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R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1324.

Examination of High Purity Copper Rods for Use in Production of Copper Crushers (Pressure Cylinders).

(Copy No. 18.)

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 Problem and Object of Investigation:

The problem of the introduction into Canada of independent production of copper crushers (known in the United States as "pressure cylinders"), used for measurement of pressures developed in gun barrels by the explosion of the propellant, was initiated on July 25th, 1942, at a conference, by Mr. A. N. Budden, D.A.D.S.A., for Directorate

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

of S.A. and S.A.A., for Inspector-General, Inspection Board of United Kingdom and Canada, Ottawa, Ontario.

The introduction of copper crusher production in Canada makes necessary the preparation of a specification for the material to be used and also the examination of available copper rod for determination of its suitability for this purpose. At the conference it was agreed that the Metallurgical Laboratories of the Department of Mines and Resources at Ottawa would undertake this project.

Available information, an assortment of sample crushers, and various British and American specifications and drawings were submitted by Mr. A. N. Budden as obtained, together with some twelve letters, dated from July 30th to November 13th, 1942. For the examination of the quality of the available copper rod material, five samples were submitted.

This present report covers only the results of the examination of the submitted copper rods in respect to their intended use in the manufacture of copper crushers.

In the report immediately following, Report of Investigation No. 1325, the available existing specifications and also information given in the literature will be considered.

In a third report, No. 1326, a specification will be proposed for copper rods to be used in the production of copper crushers in Canada.

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Nature of Samples Received:

For the comparative examination of available high-purity copper rods for the production of crushers, the following sample rods were received:

Table I.

Sample Rod No.	Nominal diameter, inches	Rod manufacturer or supplier	Copper producer	Quality of copper sample
1	0.315	Phillips Electrical Works Limited, Brockville, Ontario.	International Nickel Co.	Horizontal cast electrolytic copper.
2	0.315			Vertical cast electrolytic copper.
3	0.5	Canada Wire & Cable Co., Leaside, Ontario.	Noranda Mines Limited.	Electrolytic copper.
4	0.4			
5	0.485	Westinghouse E. & M. Co., Pittsburgh, Pa.	(probably) Scomet Engineering Company, New York, N.Y.	O.F.H.C. (oxygen-free, high conductivity) copper.

All of the copper rods submitted had rather poor surfaces, showing many defects (scratches received during production, scale from annealing, etc.). Some of these surface defects, especially the pitted areas, were quite deep.

Annealing of the Samples Received:

To ensure the uniformity of the submitted copper rods for comparison of their properties, all samples were given the following treatment:

A 1-hour annealing in salt bath at 540° C. (1000°F.); air-cooling.

Cleaning by immersing in aqueous solution of sulphuric acid and then rinsing in hot water.

Chemical Analysis:

1. Spectrographic Analysis:

The spectra were standardized against Hilger pure copper electrodes in order to make some estimate of quantities of impurities. Manganese was not determined in the Hilger electrodes.

Table II.

Element:	Sample No. 1	2	3	4	5
Mn	N*	Barely detectable.	N	Barely detectable.	Distinct trace.
Pb	N	Barely detectable; -0.0001%.	N	Very faint trace; -0.0004%.	Very faint trace; -0.0004%.
Sn	N	N	N	Barely detectable; -0.0002%.	N
Fe	Barely detectable; -0.0005%.	Very faint traces; -0.001%.	Barely detectable; -0.0005%.	Trace; -0.004%.	Barely detectable; -0.0005%.
Ni	-0.0004%.	-0.0004%.	-0.0004%.	-0.0004%	-0.0004%.
P, Bi, As, Sb, Cr, Si, Te	None detected				

* N = None detected.

Note: The minus sign as used here indicates "less than".

2. Wet Analysis:

The "distinct trace" of manganese found by the spectrographic analysis in Sample No. 5 was determined as 0.0014%.

The determination of the oxygen and sulphur contents was carried out by the International Nickel Company at Copper

(Chemical Analysis, cont'd) -

Cliff, Ontario, (their Lab. No. 222373-77), with the following results:

Table III.

Sample No.	Oxygen	Sulphur
	- Per cent -	
1	0.0039	0.0013
2	0.0036	0.0014
3	0.0035	0.0014
4	0.0040	0.0013
5	0.0037	0.0014

Physical Properties:

1. Density:

Density determinations were made by the method of weighing in air and water respectively, on machined test pieces.

