Tile

# FILE GODY

O T T A W A November 17th, 1942.

REPORT

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).

distinction when althoughters and hard state and above taken and althoughters are also althoughters and althoughters are also althoughters and althoughters are althoughters and althoughters are also althoughters are also althoughters are also althoughters are also althoughters and althoughters are also althoughters are also althoughters and althoughters are also all althoughters are also althoughters are also althoughters are also all althoughters are also all althoughters are also althoughters are also all all althoughters are also althoughters are also all althoughters are also all althoughters are all althoughters are also all alt

BUREAU OF MINES DIVISION OF METALLIC MINERALS

ORE DRESSING AND METALLURGICAL LABORATORIES

DEPARTMENT
OF
MINES AND RESOURCES
MINES AND GEOLOGY BRANCH

OTTAWA

November 17th, 1942.

REPORT

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).

# 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.

#### 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.

| errama ermiérri (82 junitée suit en   | Isanimal.  | 8 ROCI   | Contract (Maintenantin) I Contact assessed in overlandors and on the foreign of the<br>G   | : Qualley of   |
|---------------------------------------|--|--|--|--|
| Sample                                | :diameter,   | :manufacturer  | : Copper   | copper   |
| Rod No.                               | : inchas   | *1 0   | : producer   | sample   |
|                                       | 3  | The state of the s       | "g<br>on the figure and empty in providence of the material and the figure of the figure of the figure of the material<br>Language and the figure of | And a 1-m month accountly were startly from the startly and the startly of the st |
| 3.                                    | : 0,315 )  | :Phillips Elec-  |  | : Morizontal cast  |
|                                       | , ,  | : trical Works   | ):Intérnational  | : electrolytic   |
|                                       | )  | : Limited,   | ): Nickel Co.  | s copper,  |
| \$                                    | ; 0,315  | : Brockville,  | ) :  | : Vertical cast  |
|                                       | ;  | : Ontario.   | ) a  | : electrolytic   |
| exception with process of distance of | Commence of the property of which a property of the comments o | D<br>D<br>Describes of completenests transposes of the particles a proper compression of the property of the property of the particles of the partic | A CONTRACTOR OF THE PROPERTY O       | : copper.  |
| 3                                     | : 0,5  | : Canada Wire  | ) :  | 2 September 2015 April |
|                                       | ;  |  | ):Norenda Minos  | u: Electrolytic  |
| 4.                                    | ; 0,4  | : Leaside,   | : Limited.   | : copper.  |
| WUTER WAY ASSETS SUFFICION            | D. O. STEEN BOOKSTEE WAS DECEMBED.   | Contari, o   | A 19.  | *<br>5   |
| 5                                     | 0,485  | : Westinghouse   |  | 2 Section 1 Community and Community of the Language of the Lan |
|                                       | 6  | E. & M. Co.,   |  | O.F.H.C.   |
|                                       | ° «  | : Pittsburgh,  | :Engineering   | : (oxygen-free,  |
|                                       | a<br>a   | r Pa,  | : Company,   | : high conduct-  |
|                                       | 3  | 6  | :New York,   | : lulty) copper.   |
| THE DESCRIPTION                       | angarigan manandiningnan-sam<br>a  | de<br>de la companya da la<br>Companya da la companya da la comp  | A N. Y.  | O B STATE OF THE TOTAL THE REST OF THE STATE |

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 Roceived:

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

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

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

#### Chemical Analysis:

## 1. Spectrographic Analysia:

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.

Element: Mad Min Baroly Barely Distinct :detectable. :detectable.: traco. N: : Very faint : Very faint Pb Barely И trace; :detectable;: : trace; :-O,0004%. -0.0004%. :-0,0001%. Sn M: N N. : Barely :detectable; : :=0.0002%. Tro Baroly :Very faint :Barely :Trace: : Baroly :-0.004%. detectable; :detectdetect-: traces; able; :-0.001%. :able: -0.0005%. ~0.0005%.; ; -0,0005%.s Ni. ·-0,0004%,:-0,0004%, ;=0.0004%.;=0.0004% : =0.0004%. P, Bi, As, Sb, Cr, Si, To --None detected---

Table II.

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

D W w None detected.

