O T T A W A September 8th, 1944.

R E P O R T

of the

ORE DRESSING AND METALLURGICAL LABORATORIES.

Investigation No. 1708.

Investigation of the Magnetic Properties and Iron Content of Samples of Compass Castings and Copper Ingots.

(Copy No. 5.)

Bureau of Mines
Division of Metallic Minerals
-
Physical Metallurgy
Research Laboratories

CANADA
DEPARTMENT OF MINES AND RESOURCES
Mines and Geology Branch

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Origin of Material and Object of Investigation:

On August 7th, 1944, three compass castings (identified herein as Samples Nos. 1, 2 and 3) were submitted by the Scrap, Ingot and Tin Section, Office of the Metals Controller, Department of Munitions and Supply, Ottawa, Ontario, for examination of magnetic properties and for chemical analysis, particularly with respect to iron content.

An additional deep compass bowl, of silica bronze, (designated Sample No. 4) was subsequently submitted, along with part of an ingot of electrolytic copper (Sample No. 5) from the Ontario Refining Company. Still later, part of an additional copper ingot (Sample No. 6), from Canadian Copper Refineries, was supplied for a similar examination.

Chemical Analysis:

Preparation of Samples -

The chemical laboratory was supplied with sufficient quantities of machined chips from the interior of the metal of the compass parts and with copper blocks of about 1 cubic inch from the copper ingots. Special precautions were taken in all cases to avoid contamination by iron.

Results -

Sample No.	Iron	Copper	Lead	Tin	Zinc	Silicon	Manganese	Nickel
				- Per Cent -				
1 -	0.08	61.00	0.26	1.16	37.50	-	Nil	Nil
2 -	0.04	84.77	4.41	4.47	6.20	-	Nil	Nil
3 -	0.04	85.47	4.46	4.45	5.40	-	Nil	Nil
4 -	0.06	89.55	Nil	Nil	5.36	4.68	Nil	Nil
5 -	<0.0013	-	-	-	-	-	-	Nil
6 -	0.0018	-	-	-	-	-	-	-

Preparation of Samples for the Magnetic Test:

All samples from the compass parts for the magnetic test were cut of maximum possible thickness from the various parts supplied, the width being 15/16 inch and the length 6 inches. All surface metal was removed in the milling machine and special precautions were taken to avoid contamination, during machining, by iron filings or dust.

A cylindrical specimen, of 7/8 inch diameter and 4¼ inches long, was cut from the copper ingot, Sample No. 5. The dimensions of the sample from the second copper ingot, Sample No. 6, were 7/8 inch diameter by 4-1/8 inches length.

MAGNETIC TEST:

The magnetic properties were measured by the use of mutual inductance coils. A primary direct current maintains a magnetic linkage with the secondary coil. For a steady direct current this linkage is a constant and can vary only when the nature of the core material is changed. The method consists of quickly withdrawing the test sample from the centre of the mutual inductance coils. If the permeability of the sample differs from that of air, the material will thus change the

(Magnetic Test, cont'd) -

number of magnetic lines linking the primary and secondary coils and a charge will be generated in the secondary winding. This charge is measured on a ballistic galvanometer, the deflection being a measure of the charge produced and hence a measure of the magnetic permeability.

Results of Magnetic Tests.

Sample No.	Mean deflection, millimetres	Iron content, per cent (by chemical analysis)	Remarks
1	4.0	0.08	Paramagnetic.
2	Slight.	0.04	"
3	0.5 (approximately).	0.04	"
4	Undetectable.	0.06	"
5	2	Less than 0.0013	Diamagnetic.
6	2	0.0018	"

Samples Nos. 5 and 6 showed diamagnetic properties. The deflections, although appreciable, were in an opposite direction to those found for the samples containing relatively large amounts of iron. This is in agreement with the known magnetic susceptibility of pure copper. This would indicate that additional quantities of iron could be introduced during processing and that the susceptibility would pass through zero as the iron increased, provided that the iron was magnetically soft. Samples Nos. 1, 2 and 3 were checked in the magnetometer at Ontario Hughes-Owens, Ottawa, with comparable results.

