CANADA

DEPARTMENT OF MINES

HON. P. E. BLONDIN, MINISTER; R. G. MCCONNELL, DEPUTY MINISTER.

MINES BRANCH

EUGENE HAANEL, PH. D., DIRECTOR.

RESEARCHES ON COBALT AND COBALT ALLOYS, CONDUCTED AT QUEENS UNIVERSITY, KINGSTON, ONTARIO, FOR THE MINES BRANCH OF THE DEPARTMENT OF MINES

PART V

MAGNETIC PROPERTIES OF COBALT AND OF Fe_2Co.

BY

Herbert T. Kalmus, B.Sc., Ph.D.

AND

K. B. Blake, B.Sc.

OTTAWA
GOVERNMENT PRINTING BUREAU
1916

No. 413

LETTER OF TRANSMITTAL.

DR. EUGENE HAANEL,
DIRECTOR MINES BRANCH,
DEPARTMENT OF MINES,
OTTAWA, CANADA.

Sir,—

I beg to submit, herewith, a report on "Magnetic Properties of Cobalt and of Fe_2Co." This is the fifth completed part of the series of investigations on cobalt and cobalt alloys for the purpose of increasing their economic importance; which has been the subject of the special researches conducted under my direction at Queens University, Kingston, Ontario, for the Mines Branch of the Department of Mines, Ottawa.

I have the honour to be, Sir,

Your obedient servant,

(*Signed*) **Herbert T. Kalmus.**

February 1, 1916.

CONTENTS.

ILLUSTRATIONS.

Photograph.

Drawings.

RESEARCHES ON COBALT AND COBALT ALLOYS, CONDUCTED AT QUEENS UNIVERSITY, KINGSTON, ONT., FOR THE MINES BRANCH OF THE DEPARTMENT OF MINES.

PART V.

MAGNETIC PROPERTIES OF COBALT AND OF Fe_2Co.

MAGNETIC PROPERTIES OF COBALT AND OF Fe_2Co.

INTRODUCTORY.

This report is the fifth of a series describing investigations of the metal cobalt and its alloys, with a view to finding increased commercial uses for them.

These researches on cobalt are being conducted at the School of Mining Queens University, Kingston, Ontario, for the Mines Branch, Department of Mines, Canada. The respective reports in the series, already published, are as follows:—

I. "The Preparation of Metallic Cobalt by Reduction of the Oxide," Report No. 251, Mines Branch, Department of Mines, Canada, 1913; Journal of Industrial and Engineering Chemistry, 1914, Vol. VI, pp. 107-116.

II. "Physical Properties of the Metal Cobalt," Report No. 309, Mines Branch, Department of Mines, Canada, 1915; Journal of Industrial and Engineering Chemistry, 1915, Vol. VII, pp. 6-17.

III. "Electro-plating with Cobalt," Report No. 334, Mines Branch, Department of Mines, Canada, 1915; Transactions American Electrochemical Society, 1915, Vol. XXVII pp. 75-130; Journal of Industrial and Engineering Chemistry, 1915, Vol. VII, pp. 379-399.

IV. "Cobalt Alloys with Non-Corrosive Properties," Report No. 411. Mines Branch, Department of Mines, Canada, 1916.

Early in the course of our investigations on cobalt, (December, 1912), bars of iron-cobalt alloys, approximating to the composition Fe_2Co, were cast by us at this laboratory. The magnetic permeability of these bars was tested in accordance with the method I, as described below; and the preliminary tests indicated that this compound had an unusually high magnetic saturation value.

Great difficulty was experienced in casting the bars free from blow holes, but the indications were, that sound bars of this kind would have a magnetic saturation from 5% to 10% greater than that of pure soft iron at ordinary temperatures.

Experiments were in progress concerning the casting of sound bars of this type, when a paper by Prof. Pierre Weiss[1] appeared, reporting that ferro-cobalt, Fe_2Co has a magnetic saturation 10% greater than that of soft iron at ordinary temperatures. Swedish iron and 98·5% pure industrial cobalt were cast in the composition Fe_2Co, two samples of the alloy having respectively 9·0% and 9·7% greater magnetization than that of pure Swedish iron. The ingot which gave 9% was the most compact and served to turn pole pieces for an electro-magnet. These pole pieces could not be made completely of this alloy for lack of material, so that the tips alone were made of it, as indicated by Fig. 1.

[1] Ferro-Cobalt, Pierre Weiss, Comptes Rendus, June, 1913, pp. 1970.

The fields obtained with these pole pieces, and with others of exactly the same form of Swedish iron, were measured, and in every instance the excess of magnetization of ferro-cobalt was greater than 5 per cent.

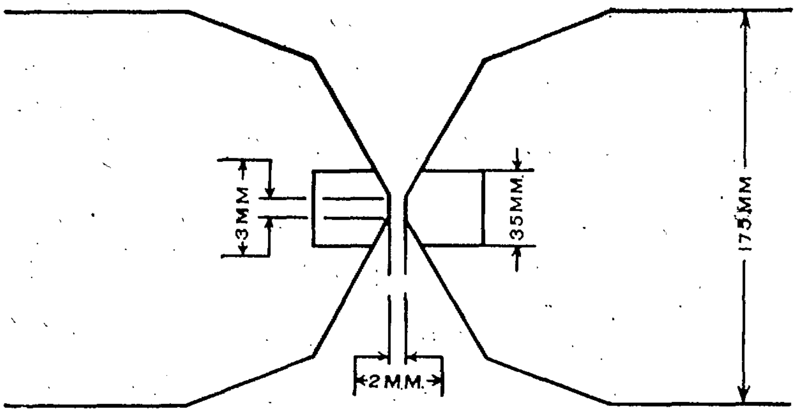


Fig. 1
Diagram showing ferro-cobalt tips of pole pieces.

These results, together with our own preliminary experiments, led us to conclude that the alloy Fe_2Co was well worth investigating.

In spite of the fact that a large amount of work has been done on the magnetic properties of pure cobalt, we concluded that new measurements might differ from those to be found in the literature on the subject, because of the very much larger quantity of really pure cobalt at our disposal than has been at the disposal of most investigators. Our permeability and hysteresis measurements could, therefore, be made under less special conditions.

This report covers only the measurements of the magnetic properties of cobalt and alloy Fe_2Co, under normal laboratory commercial conditions, and does not include variations of magnetization with temperature, transformation points, change of volume with change of magnetic flux, etc., etc. We have been particularly interested to ascertain whether or not the compound Fe_2Co could be readily cast, free from blow holes and other defects, so as to possess a magnetic permeability greater than that of soft Swedish iron, as indicated by our preliminary experiments, and by those of Prof. Weiss. As a basis for this, we first studied the magnetic properties of the cobalt itself which we have prepared in fairly large quantities, and which we used for the preparation of these alloys.

MAGNETIC PERMEABILITY AND HYSTERESIS OF PURE COBALT.

Material.

The pure metallic cobalt used in these tests was prepared at this laboratory by the method described in the first paper of this series.[1] It analyzed as follows:—

	Analysis I	*Analysis II*
Cobalt	99·60%	99·55%
Iron	0·334	0·340
Silicon	0·097	0·097
Carbon	0·122	0·129
Phosphorus	0·0046	0·0048
Sulphur	0·020	0·020
Aluminium	0·016	0·016
Nickel	None	None
Calcium	None	None
	100·194%	100·157%

Preparation of Bar.