(Chemical Analysis, contid) -

Cliff, Ontario, (their Lab. No. 222375-77), with the following results:

| and the second s | Tab.   | 6 III.  | a leletapäinipideä emisso essavaltaideit seleiteka   |
|--|--|---|--|
| Sample No.   | 6  | Mygon   | Sul.phur   |
|  | 3  | - Per c   | ent =  |
| The same and a second of the s | 3  | erreichte err seine a mit eile se, ab grauf dem hif prim telefte an erreicht gegennig ist die errei.<br>Im Britis ferreichte von erwanning met erwannten erreicht dem bild in die er steme bei die zu | ado antesa. Procesa de exemplos estas e  |
| ***  | 9  | 0,0039  | 0.0013   |
| 3  | a<br>is  | 0,0036  | 0.0014   |
| 3  | o<br>o   | 0.0035  | 0,0014   |
| 4.   | <u>.</u>   | 0.0040  | 0.0013   |
| 5  | 6  | 0.0037  | 0.0014   |
|  | ů<br>ů   |   | •  |
| ·····································  | CONTRACTOR AND ADMINISTRATION OF THE PARTY O | en er eine Berger von der   | to the synthesis and the second street of the secon |

#### 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.

| W. COMMERCIAL DESCRIPTION OF THE STATE OF TH |                           |  |  |  |  |  |  |  |
|--|---------------------------|--|--|--|--|--|--|--|
| Westmendarie to destruite an agreement and   | 44 + 44 10 FX + 14 1      | enen dermekilbenkennstannikamien arstannen ansteik   |  |  |  |  |  |  |
| Sample   | 4                         | Density,   |  |  |  |  |  |  |
| No.  | a<br>>                    | g./c.c.  |  |  |  |  |  |  |
| acceptions specification and the   | 347 (41.45 A)             | Processing the second s |  |  |  |  |  |  |
|  | Ç                         |  |  |  |  |  |  |  |
| *8   | ō                         | 8,93   |  |  |  |  |  |  |
| . <sub>دا</sub> لپ   |                           | 177 C 45 CM  |  |  |  |  |  |  |
| 2  | v                         | 8,95   |  |  |  |  |  |  |
| Æ4   | č                         | ري ۾ چيون  |  |  |  |  |  |  |
| 3  | ٥                         | 8.93   |  |  |  |  |  |  |
| Q  | 8                         | φ * s, φ   |  |  |  |  |  |  |
| Α  | 10                        | 8,95   |  |  |  |  |  |  |
| £.   | ě                         | ပ ့ စမ္  |  |  |  |  |  |  |
| 5  | c.                        | $\circ \circ \circ$  |  |  |  |  |  |  |
| 42   | 3                         | 8,94 .   |  |  |  |  |  |  |
|  | 9                         |  |  |  |  |  |  |  |
| AND THE PROPERTY OF THE PARTY O | Diggraphic and the second | n Emilia de Carlo Esta de partir desente como como esta esta esta esta esta esta esta esta   |  |  |  |  |  |  |
|  |                           |  |  |  |  |  |  |  |

## 2. Electrical Resistivity:

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

(Physical Properties, contid) - ....

Hapocimens, the section with the problem of  $eta_{ij}$ 

estron je

The following results were obtained:

Table V.

| STATES AT THE STATE OF A STATE OF | and M. Suddenburgers of the second  | 736.4                                    |  |
|--|---|--|--|
|  |   | Electrical                               | resistivity  |
| Sample   |   |  | er cubic centimetre  |
|  | 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1. 1  | Measured at                              | : Corrected to   |
| 10.11.000000000000000000000000000000000  |   | 22º 0.                                   | 2 0° C.  |
| and the over a same that per   | ine a mine Triple of the Color | ,  | CONTROL STREET, STREET |
| £.   | 9   | 1,721                                    | 1,706  |
| 2  | ** . * ** ** ***  | 1.725                                    | 1.710  |
| 3  | C II  | 1.723                                    | : 1,708  |
| Q.   | ç   | 1.731                                    | : 1.716  |
| - 5  | 6   | 1.726                                    | 1.711  |
| WHEREFELD AND BELLEVIS   | n<br>O<br>Aliekwientotkowenskiewe   | en e | o<br>o<br>delile directore and but . The . Source engine design for the estate and engine da   |

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.

