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OTTAWA July 20, 1945.

REPORT

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1908.

Metallurgical Examination of Cast Ring Finishing Dies for Hot Drawing of Seamless Tubing.

(Copy No. 6.)

Bureau of Mines
Division of Metallic
Minerals

Physical Metallurgy
Research Laboratories

CANADA

DEPARTMENT
OF
MINES AND RESOURCES

Mines and Geology Branch

OTTAWA July 20, 1945.

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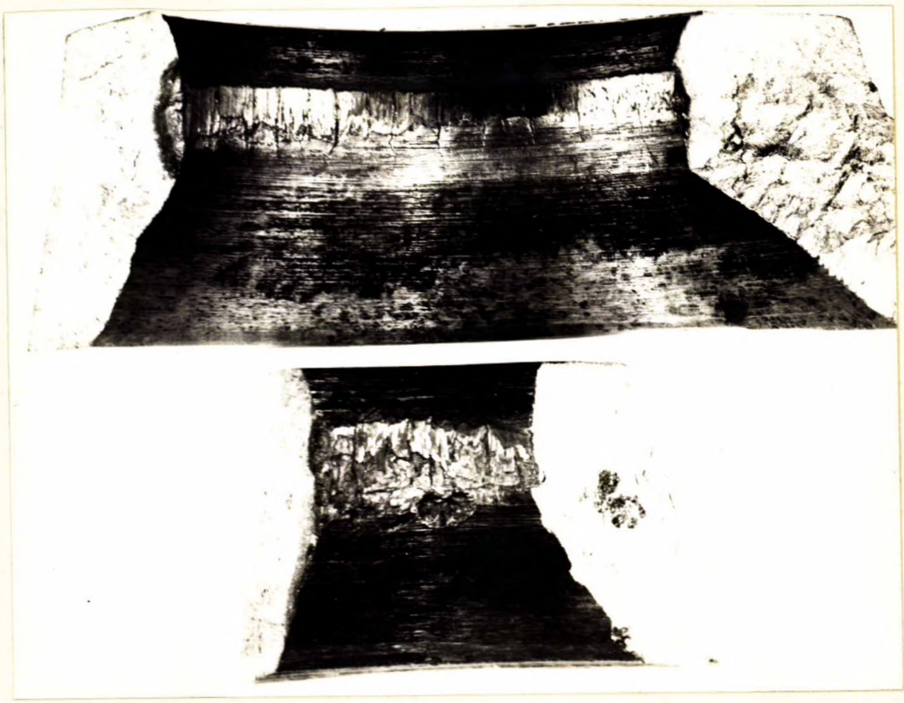
Origin of Material and Object of Investigation:

In July 1944, two pieces of cast ring finishing dies for hot drawing of seamless tubing (see Figure 1) by the Wellman-Seaver Rolling Mill process, were submitted for metallurgical examination by Page-Hersey Tubes, Ltd., Welland, Ontario. These dies (designated Nos. 1 and 2) had been selected for comparison because of the extreme divergence in their performance. Die No. 1, made by Wellman-Seaver Ltd., England, was removed from service after 625 pushed tubes, whereas Die No. 2, cast by Welland Electric Steel, Welland, Ontario, had been scrapped because of wear after 22 pieces.

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

In January 1945, a second lot of dies (see Figures 3 and 4) was submitted for similar purposes. These dies had been manufactured by the same firms as the first lot and their performance was even more contrasting. Die No. 3 (Welland Electric) had cracked after 15 pieces, whereas Die No. 4 (Welland-Seaver) was removed, still in a serviceable condition, after more than 800 pieces.

Figure 1.



No. 1.

No. 2.

PORTIONS OF CAST RING FINISHING DIES (76 MM.)
FROM WELLMAN-SEAVER ROLLING MILL.

No. 1 - Wellman-Seaver, Ltd. (England).
No. 2 - Welland Electric Steel (Welland).

(Approximately full size).

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

Figure 2.

DIE NO. 3.

Welland Electric Steel.

Broken in service.

Figure 3.

DIE NO. 4.

Wellman-Seaver Ltd.,

England.

-

Chemical Analysis:

The results of the chemical analyses made on the four dies submitted are given in the following table. These results are compared with the analysis of a die of German origin reported to have given excellent service, and with that of a die recommended by an American firm.

TABLE I. - Chemical Analyses.