A charge of about five pounds of metal, analyzing as above, was placed in a graphite crucible lined with magnesite, and melted in a Hoskins electric furnace of the plate resistor type.[2] The melt was then allowed to "soak" for forty-five minutes at a temperature from five to ten degrees above the melting point. Just before pouring, about two grams of finely pulverized aluminium were added as a degasifier. After shaking slightly, to insure good action of the aluminium, the charge was poured into an iron mould, one inch internal diameter by 18 inches long. The mould had been previously warmed to expel moisture. After cooling slowly in the mould, the bar was roughed down in the lathe to a few thousandths of an inch over size. Before finishing, it was annealed at 500°C for several hours. Finally, it was machined and filed down to the requisite dimensions, as shown below.

METHOD I.

The first set of measurements was made in the laboratory by a rapid method, as detailed below.

Apparatus

The apparatus for magnetic permeability and hysteresis measurements consists of two principal parts: the actual testing machine described below, and an apparatus for determining the induced voltage.

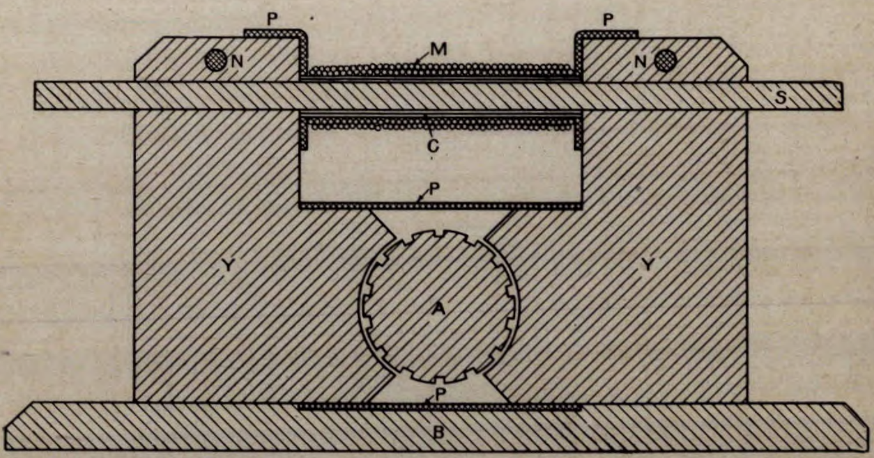
Testing Machine.

This machine is simply a bipolar electric generator, in which the sample under test forms a part of the magnetic circuit, direct connected to a 0·1 H.P. 110 volts D.C. motor. The details of the generator are shown in Fig. 2.

[1] Preparation of Metallic Cobalt by Reduction of the Oxide, Herbert T. Kalmus, Bulletin No. 259. Canada, Dept. of Mines, 1913.

[2] The furnace was described in Preparation of Metallic Cobalt by Reduction of the Oxide, Herbert T. Kalmus, Bulletin No. 259, Canada, Dept. of Mines.

The motor rotates the armature A, at a speed of 1,800 R.P.M., approximately. The magnetic field is set up by passing current through the magnetizing coil M, around the sample S to be tested. The voltage induced is



A—Armature
B—Wooden base
C—Winding core
M—Magnetizing coil

N—Clamp bolts
P—Brass plates
S—Test sample
Y—Soft iron yoke

Fig. 2. Section through apparatus

measured across brushes resting on the commutator. The sample S is machined to fit closely within the magnetizing coil.

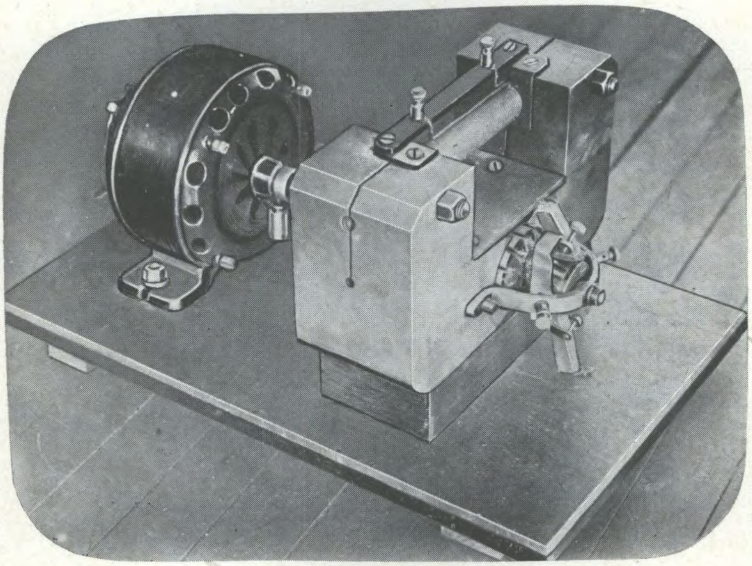
The general appearance of the testing machine is shown in Plate I.

Measurement of Voltage.

For ordinary commercial work a low range voltmeter would be sufficiently accurate to measure the induced voltage. The reading is, of course, in error by the I R drop in the armature and brushes. To avoid this error the induced voltage in these tests was measured by a null method. A simple potentiometer circuit was set up as shown in the diagram of connexions, Figure 3.

The slide wire bridge W is connected across a two volt circuit supplied by storage batteries. The exact value of this voltage was determined by checking against a standard cell (St'd) before and after every run. The switch C was placed in the circuit so that it was possible to measure either the unknown voltage or that of the standard cell without disarranging any connexions. The null point was determined by using a milli-voltmeter V, which has its zero in the centre of the scale. The range on each side of the zero was ten milli-volts.

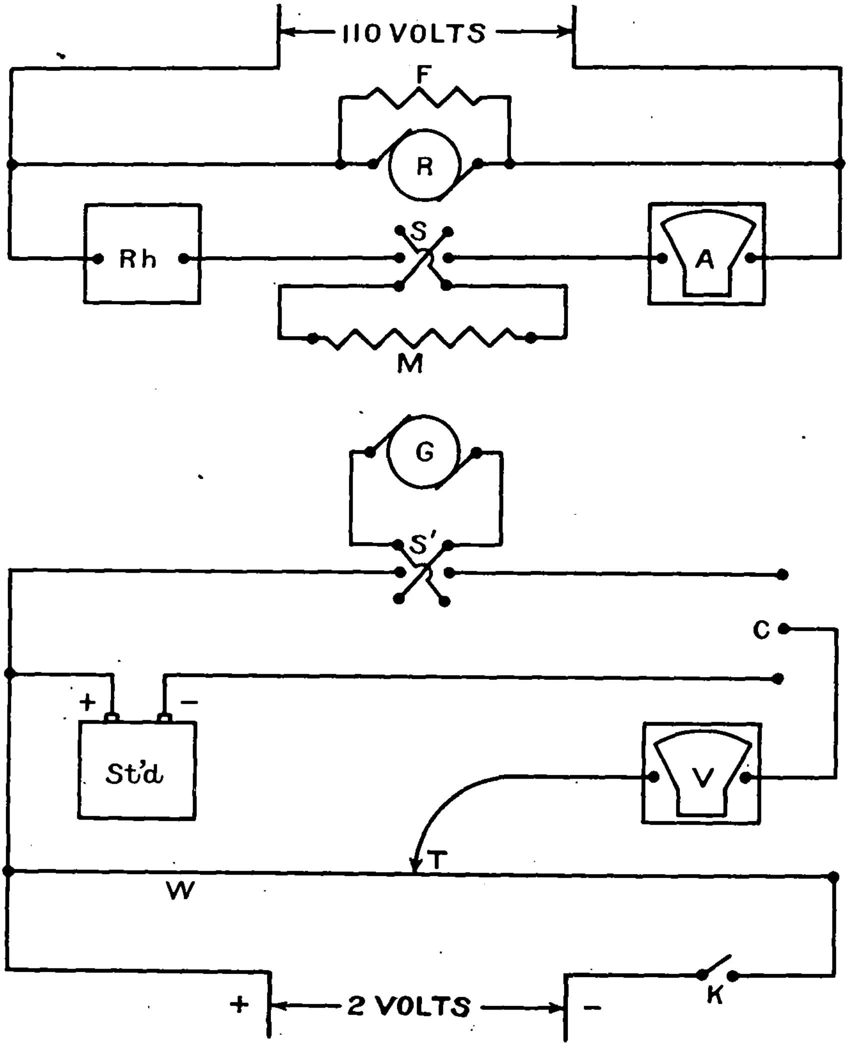
PLATE I



Testing machine.