| 中央 化水面 医克克斯氏试验检尿素 化二氯甲基酚 医加利氏试验检尿 化二氯化物医甲基甲基甲基甲基甲基甲基甲基甲基甲基甲基甲基甲基甲基甲基甲基甲基甲基甲基甲基   | er Smer J. II 3 MAGSTON 1 E NOSANTON |               | ng or property commenced to the collection of th | armonara i                             | nc.apmensouscensee | N /2  | rung der    | 中华新国际  |
|--|--------------------------------------|---------------|--|--|--------------------|---|-------------|--|
|  | Settaman dilan                       |               | l m p  | ,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,, | <u> </u>           | N O   |             | e are attractive magnitude man   |
| eren (M. Wester (M. M. Mester) werd at the Mark of Mester (M. Mester) eren werden werden der der Mester (M. Mester) er de | 240<br>                              | 9             | مريد موسود المساور المساور المساور المساور<br>مريد موردو المساور الم<br>ولي المساور الم  |  | and a section of   | Age to a property of the company of the control of |             | erig gestaanga a energ e estimatistisca fila<br>aring gestaanga a energ e estimatistisca energia<br>aring energy energy a energy energy energy e |
| Diameter of specimen, inches   | : 0,2                                | 52 :          | 0.237  | à (                                    | 0,278              | 0.282   | 9           | 0.307  |
| 0.2 per cent proof stress,   | ;<br>;<br>;10,3                      | ;<br>;        | 0.200  | 6                                      | 8,400°             | 8,000   | 9 6         | 8,100  |
| P.S.A.   | ال و ۱۸۸۷ ة                          | C/C/ s        | 0,200  | `                                      | Cop tector         | . 0,000   | ٠           | 09200  |
| Ultimate T.S., p.s.i.  | :33,5                                | ; oc          | 36,000   | 1:3                                    | 3,700              | 34,500  | 0           | 27,000   |
| Elongation in 1", per cent   | \$<br>\$ 63                          | 0<br>0        | 64   | 9 2                                    | 64                 | 58  | 4           | 62   |
| u u Su u   | : 54                                 | 0             | 48   | 65 4.                                  | 53 :               | 46  | e<br>e      | 49   |
| (2 g   | ; 0%                                 | 0.0           | *0   | D<br>4                                 | encon :            | ;   | ¢<br>9      |  |
| Reduction of area, "   | : 69                                 | 4             | 75   | à                                      | 65                 | 71  |             | 89   |
| ATTERMINATION DESCRIPTION AND AUTHORISM CONTRACTOR OF A CONTRA | a diametrican                        | aranari<br>'' | THE STREET, ST   |  | orientalienteniste | Densi partitores  | nanar.<br>Z | CANCELLER CONTROL  |

#### 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) -

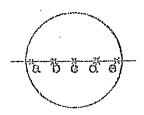


Table VII shows the results in Vickers hardness numbers:

Table VII.

| ample   | 4    |         | l, o | (  | з а                                    | た       | <u>j</u>      | ()     | N                            |
|---|------|---------|------|----|--|---------|---------------|--------|------------------------------|
| $N_{\mathcal{O}_{\mathfrak{o}}}$                    | 3 8  | 6<br>17 | b    | 9  | C                                      | t.      | d             |        | <b>6</b>                     |
| tidens in which spirit nat 8 bills als a precide to | 3    | e.      |      | 3. | ang ang mga ng bili ng kitang at a kan | 4.<br>U | ry minary non | 9      | Link in akit hiku sitai dist |
| 3.  | :51. | 7 :     | 51,9 | 0  | 52,2                                   | 35      | 2,0           | 9      | 51,9                         |
| 8   | : 50 | 3 %     | 48,6 | 3  | 47.6                                   | ° 4     | 9.4           | 11     | 53, 1                        |
| 3   |      |         | 45.3 |    |  |         |               | 8      | 47.8                         |
| 4   | : 44 | 7 :     | 44.5 | ٥  | 45.8                                   | : 0     | 4,6           | 9      | 45.6                         |
| 5   | :49. | 2 :     | 47.9 | 6. | 45.9                                   | 2 13    | 6,9           | a<br>0 | 50.7                         |

0 0

(Mechanical Proporties, cont'd) =

#### 3. Crushing Tests:

the British O.F. Specification No. XC/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.