	BRITISH		CANADIAN		GERMAN*	U.S.A.**
	Die No. 1	Die No. 4	Die No. 2	Die No. 3		
	- Per Cent -					
Carbon -	2.51	2.39	2.60	2.18	2.13	2.30
Manganese -	0.48	0.37	0.72	0.23	0.29	0.2-0.4
Silicon -	0.20	0.92	0.53	0.85	0.50	0.2-0.3
Chromium -	25.37	24.81	24.30	19.80	23.15	24.0
Nickel -	-	-	-	0.42	0.24	0.2-0.3
Molybdenum -	-	-	2.90	0.92	-	-
Tungsten -	2.88	2.74	-	4.80	4.75	5.0-5.5
Vanadium -	-	-	-	-	0.25	0.30

* From O.D.M.L. investigation report, "The Chemical and Metallurgical Characteristics of a Cast Ring Die," by T.W. Hardy and H. H. Bleakney, July 21, 1931.

** Recommendations of a U.S.A. firm (name not available). Submitted by J. A. Perry, of Page-Hersey Tubes, Ltd., Welland, Ontario.

Hardness Tests:

Hardness tests were made on the four dies submitted, using the Vickers (30-kilogram load) and the Brinell (3,000-kilogram load) hardness testers. The results are compared in the following table with hardnesses of the German die and of that recommended by the U.S.A. firm.

		HARDNESS		
		Vickers	Rockwell "C" (converted)	Brinell
British Die No. 1	-	511-527	50-51	514
" " No. 4	-	561-586	53-54½	514
Canadian Die No. 2	-	441-481	44-48	415
" " No. 3	-	557-579	53-54	477-495
German	-			388
American	-			520

Magnetic Tests:

The magnetic properties of the four dies were tested by means of a horseshoe magnet. It was found that all four dies were strongly magnetic.

Microscopic Examination:

Photomicrographs were made of the four dies submitted. All samples were etched in Vilella's reagent.

Figures 4, 5 and 6, taken at X100, X250 and X750 magnification respectively, show the microstructure of Die No. 1 (British).

Figures 7, 8 and 9 show the microstructure of Ring Die No. 2 (Canadian) at X100, X250 and X750 magnification respectively.

The microstructure of Cast Ring Die No. 3 (Canadian) is shown in Figures 10 and 11, at X100 and X250 magnification respectively.

Figures 12 and 13, taken at X100 and X250 magnification respectively, show the microstructure of Cast Ring Die No. 4 (British).

Microscopic Examination, cont'd) -

Figure 14 shows the microstructure of the German die, at X400 magnification. This photomicrograph was taken from the report by T.W. Hardy and H. H. Bleakney.

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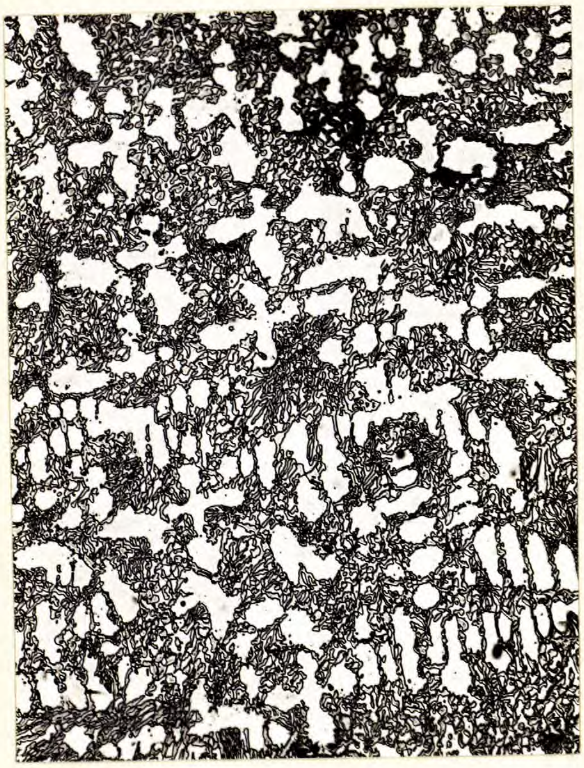
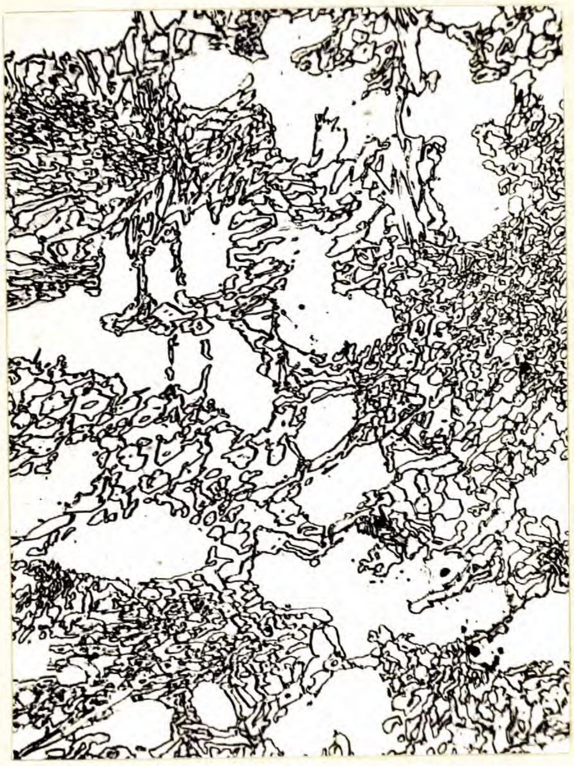
Figure 4.