Electrical Diagram.

The electrical connexions of the entire apparatus are shown in Figure 3.



M — Magnetizing coil
R — Motor armature
S,S'— Reversing switches
St'd— Standard cell
T — Sliding contact
W — Potentiometer wire
V — Millivoltmeter

Rh— Rheostat
C — Commutator
A — Ammeter
K — Switch
G — Generator
F — Motor field

Fig. 3. Diagram of connexions.

Speed Measurements.

The speed of the armature was measured by a tachometer of the centrifugal type.

PROCEDURE.

Measurements for B-H Curve.

The driving motor is started by throwing in the switch on the 110 volt circuit. The switch K is then closed, allowing the potentiometer current to flow through the slide wire bridge W. Switch C is thrown into the side connecting the standard cell with the bridge. The sliding contact is moved along until there is no reading of the milli-voltmeter, and this position, read in centimeters from the left end of the wire, is recorded. This gives us the exact value of the potentiometer circuit voltage (2 volt cell). The switch C is then reversed and the circuit again balanced, that is, the generator voltage measured in terms of the potentiometer voltage. If this generator voltage is not zero, it shows that the bar has retained a certain amount of residual magnetism. This is true, of course, because at this time there is no magnetizing current around the Sample S. This is dispelled by momentarily applying a magnetizing force in the reverse direction. When the bar has been demagnetized, everything is ready for a complete test.

The rheostat Rh is thrown into its position of greatest resistance, and measurements made simultaneously of the magnetizing current, speed of armature rotation, and the position of the sliding contact for zero current through the milli-voltmeter.

The rheostat is then advanced to its next position, and similar measurements made. This procedure is continued until the desired magnetizing force is reached.

Measurements for Hysteresis Loop.

The magnetizing current is advanced step by step to its maximum positive value. The readings are taken as before. The current is then reduced one step, and similar readings recorded. This procedure is continued from the maximum positive value of the magnetizing current to its maximum negative value, always raising the current to its positive maximum before reducing it to the desired value. It can be reversed by changing the position of the switch S. When the induced voltage changes its direction the switch S must be reversed in order to obtain a balance on the slide wire bridge.

ORIGINAL DATA.

Constants of Apparatus.

Standard cell......................	=	1·019 volts
Magnetizing turns on M............	=	105
Length of M.......................	=	12·59 cm
Conductors on A..................	=	418

Slide Wire Readings.

Standard cell against 2 volt potentiometer e.m.f.

Before run....................	32·82 cm.
After run.....................	32·80 cm.

This shows that 2 volt cell did not vary appreciably during this series of measurements.

In these tables the symbols have the following significance:—

N = Revolution of armature per minute.
I = Magnetizing current in amperes.
l = Reading of slide wire in cms.
E = Induced e.m.f. in generator.
B = Flux density in gausses.
H = Field intensity gilberts per cm.
μ = Magnetic permeability in c.g.s. units.

B—H CURVE FOR PURE COBALT. See Plot Fig. 4.

Sample H 217, bar No. 2.

Readings			*Calculations*			
N	I	l	E	B	H	μ
1900	0·71	1·51	0·0469	286	7·4	38·4
1900	1·04	2·89	0·0898	547	10·9	50·1
1900	2·19	9·82	0·3052	1858	23·0	80·9
1910	3·20	13·32	0·4140	2509	33·6	74·8
1910	4·09	15·69	0·4875	2954	42·9	68·9
1905	4·93	17·69	0·5495	3337	51·7	64·6
1910	6·60	20·99	0·6523	3952	69·2	57·1
1920	7·49	23·16	0·7200	4335	78·6	55·2
1920	9·20	25·17	0·7822	4712	96·5	47·1
1915	10·52	28·39	0·8824	5325	110·3	48·3

Check Run

N	I	l	E	B	H	μ
1905	0·88	3·40	0·1056	641	9·2	59·4
1920	2·20	9·35	0·2904	1748	23·1	75·8
1930	3·25	13·11	0·4071	2438	34·1	71·6
1920	4·10	15·60	0·4842	2917	43·0	67·8
1915	4·95	17·64	0·5475	3304	51·9	63·7
1905	6·55	20·88	0·648	3931	68·7	57·3
1920	7·40	23·30	0·724	4359	77·6	56·2
1930	9·10	25·06	0·784	4693	95·4	49·2
1925	10·40	27·12	0·842	5053	109·1	46·3

HYSTERESIS LOOP FOR PURE COBALT. See Plot Fig. 5.

Standard cell against 2 volt circuit

Before run............... 32·75 cm .
After run................ 32·75 cm .

Sample H 217, bar No. 2.

Readings			*Calculations*		
N	I	l	E	B	H
1900	6·88	20·58	0·6405	3900	72·2
1920	6·08	19·45	0·6053	3705	63·8
1915	5·05	17·86	0·5560	3355	53·0
1920	4·10	16·42	0·5109	3078	43·0
1925	2·96	14·43	0·4492	2697	31·0
1925	2·00	12·38	0·3851	2312	21·0
1945	1·06	9·85	0·3065	1822	11·1
1930	0	6·24	0·1942	1163	0·0
Magnetizing current reversed					
1930	1·04	0·24	0·0075	45	10·9
			Direction of magnetization reversed		
1945	2·07	5·57	0·1734	1030	21·7
1940	3·00	9·19	0·2859	1702	31·5
1950	3·96	11·95	0·3769	2265	41·6
1950	4·97	14·24	0·4432	2627	52·2
1945	5·95	16·41	0·5107	3070	62·4
1950	6·65	17·82	0·5544	3288	69·8

Diameter of Bar.

The following measurements of diameter were made with a Starret micrometer caliper, reading directly to thousandths of a centimetre, and by estimation to ten-thousandths.

Readings in Centimetres.

1·2565	1·2572	1·2555	1·2566	1·2571
1·2570	1·2580	1·2589	1·2578	1·2593
1·2580	1·2564	1·2574	1·2568	1·2565
1·2562	1·2571	1·2571	1·2580	1·2573

Mean Value = 1·2572 centimetres.

CALCULATIONS.—

The value of the magnetizing force was calculated by the familiar electro-magnetic formula $H = \frac{4 K ni}{l}$ where H is the magnetizing force; n, the number of turns on the coil; i, the current in amperes; and l, the length of the coil in centimetres. Substituting the constants of the apparatus in this equation, we have:

H in gilberts per cm. = 10·48 I in amperes.

