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EXAMINATION OF BOILER TUBING FOR DDE 261 AND CLASS

by

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PHYSICAL METALLURGY DIVISION

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Mines Branch Investigation Report IR 60-40

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R.F. Knight*

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SUMMARY OF RESULTS

Visual examination of marine boiler tubing samples indicated that they had been cold-drawn as required by the specification. Chemical analyses showed that the specification had been adhered to in this regard except for a negligible discrepancy in the silicon content of two of the tubes. Microscopic observations of the alloy superheater tube showed that it had not been given either of the specified heat treatments. Visual and microscopic observations showed that the tubes were rejectable since they did not conform with Sections 3.2.3 and 3.9 of the specification.

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INTRODUCTION

On December 30, 1959, samples of boiler tubing were received from the Naval Secretary for examination. The tubing had been ordered to a specification (MIL-T-16286B(SHIPS)) which required a high-quality cold-drawn material. Naval examiners claimed that the material received did not have the finished appearance normally associated with cold-drawn seamless tubing, and that it did not conform with Sections 3.2.3 and 3.9 of the specification. These sections are as follows:

"3.2.3. Finish. - The tubes shall be free from mill scale. Slight surface imperfections may be removed by grinding provided the wall thickness is not reduced below the minimum and the ground areas are well faired into the remaining portion of the tube. The grinding medium shall be 180 grit or finer. Special precautions shall be taken with class c tubes to insure that no metallic material is contained in the grinding medium."

"3.9. Workmanship. - The workmanship shall be first class in every respect. The tubes shall be clean, smooth, and commercially straight, with the ends cut square and free from burrs. They shall be free from injurious defects such as laminations, tears, snakes, rings, seams, laps, pits, and sinks. Class c tubes shall not be furnished with a centerless ground finish."

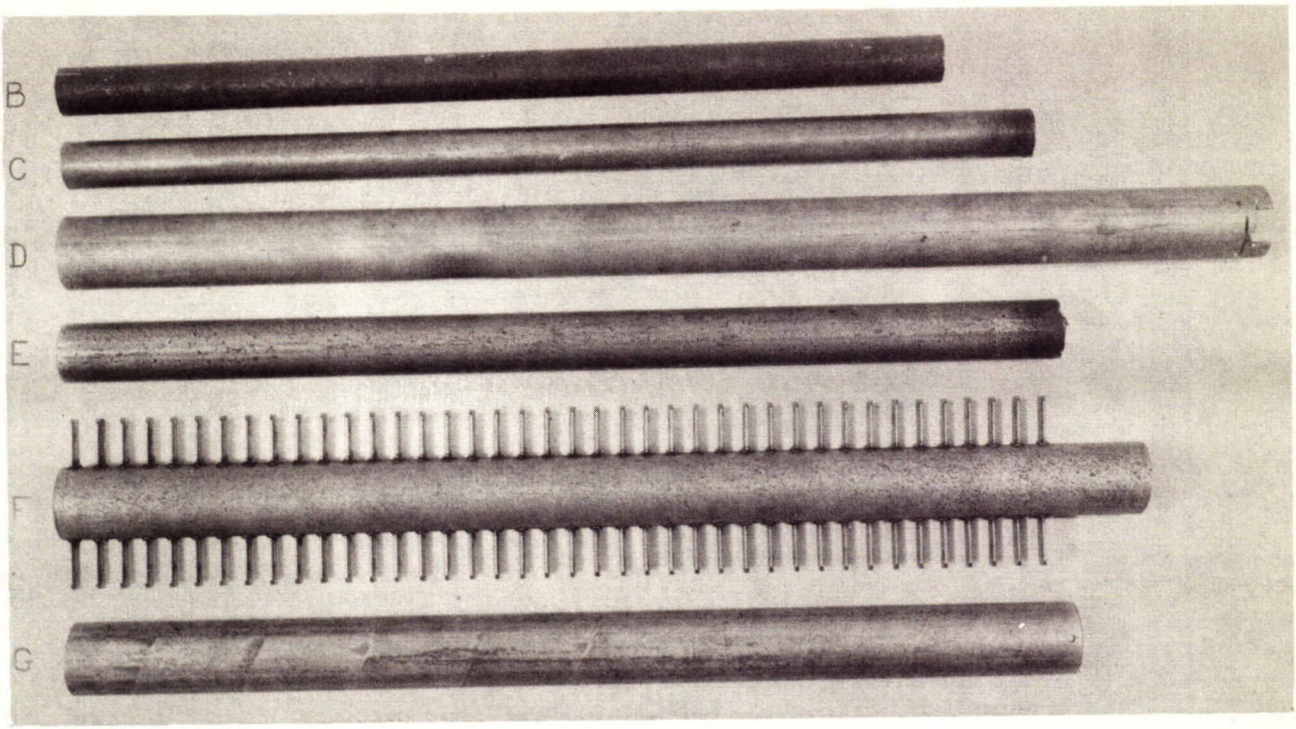
It was requested that a report be prepared concerning the appearance, quality, and evidence of the mode of manufacture of the tubing.