X100, Vilella's etch.

Figure 5.



X250, Vilella's etch.

Figure 6.

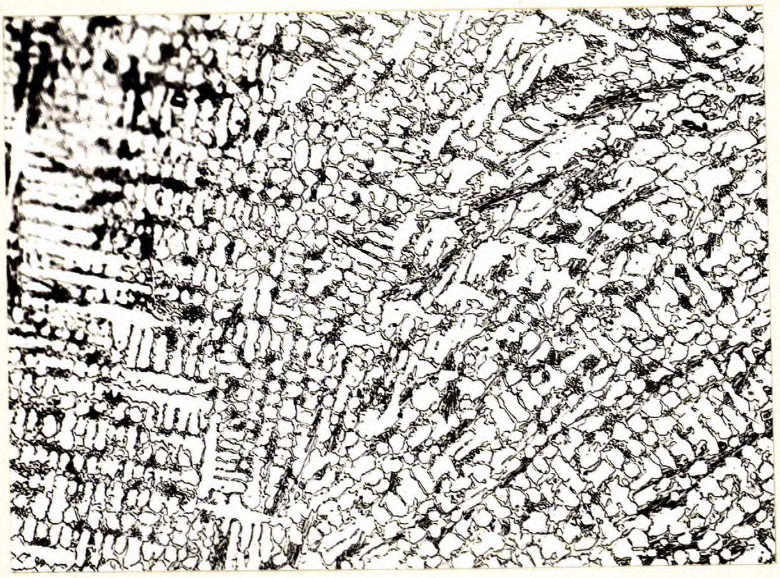
X750

CAST RING DIE NO. 1 (BRITISH).

Proeutectic structure. Dendrites of alpha solid solution and eutectic. Carbides, trigonal.

(Microscopic Examination, cont'd) -

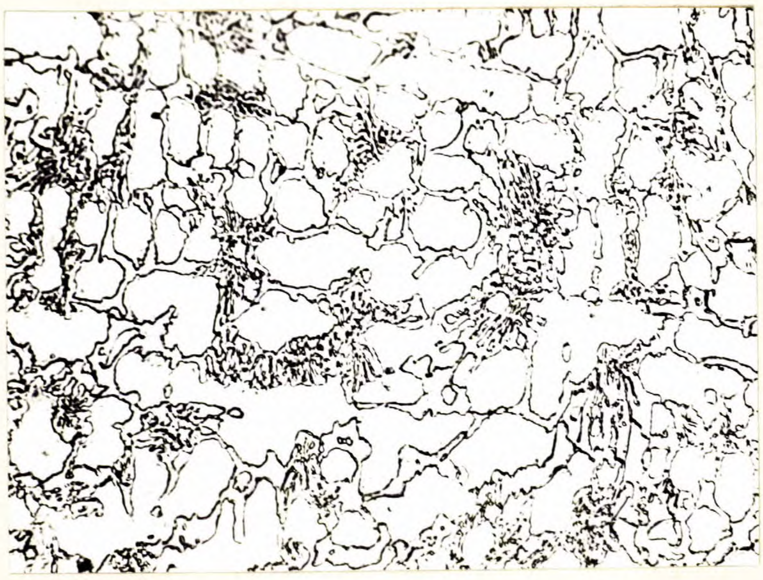
Figure 10.



X100, Vilella's etch.

-

Figure 11.



X250, Vilella's etch.

-

CAST RING DIE NO. 3 (CANADIAN).