The equation for calculating the magnetic flux is the fundamental equation of the generator.

$$E = \frac{n P \varnothing N}{P' \times 10^8} \text{ volts,}$$

where E is the induced voltage; n, the revolutions per second; p, the number of field poles; $\varnothing$, the magnetic flux in maxwells; N, the number of conductors on the armature; and P′, the number of parallel paths through the armature. Giving these quantities their proper values, and substituting for $\varnothing$, the flux density B, times the cross sectional area of the sample, we obtain B in gausses $= 1\cdot156 \frac{E}{N} \times 10^7$.

E is the induced voltage and N the revolutions per minute.

RESULTS.—

The results of the above data are best shown by the curves, Figures 4 and 5.

DISCUSSION OF RESULTS.—

The results obtained by this method cannot be considered accurate to better than one or two per cent. The chief source of error lies in the assumption that the reluctance of the remainder of the magnetic circuit is negligible in comparison with that of the test piece. This is true of the iron yoke, but probably not of the air gap around the armature. Another source of error is the assumption that the leakage flux in the air gap is negligible. The readings of magnetizing current and speed are not reliable to more than half of one per cent.

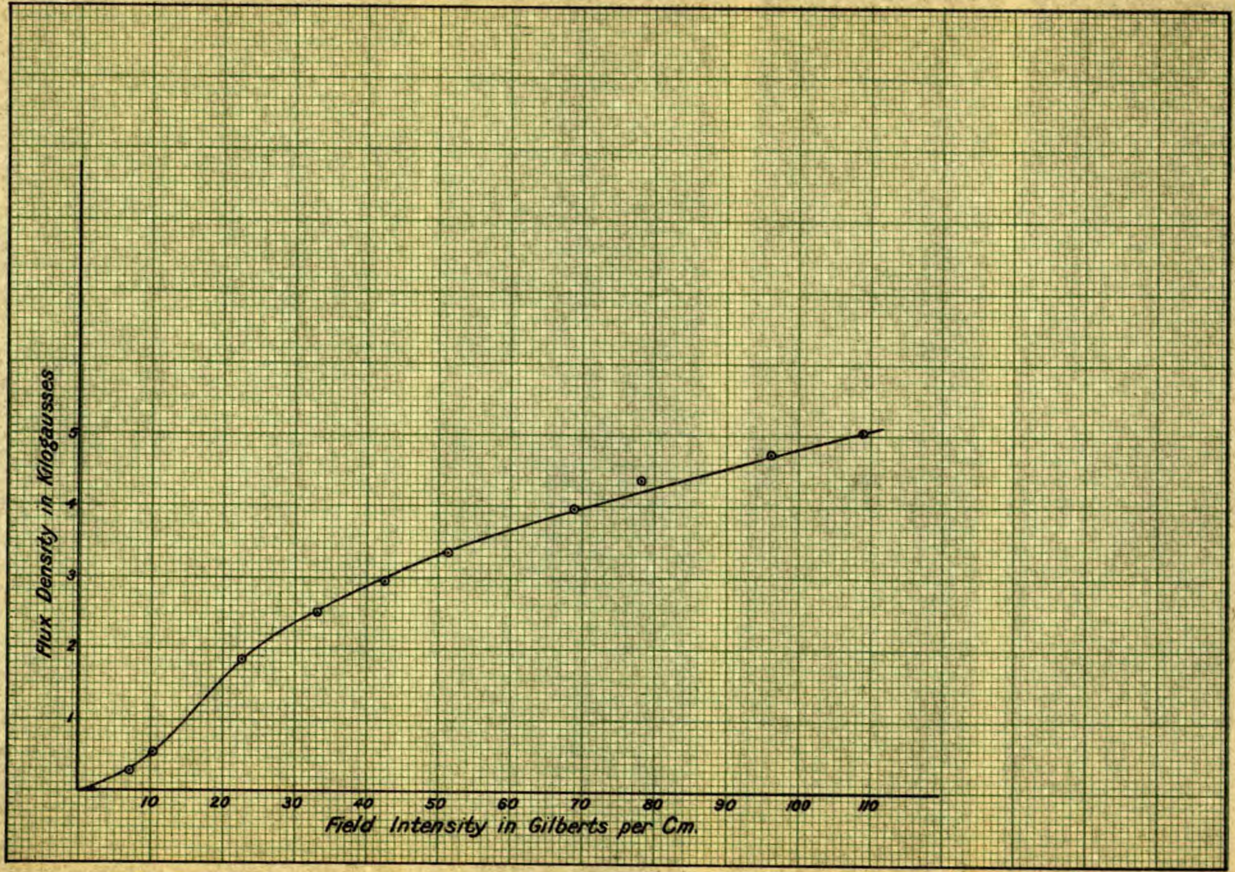


Fig. 4. B-H Curve for Pure Cobalt - Sample H 217

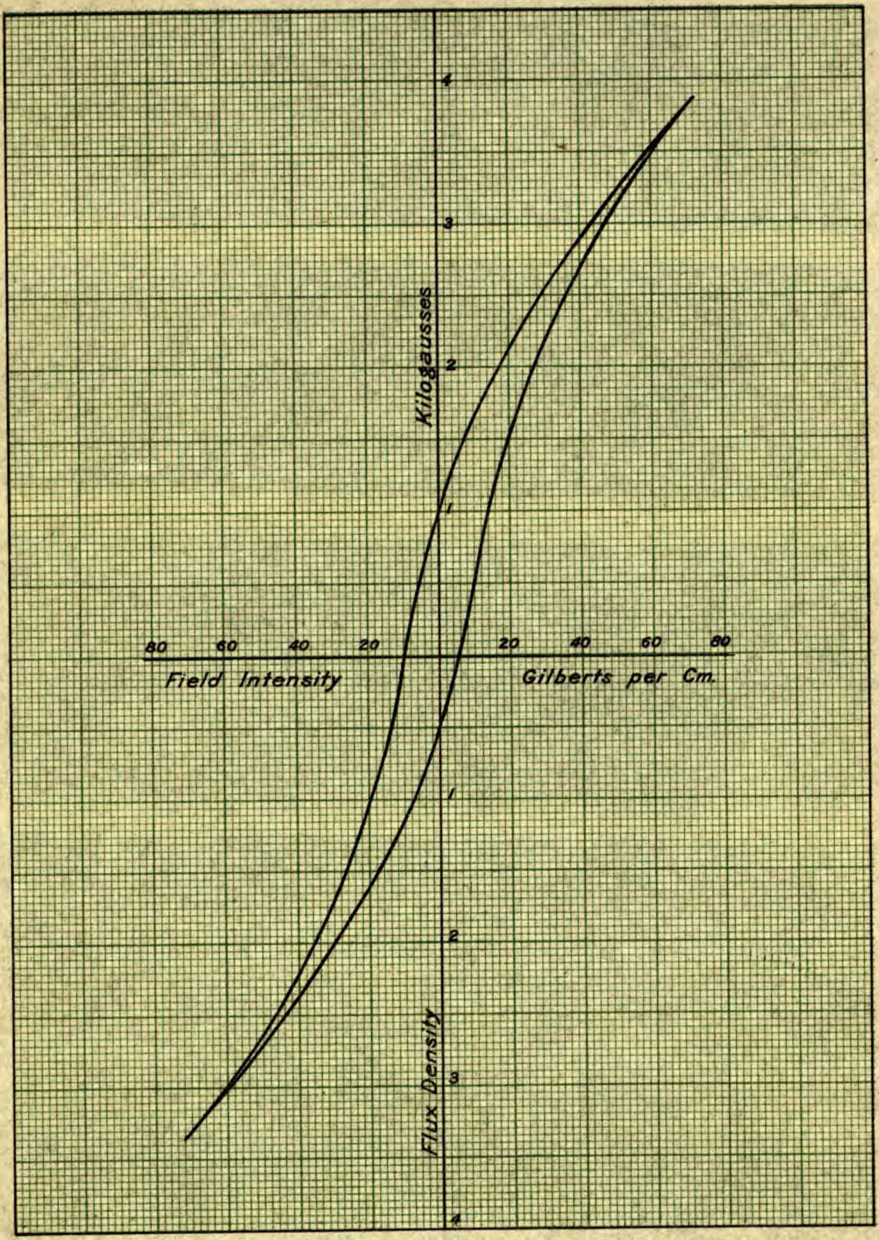


Fig. 5. Hysteresis Loop for Pure Cobalt - Sample H 217

MAGNETIC PERMEABILITY AND HYSTERESIS OF PURE COBALT

METHOD II.