The equipment available in these Laboratories for magnetic testing could only be used for the determination of magnetic susceptibility or permeability, and not remanence of

(Magnetic Test, cont'd) -

magnetization, on these feebly magnetic samples. Remanence is important in that it is a measure of the magnetization in the absence of a magnetizing field. A material of relatively high permeability but low remanence may be satisfactory for certain uses. Trouble is encountered where permanent poles are established in the piece, e.g. in a compass bowl, thereby causing a deflection which varies with the orientation of the instrument in the earth's magnetic field.

The iron content cannot be an index of the magnetic properties in view of the fact that prior thermal and mechanical treatments enormously affect the magnetic properties of the material. For instance, the solid solution of iron in copper renders the former non-magnetic. Work by Gordon and Cohen(1), Bitter and Kaufmann(2) indicates that the precipitation of iron from copper by suitable heat treatment results in a non-magnetic form and may be subsequently converted to a magnetic form by simple cold-working. It is thought by these authors that the first precipitation is face-centred cubic in structure like the mother lattice of copper and that it is relatively stable in the absence of cold work. This face-centred, non-magnetic form of iron is analogous to the non-magnetic, face-centred austenite lattice of iron. Constant, Leander and Faires(3) confirm the belief that copper and alpha brass precipitate this face-centred non-magnetic form of iron. Subsequent cold work transforms this unstable non-magnetic phase into the body-centred magnetic phase. This precipitation of the non-magnetic iron is retarded if the original quench temperature is low. The effect of cold work on the non-magnetic phase is therefore much reduced. C. S. Smith(4), by slowly cooling a 70-30 brass containing 0.053 per cent iron from 800° to

(Magnetic Test, cont'd) -

400° C. before quenching, greatly reduced the rate of precipitation and therefore the change in magnetic properties during cold-working. The chemical analyses for zinc showed that Samples Nos. 2, 3 and 4 are alpha brass.

On the other hand, under the microscope Sample No. 1 was seen to be about two-thirds beta brass, as was to be expected from the chemical analysis. The precipitated iron from the beta brass lattice has a body-centred cubic structure and becomes magnetic as soon as its size permits. For low iron contents such as the ones under study here, it has been found that quenching from around 750° or 800° C. gives a material of lowest magnetic remanence. Subsequent reheating will, of course, bring out the magnetic phase. The effect of cold work is very small.

Recommendations:

From the reclamation point of view, it would seem that keeping the iron in solid solution by quenching has great possibilities. For alpha brass, slow furnace cooling from 800° C. to 400° C. in about 3 hours, then followed by a quench, will hold the iron in solution and make it less susceptible to the effects of cold work in bringing back magnetization. For beta brass, quenching from 750° or 800° C. will give material of lowest magnetic remanence. The effects of cold work are very small for this material.

These recommendations refer only to iron contents of the order concerned here.

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B I B L I O G R A P H Y

(1) R. B. Gordon and M. Cohen: "Age-Hardening of a Copper-Cobalt and a Copper-Iron Alloy." Symposium on Age Hardening of Metals, pp. 161-184, American Society for Metals, 1940.

(2) F. Bitter and A. R. Kaufmann: "Magnetic Studies of Solid Solutions, I -- Methods of Observation and Preliminary Results on the Precipitation of Iron from Copper." Phys. Rev. (1939), 56, pp. 1044-1051.

(3) F. W. Constant, H. E. Leander and R. E. Faires: "Effect of Heat Treatment on Ferro-magnetic Impurities" (Abstract). Phys. Rev. (1940) 57, p. 1089.

(4) C. S. Smith: "Magnetic Studies on the Precipitation of Iron in Alpha and Beta Brass." A.I.M.M.E. Metals Technology, Tech. Publication No. 1394 (1942), pp. 1-11.

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