Proeutectic alloy. Structure: alpha solid solution and eutectic. Trigonal type carbides.

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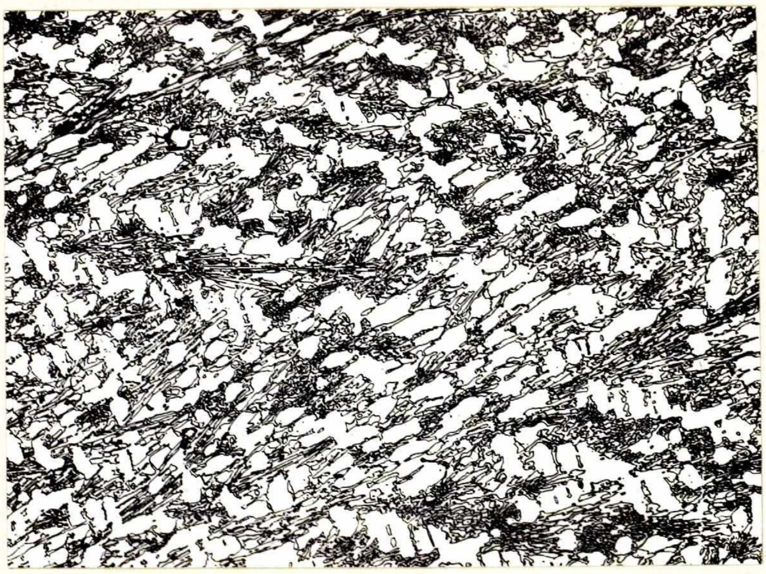
(Microscopic Examination, cont'd) -

Figure 12.



X100, Vilella's etch.

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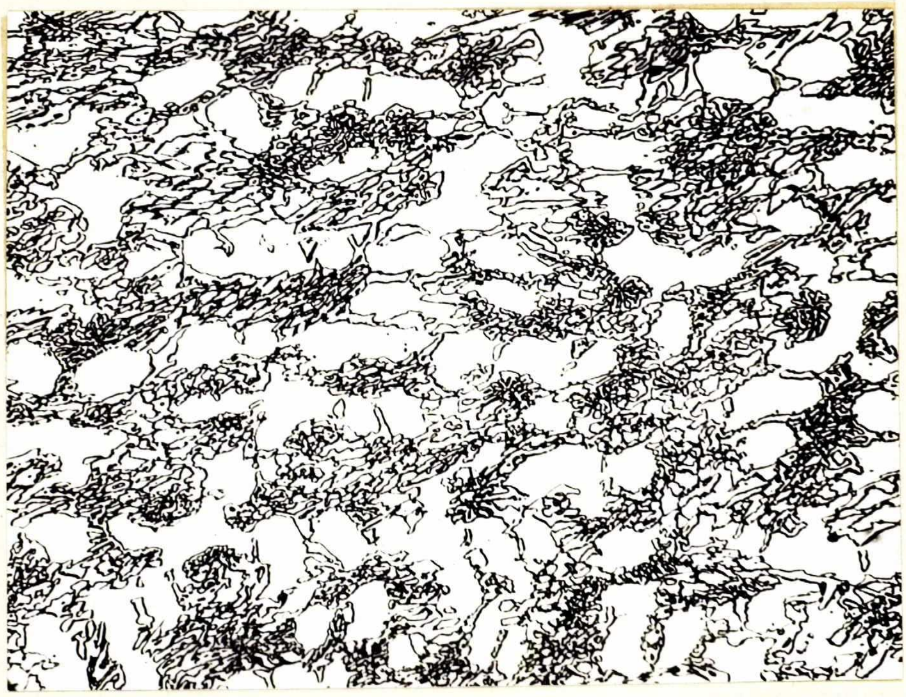
Figure 13.



X250, Vilella's etch.

-

CAST RING DIE NO. 4 (BRITISH).

Proeutectic alloy. Structure: alpha solid solution and eutectic. Trigonal type carbides.