IDENTIFICATION

The tubes received by the Mines Branch were identified by the letters from B to G inclusive. Tube B was a representative sample of a generator tube as received by Court Industries, St. Catherines, Ontario, for pickling and electro-plating of zinc. Tube C was an average generator tube after pickling and before plating. Tube D was one of the better economizer tubes after pickling and plating. Tube E was an example of the poorest quality of superheater tube after pickling and plating. Economizer tube F was typical of the poorest quality tubes in the pickled condition. Tube G illustrated the spiral markings which were seen on many of the economizer tubes.

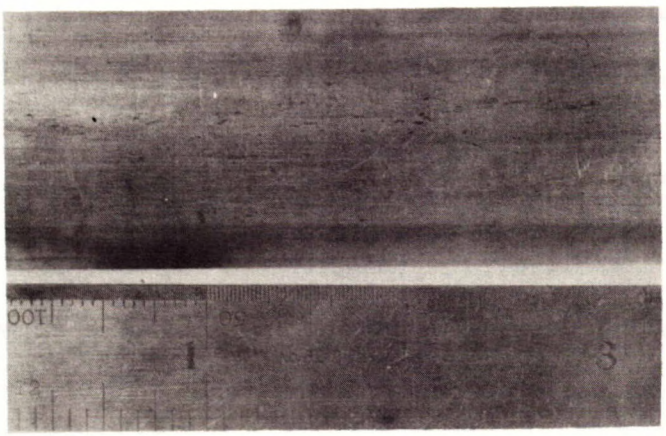
VISUAL EXAMINATION

Figure 1 shows a view of the tubing samples. Figures 2 and 3 show views of a tube, the surface finish of which is considered by the Navy to be a standard of minimum acceptability. A poorer finish is considered to be rejectable. For brevity this will be termed the "minimum-acceptability standard".



Approximately $\frac{1}{4}$ full size.

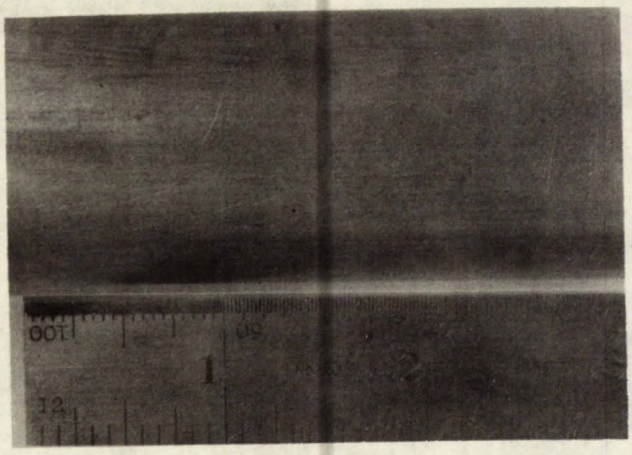
Figure 1. - Boiler Tubing Samples



Full size.

Figure 2. - Minimum-acceptability Standard.

Shows a view of the worst surface.



Actual size

Figure 3. - Minimum-acceptability Standard.

Shows a view which is representative of the majority of surface areas on this tube.

The dark appearance of tube B (in Figure 1) is due to the complete coating of mill scale on the surface. Such scale was found on all the tubes received by Court Industries. Tubes C and D, while having a better finish than tubes E, F and G, were not of as good quality as the minimum-acceptibility standard. They had a number of score marks, small pits and seams. Tubes E and F were markedly pitted, apparently due to the retention of patches of mill scale on the tubes throughout the processing to the final pickling operation. Tube G showed spiral markings both on the inner and exterior surfaces. These are due to excess pressure exerted by the straightener, presumably to compensate for excessive warpage. Measurements on tube E showed variations of only 0.005 in., both in wall thickness and in outside diameter. This high degree of concentricity is indicative of a cold-drawing operation. The interiors of the tubes were shiny and exhibited

the circumferential chatter markings typical of cold-drawn tubing.