The following results were obtained:

Table IV.

Sample No.	Density, g./c.c.
1	8.93
2	8.95
3	8.93
4	8.93
5	8.94

2. Electrical Resistivity:

The measurements of electrical resistivity were carried out by the National Research Laboratories, Ottawa, Ontario, (Report No. PHE-452), on the sample rods in the "as received" condition, without special preparation of

(Physical Properties, cont'd) -

specimens.

The following results were obtained:

Table V.

Sample No.	Electrical resistivity@ in microhms per cubic centimetre	
	Measured at 22° C.	Corrected to 20° C.
1	1.721	1.706
2	1.725	1.710
3	1.723	1.708
4	1.731	1.716
5	1.726	1.711

These measurements were made with room temperature of 22° C., and corrected to 20° C.

Due to the physical condition of these rods (surface defects from the production), it is difficult to estimate the error of these measurements. It is believed that the error will not exceed $\frac{1}{4}$ of one per cent.

@ The International Annealed Copper Standard, adopted in 1913 to represent the average of high-grade commercial conductivity copper, has, at 20° C., a resistivity of 1.7241 microhms (cm.).

U.S. Army Specification No. 57-154-1A, covering the inspection of special copper rods for pressure cylinders (copper crushers), requires that the electrical resistivity of these copper rods at 20° C. shall not exceed 1.71263 microhms (cm.).

Mechanical Properties:

1. Tensile Tests:

Table VI.

	Sample No. 1	2	3	4	5
Diameter of specimen, inches	0.252	0.257	0.278	0.282	0.307
0.2 per cent proof stress, p.s.i.	10,300	9,200	8,400	9,000	8,100
Ultimate T.S., p.s.i.	33,500	36,000	33,700	34,500	27,000
Elongation in 1", per cent	68	64	64	58	62
" " 2", "	54	48	53	46	49
Reduction of area, "	69	75	65	71	89

2. Hardness:

Hardness was determined by the Vickers method, using a 10-kilogram load. The locations of the hardness tests are shown in the following sketch: (cross-section of bar) -

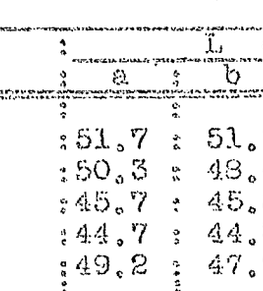


Table VII shows the results in Vickers hardness numbers:

Table VII.

Sample No.	Location a	b	c	d	e
1	51.7	51.9	52.2	52.0	51.9
2	50.3	48.6	47.6	49.4	53.1
3	45.7	45.3	44.4	47.6	47.8
4	44.7	44.3	45.8	44.6	45.6
5	49.2	47.9	45.9	46.9	50.7

(Mechanical Properties, cont'd) -

3. Crushing Tests:

The British O.F. Specification No. XG/4.B, governing the supply of copper rods for the production of copper crushers, requires that a piece of rod, one inch in length, will be placed on end, and must be capable of being cold-hammered or crushed down to a thickness of 0.375 inch, without showing either crack or flaw. This test was carried out on samples 1-inch long in the "as received" condition on the tensile test machine, with results given in Table VIII:

Table VIII.

Sample No.	Diameter before test, inches	Length, in inches: Before test	After test	Load, in pounds	Condition of surface, after test
1	0.315	0.995	0.375	10,800	Without cracks.
2	0.315	0.993	0.375	10,650	" "
3	0.500	0.985	0.375	29,300	" "
4	0.400	0.997	0.375	16,100	" "
5	0.485	0.998	0.375	25,300	" "

4. Compression Tests:

Comparative compression tests were made to determine the uniformity of the examined material and to check the behaviour of the material at different speeds of load application. For this test, two different sizes of specimens were used. For Samples Nos. 1, 2 and 4, the nominal specimen dimensions were: diameter - 0.30 inch, and height - 0.60 inch.

For Samples Nos. 3 and 5, the nominal specimen dimensions were: diameter - 0.465 inch, and height - 0.930 inch.