Introduction.

The magnetic permeability, and the hysteresis loop of a sample of pure cobalt prepared at this laboratory were measured by Mr. Carl Schurig, of the Department of Electrical Engineering, Massachusetts Institute of Technology. The determinations were made with great accuracy on refined apparatus as described below.

Material.

The sample bar of cobalt used in these tests was from the same melt as the bar tested by Method I. Consequently, the preparation and analysis of the material are identical with that described above.

Preparation of Bar.

Since this sample bar was cast from the same melt as the previous one, the details of preparation are identical, except that the mould was one-half inch square by nine inches long. The final dimensions of the bar were quarter-inch in diameter by seven and one-half inches long.

Method.

The method and the apparatus used in the permeability and hysteresis measurements of cobalt rods were based on the work of C. W. Burrows at the U. S. Bureau of Standards, as described in Reprint No. 117 of the U. S. Bureau of Standards, entitled, "The Determination of the Magnetic Induction in Straight Bars." The chief difficulty in testing straight bars of moderate length by a primary method, is due to the fact that, the test material does not comprise the total reluctance of the magnetic circuit and that, therefore, correction must be made for the reluctance of the yokes closing the magnetic circuit. In the Burrows method, this is done by applying a compensating winding, which is then placed near the yokes, independent of the main magnetizing circuit, and in which a magnetomotive force is produced sufficient to overcome the reluctance of the yokes. With this accomplished, no leakage of flux will take place, and the magnetizing force along the bar may be calculated from the current-turns of the main magnetizing coil uniformly wound over the test bar between the yokes. The change in flux density in the specimen due to a change in the magnetizing force is found by measuring the quantity of electricity displaced in a circuit containing a test coil wound over the central part of the test specimen, when the magnetizing current is suddenly changed by a known amount.

Apparatus.

The various windings of the magnetizing circuit are shown in Fig. 6. The coils are wound on two thin fibre tubes, each of $\frac{1}{4}$ inch internal diameter, and approximately 6 inches long. The test coils are wound directly on the tubes, in order that the correction for the flux passing through the test coil, but outside of the test specimen, may be small. The main test coil t, consists of 80 turns of No. 28 "B and S. gauge," silk covered copper wire, and is wound over the central part of the tube C_1. In order that the uniformity of flux all along the test bar placed in tube C_1 may be tested, two equal end

Burrows Permeameter for $\frac{1}{4}''$ rods, $7\frac{1}{2}''$ long.

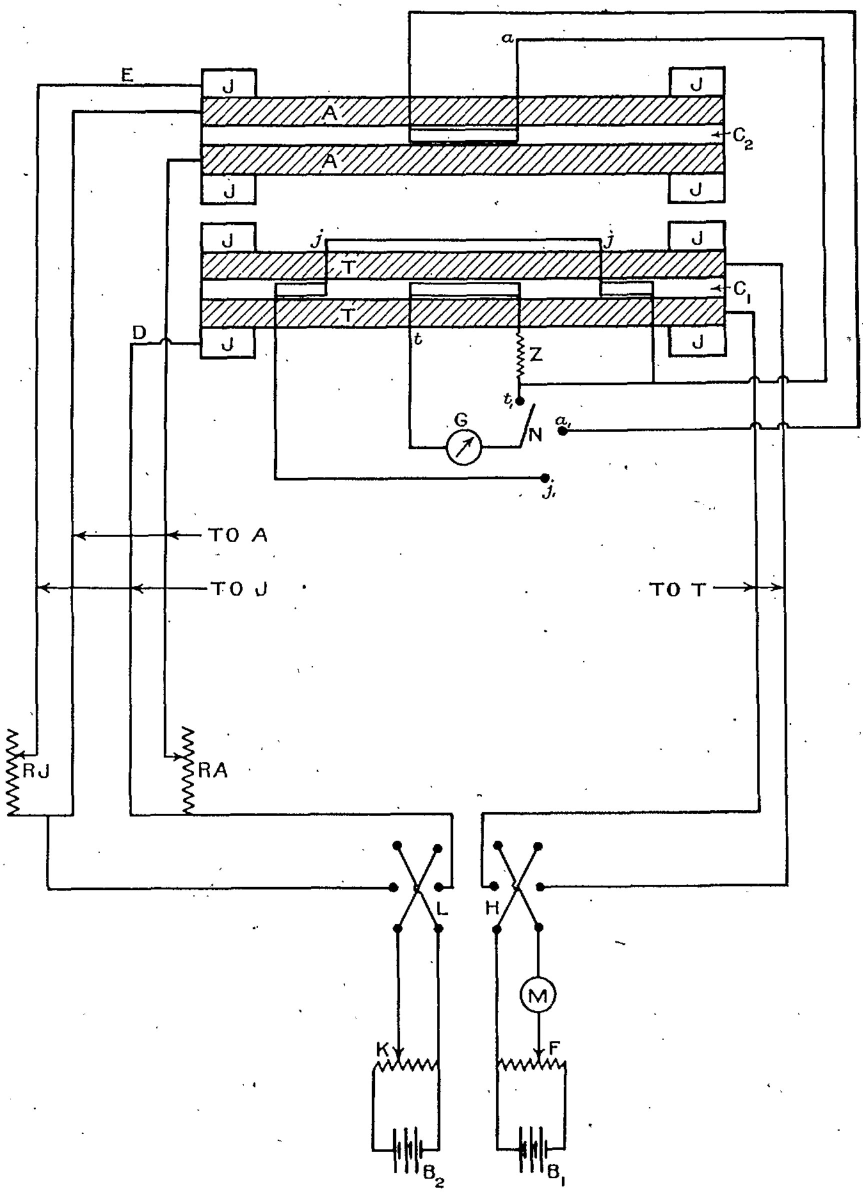


Fig 6. Connexions for permeability test.

test coils jj are wound on the tube C_1, each approximately half-way between the main test coil t, and one end of the tube, and each having 40 turns. Coils jj are connected in series aiding. Thus, the flux along the test bar will be uniform when on reversal of the magnetizing force zero quantity of electricity is displaced through a closed series circuit containing coil t connected in opposition to coils jj. Test coil a, wound on the tube containing the auxiliary bar, is identical with winding t. Hence, the flux in the auxiliary bar will be equal to that in the test bar when on reversal of the magnetizing currents zero quantity of electricity is displaced through a series circuit containing coils t and a, connected in opposition. The main magnetizing winding for the test bar is T; consisting of ten layers of number 19 "B. and S. gauge" double cotton covered copper wire, uniformly wound around, and covering the entire length of the tube. The magnetizing winding A, for the auxiliary bar, is identical with winding T. Circuits A and T are independent, and the currents they carry are separately regulated, in order that two bars with unequal magnetic characteristics may be employed in a single test with as much ease as two identical ones. In order that uniformity of flux may be secured in the bars, a compensating circuit, consisting of four equal coils J, over the ends of the solenoids, is employed. All four compensating coils are connected in series aiding (the interconnexions of these coils are not shown in Fig. 6; the terminals of the series circuit of the four compensating coils are represented at D and E in Fig. 6). The remainder of the apparatus used as shown in Figs. 6 and 7 is briefly referred to under "Procedure."