CHEMICAL ANALYSIS

Drillings were taken for chemical analyses from each of the tubes. All tubes except tube E were ordered to Class a of the specification. Tube E was ordered to Class f. The results of the analyses, together with the specified analyses for Classes a and f tubing are listed in Table 1

Table 1

Chemical Analyses of Tubing

% Element	Class a	Tube B	Tube C	Tube D	Tube F	Tube G	Class f	Tube E
C	.06-.18	.12	.10	.11	.13	.14	.15 max.	.09
Mn	.27-.63	.50	.59	.45	.52	.53	.30-.60	.48
Si(1)	.10 min.	.07	.06	.06	.10	.10	.50-1.00	.73
S	.040max.	.035	.032	.021	.034	.034	.030max.	.018
P	.045max.	.023	.023	.014	.018	.018	.030max.	.018
Cr	-	-	-	-	-	-	1.00-1.50	1.16
Mo	-	-	-	-	-	-	.45-.66	.56
Al(2)	-	.11	.10	.09	.10	.11	-	.07

(1) - In the case of Class a tubing, when deoxidizing practices involving aluminum in the ladle are employed, the silicon content may be 0.07 per cent minimum.

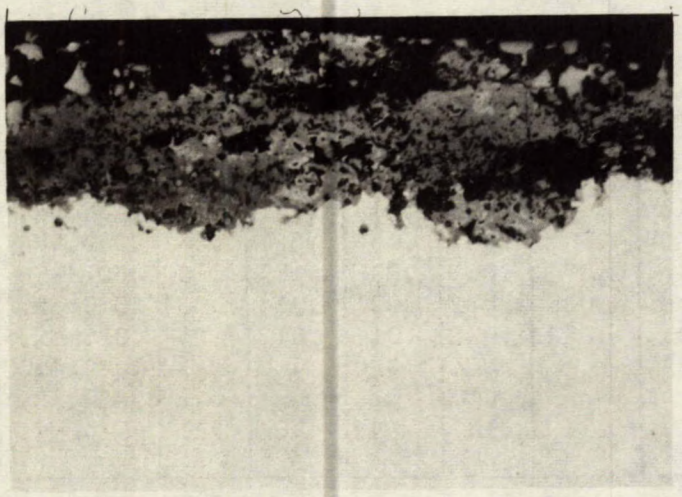
(2) - Quantitative spectrographic analysis.

All analyses were within the specified limits with the exception of silicon in tubes C and D. Since the deoxidation practice involved the use of aluminum, as indicated by the spectrographic analyses, the silicon analysis of Tube B is within the specification. The fact that

Tubes C and D have silicon contents 0.01 per cent below the limit is not significant, since this variation would have no effect on the properties.

MICROSCOPIC EXAMINATION

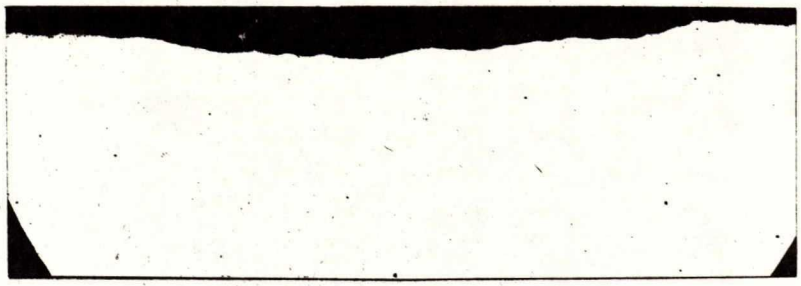
Specimens from each of the tubing samples were examined microscopically, and relevant features are illustrated in Figures 4 to 11B inclusive.



X500 - As polished.

Figure 4. - Longitudinal section from Tube B.

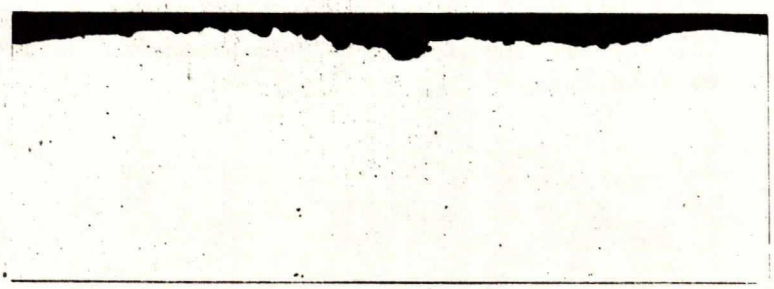
Shows the scale which was representative of the scale found on all tubes received by Court Industries.