The compression tests were obtained (a) by load increements of 2,000 pounds (where possible) up to the load

(Mechanical Properties, cont'd) -

limit of the machine; (b) by loading quickly to 10,000 pounds, then increasing by 5,000-pound increments.

The results are shown in Tables IX and X:

Table IX
(Specimen size: 0.30 in. diam. x 0.60 in.)

Load, in pounds	COMPRESSION OF SAMPLE, IN INCHES — Sample No.					
	1a	1b	2a	2b	4a	4b
2,000	0.052	"	0.051	"	0.045	"
4,000	0.161	"	0.161	"	0.158	"
6,000	0.266	"	0.268	"	0.261	"
8,000	0.338	"	0.337	"	0.333	"
10,000	0.381	0.375	0.378	0.380	0.376	0.377
12,000	0.414	"	0.409	"	0.408	"
15,000	0.444	0.441	0.437	0.440	0.440	0.442
20,000	0.477	0.474	0.471	0.475	0.475	0.476

Table X
(Specimen size: 0.465 in. diam. x 0.930 in.)

Load, in pounds	COMPRESSION OF SAMPLE, IN INCHES — Sample No.			
	3a	3b	5a	5b
2,000	0.010	"	0.008	"
4,000	0.052	"	0.051	"
6,000	0.107	"	0.112	"
8,000	0.177	"	0.177	"
10,000	0.250	0.253	0.252	0.250
12,000	0.322	"	0.326	"
14,000	0.386	"	0.391	"
16,000	0.442	"	0.447	"
18,000	0.485	"	0.490	"
20,000	0.520	0.507	0.527	0.513

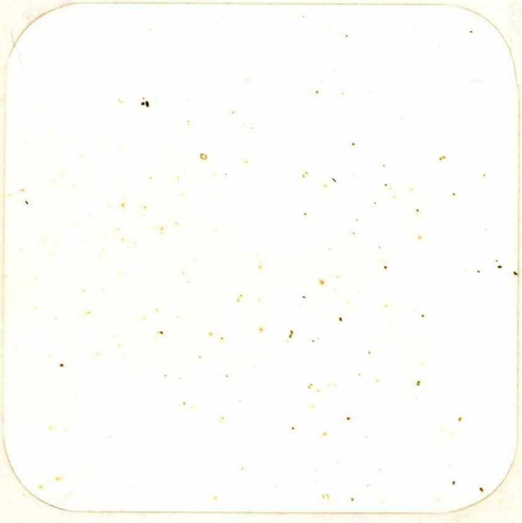
Considering the non-uniformity of the tested samples (different copper qualities and production methods) and the lack of special compression equipment (jigs, etc.), the above results show very similar behaviour in all examined samples.

Metallographic Examination:

Microscopic examination of unetched specimens showed that Samples Nos. 1 to 4 contain similar amounts of oxides (Figure 1) confirming the results of the chemical analysis (Pages 4-5).

Figure 2 shows the unetched section of Sample No. 5 (O.F.H.C. copper) practically free from oxides. This microphotograph reveals that the result of the chemical analysis of Sample No. 5, concerning the oxygen content, is not confirmed.

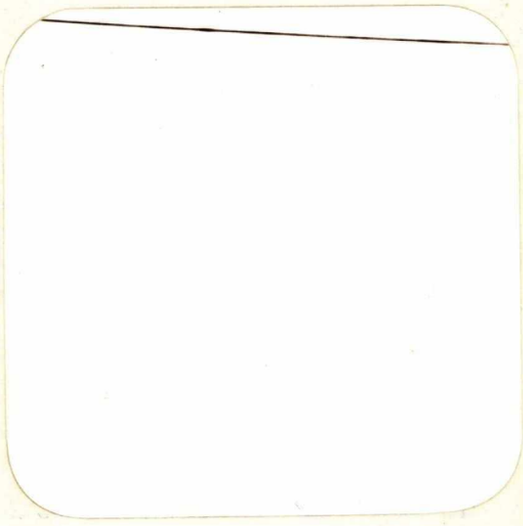
Figure 1.



X250, unetched.

Sample No. 1.

Figure 2.



X250, unetched.

Sample No. 5.