Procedure for Permeability Tests. (See Fig. 6.)

Current for the main magnetizing circuit T, is taken from battery B_1 through a drop wire F, and through the precision ammeter M to the reversing switch K and from there to T. Battery B_2 supplies both the auxiliary magnetizing circuit A and the entire compensating circuit J through drop wire K and reversing switch L. Switches L and H are coupled so as to act simultaneously. Circuits A and J are independently regulated by rheostats Ra and RJ, respectively. The secondary circuit contains a switch with three contacts t_1, a_1, and j_1 in order that coil t may be closed through the ballistic galvanometer G, either on itself, through coil a, or through circuit j.

The test specimen, in solenoid C_1, and the auxiliary bar, in solenoid C_2, are firmly clamped between soft iron yokes, (not shown), which are brought as close to the coils as possible. The magnetic circuit is demagnetized by gradually lowering the magnetizing force from a large value to zero, by means of drop wires F and K, and by simultaneously reversing switches H and L at an approximate rate of two reversals per second. Then the magnetizing current for circuit T is raised from zero to the value corresponding to the lowest value of the magnetizing force desired by adjusting F and observing M. By means of K and Ra the current in A is adjusted until on simultaneous reversal of switches L and H no deflection is obtained on the ballistic galvanometer G when switch N is closed on contact a_1. Then RJ is adjusted until on simultaneous reversal of switches L and H no deflection occurs on the galvanometer when switch N is thrown to j_1. Before the final reading is made in any of these adjustments, the magnetic material is brought into a cyclic magnetic state, which is accomplished by means of a number of successive reversals of switches L and H, after the final adjustments of current have been made, but before the check readings for uniformity of flux are taken. After the uniformity of flux is secured, switch N is connected to t_1 and the ballistic deflection of the galvanometer is taken on reversal of switches L and H. The current reading on M is also taken. The current through M is then increased to a value corresponding to the next higher value of the magnetizing force at which the value of the magnetic flux density in the specimen is desired, and the above procedure is repeated. In order that the normal induction curve is not deviated from, all adjustments of current are made in an upward direction, and the current is not diminished, except, of course, by complete reversal.

Burrows Permeameter for ¼″ rods 7½″ long.

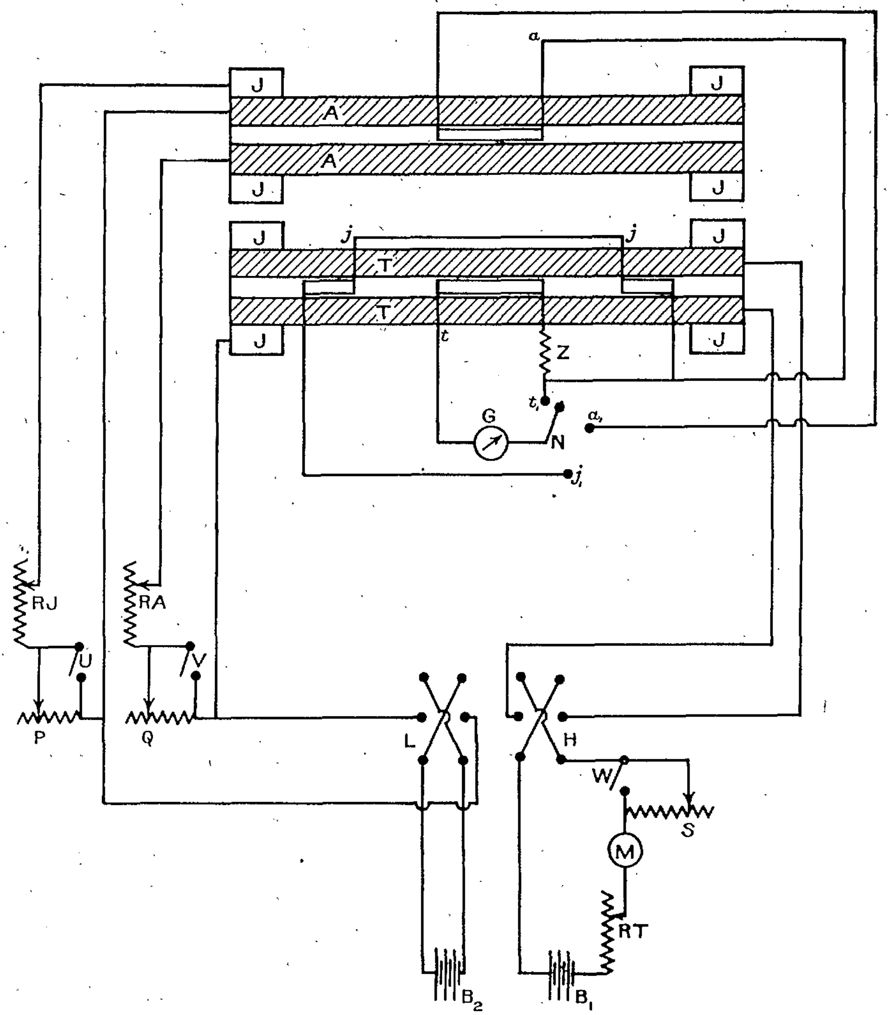


Fig. 7. Connexions for hysteresis tests.

Procedure for Hysteresis Tests (See Fig. 7.)

In order that it be possible to measure the change of induction in the specimen when the magnetizing force is changed at one step from a maximum to any other point on the hysteresis loop, the connexion in Fig. 7 is used. P, Q, and S, are rheostats placed in circuits J, A, and T, respectively, and connected to the respective switches U, V, and W, in order that rheostats P, Q, and S, may be included in, or excluded from, the circuits, as may be desired. After the magnetic circuit has been demagnetized, switches U, V, and W, are closed, and by means of rheostats RT, RA, and RJ, the magnetizing circuits are adjusted for the point chosen as the tip of the hysteresis loop. On simultaneously opening V and W, and thereby inserting resistances in circuits A and T, the deflection of the ballistic galvanometer is observed, with switch N on a_1. Switches V and W are closed again, and resistance Q is adjusted, until the galvanometer shows zero deflection with N on a_1, when V and W are simultaneously opened. Then switch N is thrown to j_1, and resistance P is adjusted until the galvanometer does not deflect when W and U are simultaneously opened. Before the check readings for the final settings of P, Q, and S, are taken, switches U, V, and W, are closed, and switches L and H are simultaneously reversed a few times to bring the material to a cyclic magnetic state. Then N is thrown to t_1, and the change of current through ammeter M as well as the galvanometer deflection are observed when switches U, V, and W, are simultaneously opened. The material is then brought back to the magnetic state represented by the tip of the hysteresis loop, and the entire procedure is repeated for as many points along the downward part of the loop as are desired for positive values of the magnetizing force. Changes from maximum magnetizing force (*i.e.* from either tip of the loop) to one of opposite direction, are obtained by simultaneously reversing switches L and H, and opening switches U, V, and W. In this manner, points on all parts of the hysteresis loop are found.