X36 - As polished

Figure 5. - Longitudinal section from Tube F.

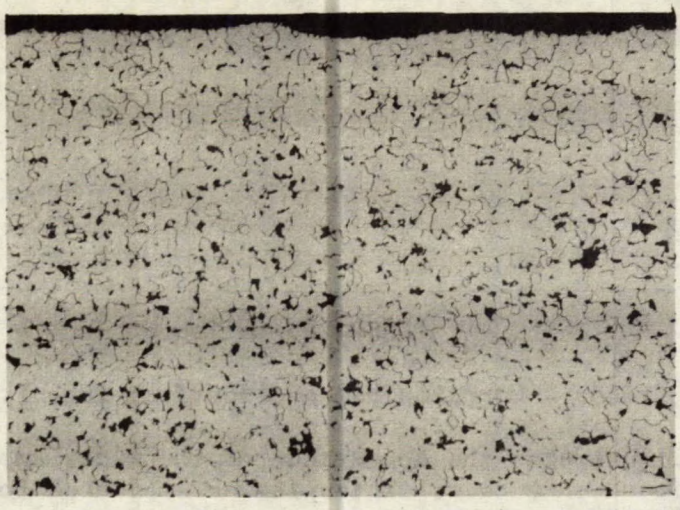
Illustrates the appearance of the wide, smooth pits found on tube F. This pit was estimated to be 0.005 in. in depth.



X36 - As polished

Figure 6. - Transverse section from Tube E.

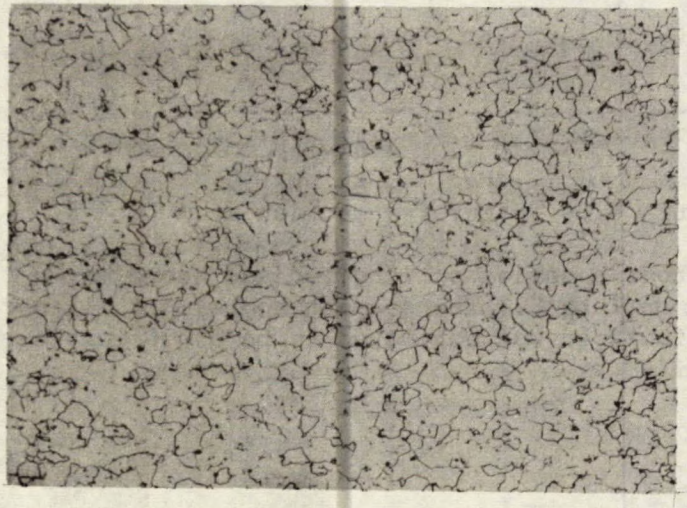
Shows a series of longitudinal score marks found on Tube E. The deepest score mark illustrated in this field was estimated to be 0.006 in. in depth.



X100 - Etched in 2% Nital.

Figure 7. - Longitudinal section from Tube F.

Illustrates the slight surface decarburization found on Tube F.



X100 - Etched in 2% Nital

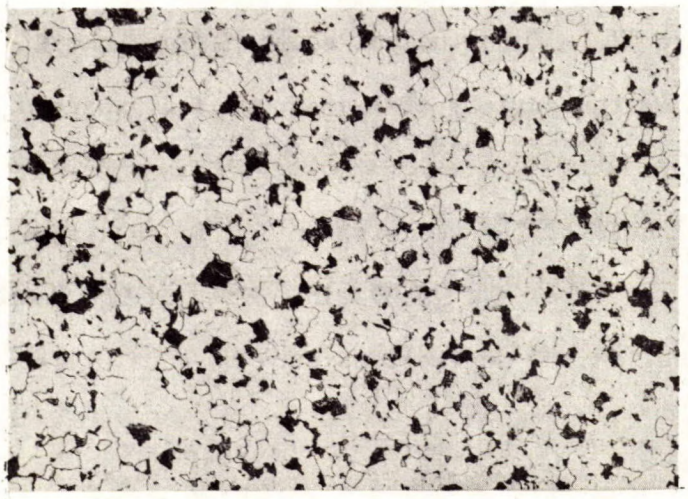
Figure 8. - Longitudinal section from Tube C.