| Sampl                         | o:D   | iamo tor  | (1<br>6       | Lengt                                   | h,            | in inches  | g: Load,   | 0     | Conditio                        | m of                         |
|-------------------------------|---|---|---------------|---|---------------|--|--|-------|---------------------------------|------------------------------|
| No.                           | d:  | efore test  | 593           | Before                                  | ٥             | After  | e in   | 2     | surfac                          | 30,                          |
| multi faerrum 1115            | 0<br>*  | inches  | u<br>u        | test                                    |               | test   | :pounds  | 3     | after to                        | 3 13 Ú                       |
| AAASE MARKER ESTATES          | A SALAN AND AND AND AND AND AND AND AND AND A | (中) (1997年) (1997年) (1997年) (1997年) (1997年) (1997年) (1997年) | 0             | a mentenanga kegunga melahin ngaengan m | 2             | www.duberrell.rg.rg. Willess Wilder Professor Statement  | C CONTRACTOR CONTRACTO | 0     | ing symethy coloublessauchieses | Bergeral arterior was finder |
| 1                             | 0   | 0.315   | 6             | 0,995                                   | 3             | 0,375  | ::10,800   | ņ     | Without                         | cracks.                      |
| 2                             | 0   | 0.315   | ÷             | 0 993                                   | 9             | 0.375  | :10,650  | 9     | 86                              | . 17                         |
| 3                             | c   | 0.500   | 3             | 0.985                                   | 15 -          | 0.375  | :29,300  | · ·   | 19                              | 99                           |
| Ą                             | ပ   | 0.400   | 0             | 0,997                                   | 3 '           | 0.375  | :16,100  |       | 97                              | 15                           |
| . 5                           | 0   | 0.485   | . 3           | 0,998                                   | 9             | 0.375  | :25,300  |       | ît.                             | 71                           |
| arthemanne<br>The statemanner | g<br>Santanara                                | n come more propagative de l'                               | b<br>Diameter | rengaran da da kasasa da                | 4<br>******** | engalar serialah biranggala seria 4 milyakan seria 1 mily | n<br>O   | enan. | randrationer by Everychic       |                              |

#### 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 increments of 2,000 pounds (where possible) up to the load

(Mechanical Properties, contid) =

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,  |   | C             | DMPRESSI(                                    | ON OF SAI   | WPLE, I   | N INCHES   |          | Charles Maintenanting of Education Co.   |  |  |
| î.ra   |   |               | Sam  | p l e   | No.   |  |          | Deal San Control of Co |  |  |
| pounds :   | 18  | 0             | 1.5  | 2a  | : 2b  | 88   | 9        | 40   |  |  |
| AND ACCUSED THE ACCUSE AND ACCUSED ON  | CHARLES OF STATES AND ASS                                 | 9             | COLUMN ACCOUNT AT ALL VIOLENCE MANY WALL AND | e karanda i Bulgi nica i tarani daba a k <sup>ara</sup> n nafi njangu i f | Co<br>Co  | A STATE OF A STATE OF THE STATE | 4        | er capitalistic est a l'action sur des sur de sur de se sur de se sur de se sur de se  |  |  |
| 2,000 s  | 0,052   | 9             | <b>~</b>                                     | 0.051   | <b>a</b>  | 0.045  | 9        | . ⇔  |  |  |
| 4,000  | 0.161   | ٥             | em (   | 0,161   | 6 en  | 0,158  | 0        | ಎ  |  |  |
| 6,000 s  | 0,266   | o<br>o        | <b>⇔</b>                                     | 0,268   | , no  | 162,0  | 2        | ಯ  |  |  |
| 8,000  | 0、338   | ò             | ea (   | 0,337   | ್ ಮ<br>೧  | 0,333  | å        | <b>a</b>   |  |  |
| 10,000   | 0,381   | 4             | 0.375  | 0,378   | ; 0.380   | 0.376  | 9        | 0.377  |  |  |
| 12,000   | 0.414   | ŝ             | agen G                                       | 0,409   | to<br>Operation   | 0.408  | 0 10     | et.s   |  |  |
| 15,000   | 0.444   | 4             | 0.441  | 0.437   | 0.440   | 0.440  | 9        | 0.442  |  |  |
| 20,000   | 0.477   | o<br>ts       | 0.474  | 0.471   | 0.475   | 0.475  | a<br>o   | 0.476  |  |  |
| new Direction in the contract and the contract of the contract | 's to the age" of the all and all the best of the all the | to<br>Carefun | (1<br>                                       |   | A<br>A<br>Bendaria de la Composição de Composição de Composição de Composição de Composição de Composição de Composição | and being a servery as thirty of the serve Address   | O.<br>th | end various out & end responde to the first of the   |  |  |