Calibration of Ballistic Galvanometer.

A long air core solenoid of known dimensions, and uniformly wound with a known number of turns, was employed in the calibration of the ballistic galvanometer. A secondary winding of a known number of turns wound on the central portion of the solenoid was connected in series with the galvanometer and winding t (see Figs. 6 and 7). It was kept in the circuit throughout all tests, in order that the resistance of the galvanometer circuit remain constant. (Z represents the resistance of the secondary of the calibrating solenoid.) Hence, the ballistic deflection of the galvanometer due to a known change of flux resulting from a known change of current in the standard solenoid, may be observed.

Method of Determining Results.

The magnetizing force due to a given current through the main magnetizing coil is calculated from the current turns of this coil. The corresponding flux density in the test specimen is approximately equal to B^1—the product of the ballistic deflection and the galvanometer constant. The value of B^1 must be corrected for the flux linking the secondary, but not passing through the specimen. Then the correct value of the flux density B in gausses is—

$$B = B^1 - \frac{(a_2 - a_1)}{a_1} H,$$

in which a_1 is the effective area of cross section of the specimen; a_2 the area of cross section of the test coil; and H the magnetizing force in gilberts per cm.

Following are the data of these observations in tabulated form, as well as the computed values, in which the symbols have the following significance:—

I = Magnetizing current in amperes.
D = Galvanometer deflection in mms. upon opening circuit.
H = Field intensity in gilberts per cm.
B' = Total flux through test coil, in gausses.
B'' = Flux through test coil and not through specimen in gausses.
B = Corrected flux through specimen in gausses.
$\mu = \frac{B}{H}$ = magnetic permeability of specimen in c.g.s. units.

DATA OF PERMEABILITY TEST (See Plot, Fig. 8).

Cobalt Rod No. 1 H. 217.

July, 1914.

Measurements		*Computation*				
I Amperes	D mm.	H =120 I	B′ =155 D	B″ =1·4 H	B =B′-B″	μ = B/H
0·0102	0·2	1·2	30	0	30	25
0·0204	0·7	2·5	110	0	110	44
0·0304	1·2	3·7	190	10	180	49
0·0440	1·9	5·3	290	10	280	53
0·0680	3·4	8·2	530	10	520	63
0·1284	8·0	15·4	1240	20	1220	79
0·1720	11·4	20·7	1760	30	1730	84
0·1820	11·9	21·9	1840	30	1810	83
0·233	15·0	28·0	2330	40	2290	82
0·280	17·0	33·6	2630	50	2580	77
0·360	20·4	43·2	3160	60	3100	72
0·422	22·9	50·7	3550	70	3480	69
0·512	25·7	61·6	3980	90	3890	63
0·600	28·0	72·1	4340	100	4240	59
0·632	29·4	75·9	4560	110	4450	59
0·697	30·5	83·7	4730	120	4610	55
0·808	33·4	97·0	5180	140	5040	52
0·929	35·8	111·3	5550	160	5390	48
1·074	39·0	129·0	6050	180	5870	45
1·260	42·2	151·2	6550	210	6340	42

DATA OF HYSTERESIS TESTS (See Plot, Fig. 9).

The following are the data of these observations in computed form, as well as the computed values in which the symbols have the following significance:—

dI = Change in magnetizing current.
Defl = Deflection of ballistic galvanometer in mms.
dH = Change in field intensity in gilberts per cm.
dB′ = Change in total flux through test coil in gausses.
dB″ = Change in flux through test coil and not through specimen in gausses.
dB = Change in actual flux through specimen in gausses.

Cobalt Sample No. 1.

July, 1914.

dI Amp.	Defl mm.	dH= 120 d I.	dB′ = 308 D	dB″= 1·4 dH′	dB= d(B′-B″)
0·250	1·9	30	590·	40	550
0·704	4·9	85	1510·	120·	1390
1·076	8·0	129	2460·	180	2280
1·464	11·9	176	3660·	250	3410