Shows the microstructure of the tube with the lowest carbon content of all the plain carbon tubes, ie 0.10% C.

X100 - Etched in 2% Nital

Figure 9. - Longitudinal section from Tube G.

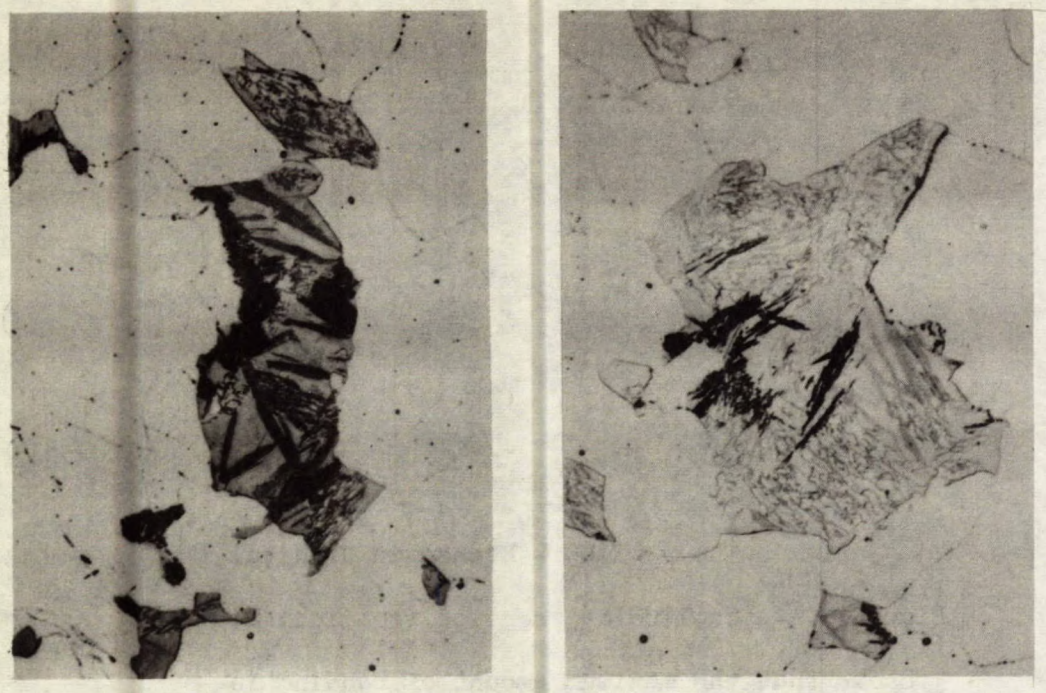
Shows that the maximum amount of banding in the tubes was only a slight trace.



X100 - Etched in 2% Nital.

Figure 10. - Longitudinal section from Tube E.

Illustrates the microstructure of the alloy superheater tube.



X1000 - Etched in 2% Nital

A B

Figure 11. - Longitudinal section from Tube E.

Shows the variety of transformation products seen in the dark etching areas of Figure 10.

The thickness of the scale shown in Figure 4 appeared to be average for the whole tube, i e 0.002 in. Most of the deeper scale patches filled wide, smooth depressions such as that illustrated in Figure 5.

All the tubes showed slight surface decarburization. The small degree of decarburization illustrated in Figure 7 was the maximum amount that could be found.

All the tubes except tube E had the type of microstructure that would be expected after slow-cooling steels of the analyses

reported from above the critical temperature. The presence of transformation products, mainly martensite and bainite, in the dark etching areas of tube E, indicate that the cooling rate from above the critical temperature was too fast to obtain a suitable microstructure with this composition. That is, the alloy superheater tube had not been given either of the specified heat treatments, i e. full annealing, or normalizing and tempering at 1200°F. A more normal microstructure for this grade of steel with the proper heat treatment would be like that of Tube C (Figure 9).

CONCLUSIONS

1 - All the tubing samples were within the chemical specification, except for an insignificant discrepancy in the silicon content for two of the samples.

2 - Visual evidence indicated that the tubes had been cold-drawn, as required by the specification.

3 - Tube E had not been given either specified heat treatment.

4 - The presence of mill scale was not in compliance with Section 3.2.3 of the specification.

5 - The surface finish of the tubes was not consistent with good workmanship.

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