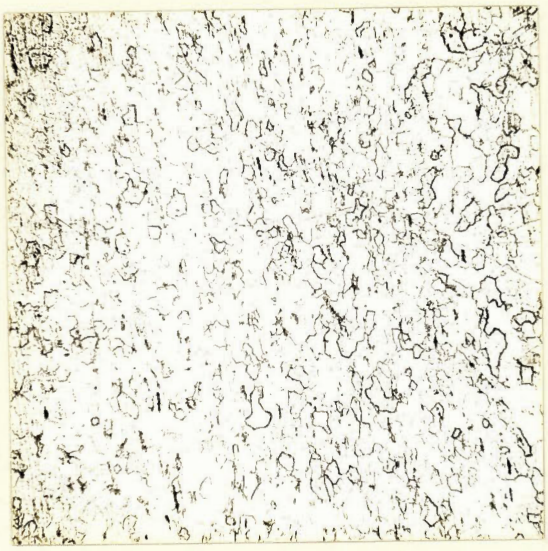
HEAT-TREATED FOR 20 MINUTES AT 1650° F. AND AIR-COOLED.

(Note the refined normalized structure of the weld metal and also the refinement of the structure of the metal in the tubular body.)

(Continued on next page)

(Microscopic Examination, cont'd) -

Figure 16.



Structure of metal in the tubular body before normalizing, in an area not affected by the weld.

X100, nital etch.

(Compare with the body metal in Figure 15.)

DISCUSSION OF RESULTS:

It is evident from a study of the photomicrographs presented above that the heat treatment of stress relieving at 734° F. for ½ hour and air-cooling has not affected the structure created by the welding. The dendritic structure evident in the weld metal is brittle and therefore not the most desirable where impact or shock stresses must be resisted.

The normalizing treatment of 20 minutes at 1650° F. has brought about a desirable transformation in the structure of the weld metal and also has returned the structure of the

(Discussion of Results, cont'd) -

metal in the tubular body adjacent to the weld to a normal condition. (Compare Figures 15 and 16). The structure of the metal in the case adjacent to the weld has been refined by this treatment as compared with the structure created by the heat of welding. However, this structure, as compared with that shown in Figure 12, is coarser than the original structure. Figure 8 would indicate that this coarser structure now exists throughout the base, a condition not altogether undesirable. The metal structure now existing in the weld is characteristic of a metal having good ductility and shock resistance and is desirable where impact or shock stresses must be resisted.

The Vickers tests indicate that the zones of hard metal created by the welding have been eliminated only by the treatment at 1650° F. Since the impact resistance of mild carbon steels normally varies inversely with the hardness, this Vickers chart verifies the conclusions arrived at from the microscopic examination. The increase in hardness of the annealed case in the tubular body adjacent to the weld is due to the higher carbon content of the weld metal.

The tensile tests indicate that providing proper technique is developed, welding will be a satisfactory way to manufacture this article. However, as the investigation has revealed, there is at present a wide variation in the apparent depth of penetration of this weld. The depth

(Discussion of Results, cont'd) -

of the weld will not be affected by any subsequent heat treatment. It was just a coincidence that the only case exhibiting a deep enough weld was the case marked "N".

The following three paragraphs are taken from "Steel and Its Heat Treatment," by Bullens (Battelle),* Vol. 2, page 207:

"In welding, the metal of the weld, and that adjacent to it, are heated above the critical, and are cooled rapidly by the chilling effect of the parent metal which is being joined. The rate of cooling, when the parent metal is cold, may be of the order of that of an air blast, or even of an oil quench.

"As a general guide, the American Welding Society places a limit of 200 Brinell (96 Rockwell B)** on the weld or any metal adjacent to it, in steel to be welded cold and without a stress-relief anneal. The steel maker stays within this limit by holding the C low, ordinarily below 0.15%, and selecting ferrite-forming elements that strengthen the steel in the as-rolled or normalized condition but that do not introduce appreciable tendency toward air hardening. If such elements are used, their amount is strictly limited.

"Higher C grades are welded, but not, in the best practice, without a stress-relief anneal. The 'American Welding Society Handbook' suggests that, if the metal adjacent to the weld shows any zone between 200 and 250 Brinell, slight preheat is desirable in heavy sections, and stress relief advisable for light and mandatory for heavy sections; if there

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* Published by John Wiley & Sons, Inc., New York (1939).
** Equivalent to 200 Vickers.

(Discussion of Results, cont'd) -

"is a zone of 250-300 Brinell, the preheat should be to at least 300°, and all welds should be stress-relief annealed; if the steel hardens to 350 Brinell, the preheat should be to 400° or higher and the weld should be immediately stress-relief annealed before it is allowed to cool."

From Volume 1, page 142, of the same book we quote as follows:

"When a welded specimen shows any zone over 200 Brinell, a stress-relieving draw is used, in best practice, to prevent having a brittle joint. Large welded pipes are stress relieved by annealing at around 1200° F."

The metal in the tubular body of these cases does not show dangerous hardening since it is of low carbon. However, the metal in the base does. Apparently, while this type of structure (Figure 14) is characteristic of a brittle material, in the low carbon range existing it is not considered troublesome for normal structural fabrication and the 1200° F. stress-relieving anneal is considered sufficient. This, however, need not necessarily apply where an explosive shock is to be resisted.

Conclusion:

The normalizing treatment at 1650° F. gives the best metallurgical structure of the three specimens submitted, when toughness is of prime importance.

Recommendations:

In view of the wide variation noted in the thickness of the weld, the manufacturing practice should be

(Recommendations, cont'd) -

improved in order to obtain more uniformity of weld.

As a routine inspection, cases could be picked at random, at a suitable place in the manufacture, and strips about 3/8 inch wide cut out. It is quite feasible to break the tubular body away from the base, even in a good weld, by bending with the hands with a strip of this size. The depth of penetration of the weld can be very readily noted on the fracture.

The source of this variation may either be in the welding or arise from some irregularities in the machining set-up. Sufficient samples were not submitted to permit arriving at any definite conclusion on this count.

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