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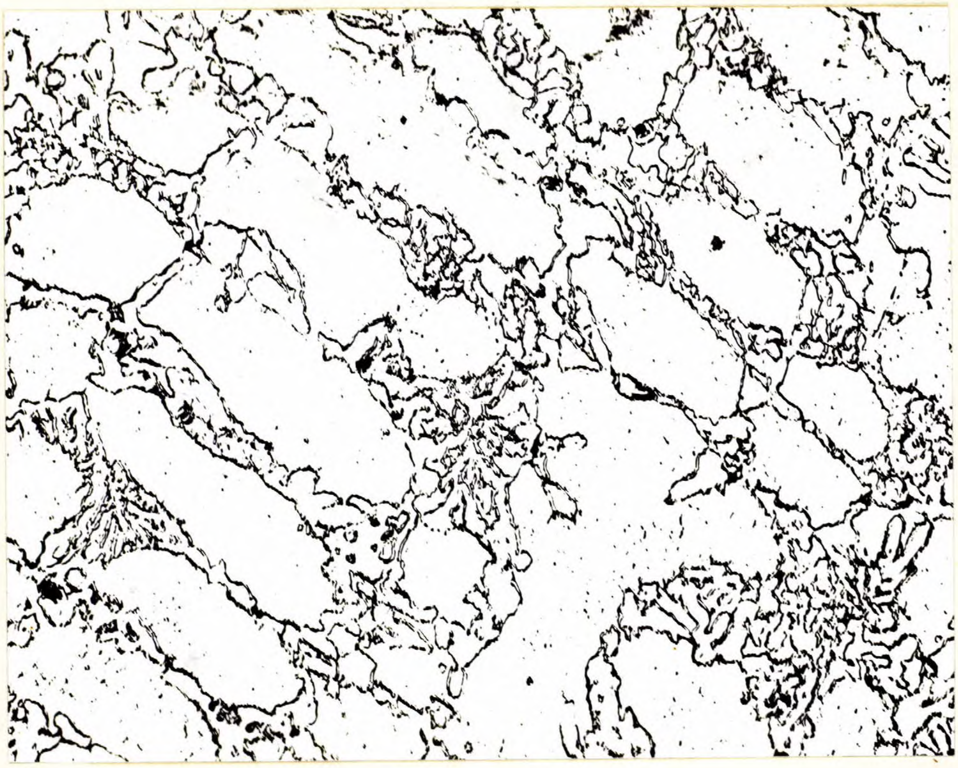
(Microscopic Examination, cont'd) -

Figure 14.



X400, Vilella's etch.

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CAST RING DIE (GERMAN ORIGIN).

Proeutectic alloy. Structure: alpha solid solution and eutectic. Trigonal type carbides.

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Discussion:

Alloys Nos. 1 and 4, both manufactured by the British firm, Wellman-Seaver Limited, are very similar in chemical composition, that is, they are cast irons containing chromium and tungsten as the chief alloying elements.

Ring Dies Nos. 2 and 3, both fabricated by Welland Electric Steel, differ from the British-made alloys in that they both contain molybdenum. Alloy No. 2 contains 2.90 per cent molybdenum and no tungsten, whereas Alloy No. 3 contains 0.92 per cent molybdenum and 4.80 per cent tungsten.

(Discussion, cont'd) -

The following is a summary of the performance of the dies under investigation:

Die No.	Manufacturer	Reason for Removal	Pieces Completed
1	Wellman-Seaver Ltd. (England)	Worn.	625
4	" " " "	"	800+
2	Welland Electric Steel (Canadian)	"	22
3	" " "	Cracked.	15

Microscopic examination reveals a strong similarity in microstructure in Alloys Nos. 1, 3 and 4, in contrast to the entirely different structure of Alloy No. 2.

Assuming that the alloying elements molybdenum and tungsten, in the quantities present in these alloys, do not materially affect the microstructure, the difference in structure can be explained by the quantities of carbon and chromium present.

Alloys Nos. 1, 3 and 4 may be considered proeutectic alloys. The microstructure consists of dendrites of alpha solid solution (white) and a eutectic containing carbides of the predominantly trigonal variety $(Fe, Cr)_7 C_3$. The carbon content has a very profound influence on the microstructure. As the carbon content is increased the relative proportion of alpha solid solution is decreased and the eutectic increased. This explains why Alloy No. 3 (2.18 per cent C) contains a larger percentage of alpha solid solution than either of Alloy No. 1 (2.51 per cent C) or Alloy No. 4 (2.39 per cent C). This condition is also accentuated by the lower chromium content of Alloy No. 3, since high carbon and low chromium act in the same direction.

When the carbon content is increased beyond a certain point a hypereutectic structure results, with the appearance of a different type of carbide, known as the orthorhombic carbides $(Fe, Cr)_3 C$, shown in Figures 7, 8 and 9 (Alloy No. 2). It is admitted that the differences in carbon and chromium contents in Alloys Nos. 1 and 4 are not very great, but it is possible that

(Continued on next page)

(Discussion, cont'd) -

these differences are sufficient to result in a complete change of microstructure. It is also possible that the presence of molybdenum may act so as to influence the change from the trigonal to the orthorhombic type of carbides.