| •   |         |   |        | Table   | 3       | <b>X</b> .  |  |  |  |
|---|---------|---|--------|---|---------|---|--|--|--|
|   |         | (Specimen   | siz    | e: 0.46E  | į       | n. diam. :  | κ Ο.   | .930 in.)  |  |
| Load,                                       | 0       | COM   | PRE    | SSION OF  | S       | AMFLE, IN   | IN   | CHES   |  |
| ln  | 0       | orazion promunita montraria non sva mana antago a ta  | S      | ampl  | 0       | N O   | enter de la constitución de la c | LIGHTLY FOR RECEDITIVE PROGRAM CONTROL |  |
| pounds                                      | 0<br>6  | 30  | 0      | 36  | ()<br>2 | 5a  | g<br>b   | 5b   |  |
| S ME LONG CORPUS OF STATE OF THE SHIPLE OF  | 7       | and a sufficial in the second of the management of the form a broader of a 1979 for the second of the | Q<br>C | California y Ladino de Yora o plant april a sur a | 0       | v. meta-re dita histori salime i izing nici sakino ya ve gwela yi | E.   | 化二元二十二十二二二二二二二二二二二二二二二二二二二二二二二二二二二二二二二二  |  |
| 8,000                                       | ø.      | 0.010   | 6      | 423   | 0       | 0,008   | a<br>u   | rap .  |  |
| 4,000                                       | 9       | 0,052   | 8      | æ .   |         | 0.051   | R<br>È   | ಡು   |  |
| 6,000                                       | 0       | 0.107   | 9      | czo   | 4       | 0.112   | 0  | at:  |  |
| 8,000                                       | ti<br>D | 0.177   | 0      | en-   | 1       | 0.177   | is .   |  |  |
| 10,000                                      | Q<br>Q  | 0,250   | 0      | 0,253   | 0       | 0,252   | 0  | 0,250 .  |  |
| 12,000                                      | 9       | 0.322   | 0      | 0   | 8       | 0.326   | *  | =  |  |
| 14,000                                      | 9       | 0.386   | ā      | दक्त  | 4       | 0.391   | 9  |  |  |
| 16,000                                      | ç       | 0.442   | 9      | 0   | *       | 0.447   | ÷  | tan  |  |
| 18,000                                      | 0       | 0.485   | 2<br>G | er;   | v<br>*  | 0,490   | 9  | ಜ  |  |
| 20,000                                      | 5       | 0,520   | 9      | 0.507   | 0       | 0.527   | 9<br>R   | 0.51.3   |  |
| -   | 9       |   | 9      |   | o<br>o  |   | <b>6</b>   |  |  |
| 相对 化二甲基甲基甲基甲基甲基甲基甲基甲基甲基甲基甲基甲基甲基甲基甲基甲基甲基甲基甲基 |         |   |        |   |         |   |  |  |  |

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.

Figure 2.

X250, unetched.

X250, unetched.

Sample No. 1.

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.)

Etching reagent: 8 p. FeCl, 25 p. HCl, and 100 p. H20.

(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.



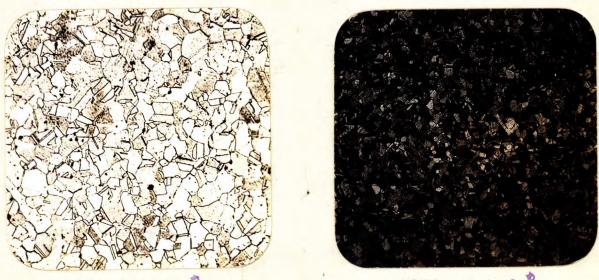
X100, etched.

SAMPLE NO. 1, EDGE.

(Average grain diameter: approximately 0.040 mm.)

Figure 9.

Figure 10.



X250, etched.

X100, etched;

## SAMPLE NO. 1, INSIDE.

(Average grain diameter: approximately 0.020 mm.)

Etching reagent: 8 p. FeCl, 25 p. HCl, and 100 p. H20.

#### 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 0.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.

000000000

0

JWM: CHB.