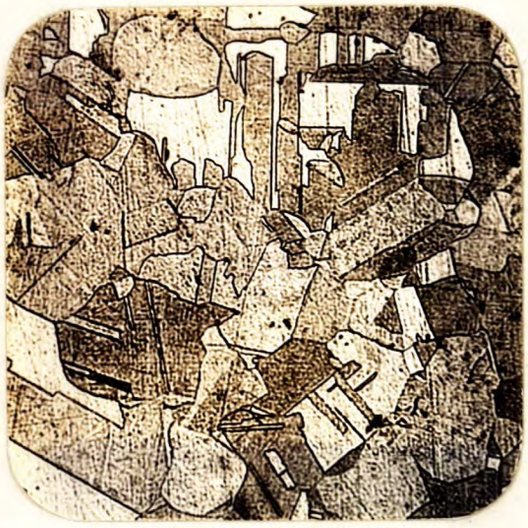
Figures Nos. 3 to 10 show the microstructure of the examined samples, in two magnifications, revealing the differences in grain size.

(Continued on next page)

(Metallographic Examination, cont'd) -

Figures Nos. 3 to 6 show average grain size in Samples Nos. 5 and 3 respectively.

Figure 3.



X250, etched.*

Figure 4.

X100, etched.*

SAMPLE NO. 5.

(Average grain diameter: approximately 0.050 mm.)

Figure 5.

X250, etched.*

Figure 6.

X100, etched.*

SAMPLE NO. 3.

(Average grain diameter: approximately 0.030 mm.)

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* Etching reagent: 8 p. FeCl, 25 p. HCl, and 100 p. H_2O.

(Metallographic Examination, cont'd) -

Figures 7 to 10 show the difference of grain size found in the same cross-section of Sample No. 1 (sample size = 5/16-inch diameter).

Figure 7.

X250, etched.*

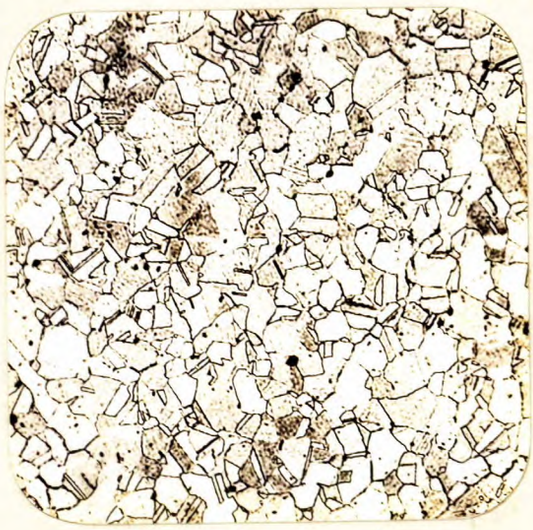
Figure 8.

X100, etched.*

SAMPLE NO. 1, EDGE.

(Average grain diameter: approximately 0.040 mm.)

Figure 9.



X250, etched.*

Figure 10.

X100, etched.*

SAMPLE NO. 1, INSIDE.

(Average grain diameter: approximately 0.020 mm.)

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* Etching reagent: 8 p. FeCl, 25 p. HCl, and 100 p. H_2O.

Discussion of Results:

The results of the examination show generally that all submitted rods were made from copper of very high purity. The results of the chemical analysis are not complete, due to there being an insufficient amount of material available for the determination of very small contents of impurities, but are sufficient to indicate that all submitted materials were of the order of 99.95 per cent copper purity.

The results of the determination of density and electrical resistivity, and the metallographic examination, confirm the above-mentioned purity of the copper.

The mechanical tests also showed the high quality of all the submitted specimens.

The micro-examination showed differences in the grain size. This could be expected since the material was taken from available stock, not especially produced for this purpose by any of the suppliers.

The examination showed that no particular advantage would be obtained by the use of copper of O.F.H.C. quality in preference to the other submitted high-purity copper grades.

CONCLUSION:

The quality of all submitted sample copper rods was found to be entirely satisfactory, except for the surface condition of the rods, which undoubtedly would be improved when demanded for the purpose of manufacturing copper crushers. Improvements in the uniformity of the material, i.e., grain size, hardness, etc., definitely are not difficult to attain when so specified.

In consideration of the proper requirements for this material, as shown in this investigation, a specification for "Copper, Rods, for manufacture of crushers," will be proposed in Report of Investigation No. 1326, now being prepared.

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JWM:GHB.