There appears to be a unanimity of opinion regarding the impaired mechanical properties (transverse and tensile strength and deflection) of a cast iron containing the orthorhombic carbides. Hence the carbon and chromium contents must be so adjusted as to avoid the formation of this carbide. For alloys containing 24 to 25 per cent chromium it is generally agreed that the carbon content should be kept lower than 2.5 per cent, for the above reason. It is a known fact that chromium cast irons containing 2.5 per cent carbon or less exhibit the greatest resistance to thermal shock. In this regard it is interesting to note that the carbon contents of the British, German and American dies, as set out in Table I, bear out this opinion.

The wearing properties of Alloy No. 2 were found to be very poor, and it is thought that this is due to the substitution of molybdenum for tungsten. Molybdenum up to 3½ per cent has little effect upon the mechanical properties but induces a considerable amount of coring in the casting.[(2)] Tungsten, however, is noted for the formation of hard, abrasion-resisting, permanent carbide particles.

Cast Ring Die No. 3 was reported to have failed by cracking after a very short service period. The chemical analysis shows a lower chromium content, 19.8 per cent, as against 23 to 25 per cent in the other alloys, but this cannot be blamed for the cracking. It should be borne in mind that these alloys are all inherently brittle and breakage will result if there is imperfect seating between the conical surfaces of the ring die and of its holder ring. Hence it is very important that the dies be ground, after casting, to very accurate dimensions.

(Discussion, cont'd) -

A comparison of the analyses of the British, German and American dies (Table I) indicates a relatively fixed chromium content, that is, 23 to 25½ per cent. No molybdenum is specified in any of the analyses. The tungsten content varies from 2.75 per cent to 5.5 per cent, and it is suggested that alloys of varying tungsten content be made to determine the effect of tungsten upon their wearing properties.

The hardness of these cast alloys can be increased by quenching from 1000° C. (1830° F.), and it is suggested that experiments be conducted to determine the properties of alloys so heat-treated.

Summary and conclusions:

1. Two lots of dies were examined, designated 1, 2 and 3, 4.

2. Dies No. 1 and 4 were of British origin (Wellman-Seaver Limited) whereas Dies Nos. 2 and 3 were of Canadian origin (Welland Electric Steel, Welland, Ontario).

3. The British dies (Nos. 1 and 4) gave very good performance, 625 and 800 pieces of tubing before scrapping.

4. The two Canadian dies selected gave very poor performance. Die No. 2 wore out after 22 pieces and Die No. 3 broke after 15 pieces.

5. Die No. 2, Canadian, was found to differ in chemical content from the British dies in that the carbon content was higher and molybdenum had been substituted for tungsten. Failure due to premature wear is ascribed to the lack of tungsten.

6. Die No. 3 (Canadian), which had cracked in service, was found to be low in chromium. Failure, however, is attributed to improper finishing of the conical die surface.

7. A survey of the analyses of dies of British, German and American origin suggests the following limits (in per cent):

(Continued on next page)

(Summary and Conclusions, cont'd) -

Carbon	Chromium	Tungsten
2.15-2.50	23-25	2.75-5.5

8. The carbon content should be kept below 2.5 per cent in order to prevent the occurrence of the orthorhombic type of carbides.

9. The hardness of these alloys can be increased by quenching from 1830° F.

Recommendations:

1. It is recommended that alloy rings be cast in the experimental foundry of these Laboratories and tested in actual service. (A pattern for the 76-mm. die was supplied by Page-Hersey Tubes, Limited).

2. The first dies cast should have the following nominal composition:

		Per Cent
Carbon	-	2.3
Manganese	-	0.20-0.40
Silicon	-	0.20-0.40
Chromium	-	25.0
Tungsten	-	2.75

3. Dies should be made of the above chemical composition but varying the amounts of tungsten. It is also suggested that small amounts of nickel and vanadium be added.

4. A study should be made of the effect of heat treatment on the serviceability of the dies.

References:

1. ALLOYS OF IRON AND STEEL (Kinzel and Franks), Vol. II, pp. 233-240.

   McGraw-Hill Book Co., Inc., New York, 1934.

2. THE BOOK OF STAINLESS STEELS (E. E. Thum), pp. 359-361.

   American Society for Metals, Cleveland, Ohio, January 1935.

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