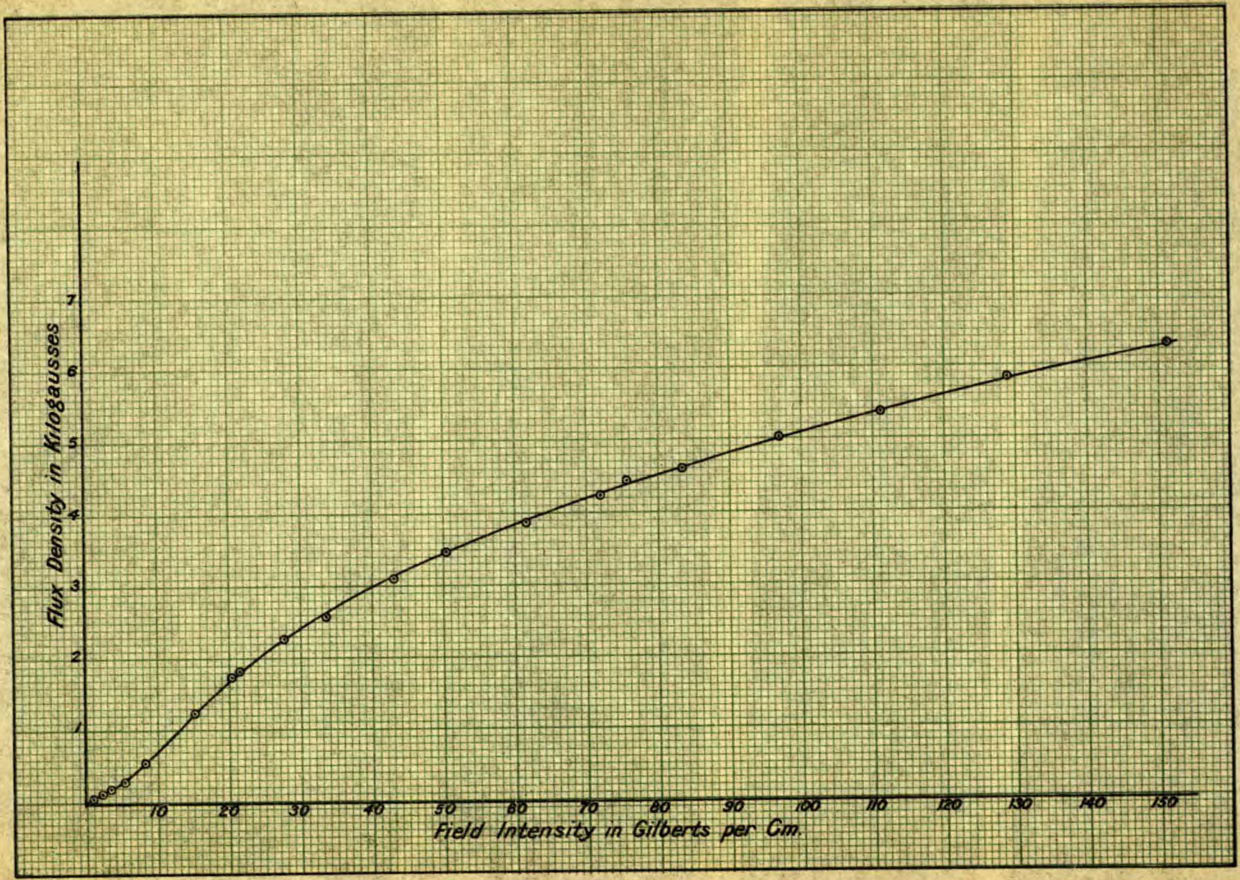


Fig. 8. B-H Curve for Pure Cobalt - Sample H 217

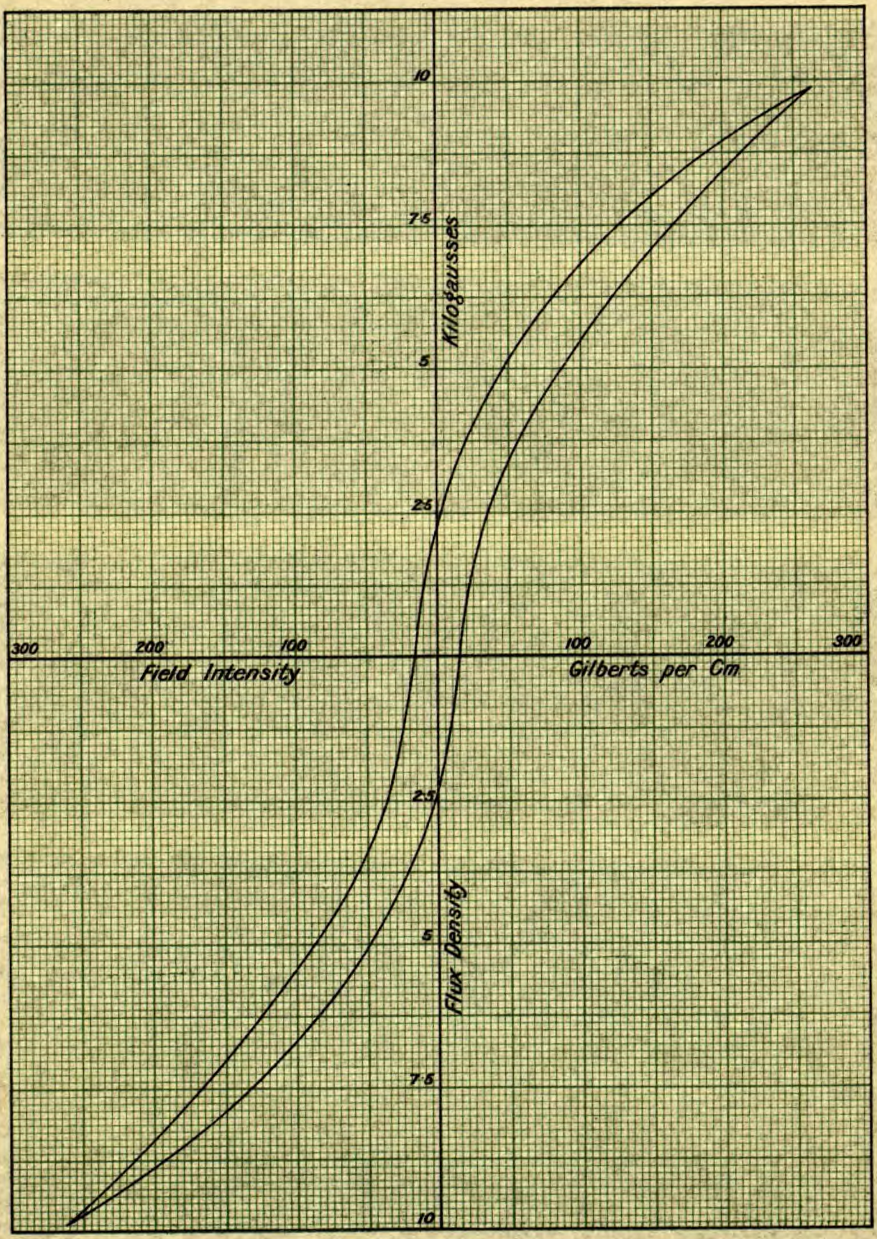


Fig. 9. Hysteresis Loop for Pure Cobalt - Sample H 217

d I Amp.	Defl mm.	dH = 120 d I.	dB' = 308 D.	dB″ = 1·4 d.H'	dB = d(B'-B″)
1·644	14·8	197	4560	280	4280
1·826	17·3	219	5320	310	5010
1·866	18·0	224	5540	310	5230
1·900	19·9	228	6120	320	5800
2·200	27·0	264	8320	370	7950
2·344	39·2	281	12180	390	11790
2·46	42·1	295	12980	410	12570
2·85	50·5	342	15560	480	15080
3·22	55·3	386	17030	540	16490
3·63	59·9	435	18440	610	17830
3·86	62·0	464	19100	650	18450
4·12	64·9	495	19970	690	19280
4·40	66·5	529	20500	740	19760
0·286	2·0	34	620	50	570
0·587	3·7	71	1140	100	1040
0·704	4·6	85	1420	120	1300
0·864	5·9	104	1820	150	1670
1·028	7·3	123	2250	170	2080
1·242	9·3	149	2860	210	2650
1·422	11·3	171	3480	240	3240
1·640	14·1	197	4350	280	4070
1·962	19·8	236	6100	330	5770
1·930	18·9	232	5820	320	5500
2·200	26·0	264	8000	370	7630
2·404	40·0	289	12320	400	11920
2·292	21·1	275	9600	380	9220
2·520	43·0	302	13240	420	12820
2·738	48·0	329	14780	460	14320
3·044	52·3	366	16100	510	15590
3·346	56·0	401	17240	560	16680
3·616	58·6	434	18060	610	17450
3·904	61·2	469	18860	670	18190
4·15	64·5	498	19880	700	19180
4·40	66·5	529	20500	740	19760

PERMEABILITY AND HYSTERESIS MEASUREMENTS MADE BY AMERICAN ROLLING MILL CO., MIDDLETOWN, OHIO.

In addition to the above two sets of measurements, a third set was made by the American Rolling Mill Company, Middletown, Ohio.

They used material identical with that used by us in Method I, that is, pure cobalt H 217, bar No. 2.

Without giving all the numerical values of their measurements, the following plots show the results.

THE ALLOY Fe_2Co.

During the year 1912 samples of the alloy Fe_2Co were prepared by us at this laboratory from American ingot iron with less than 0·1% total impurities, and with cobalt analyzing as given on page 3. The alloy was also prepared from electrolytic iron of even a greater degree of purity, and cobalt of the same analysis. These alloys analyzed: cobalt 33·33% to cobalt 33·36%.

The greatest difficulty was found in casting this alloy to obtain sound bar; in fact, as yet we have not been able to cast this alloy with any degreee of regularity as regards soundness and structure. Under the microscope the structure appears to be a light ground work, more or less covered with microscopic cracks. These cracks are more or less discontinuous. The whole structure suggests lack of cohesion.

Several smaller pieces were prepared in the Arsem electric vacuum furnace which were particularly free from these small cracks. These samples, however, were not of sufficient size to turn bars for satisfactory measurements of magnetic properties by the methods above described. The microstructure gave no clue as to why this alloy possessed higher magnetic saturation value than pure iron, but this fact could be readily ascertained by the simplest test with a small hand magnet; that is, the hand magnet would lift considerably heavier pieces of the alloy than of pure iron.

A preliminary measurement was made of the magnetic saturation value, together with the magnetic permeability in medium fields, which showed the alloy to have a saturation value of magnetization roughly 10% higher than that of pure iron, and a permeability in fields of about 100 gilberts per cm., more than 15% in excess of that of pure iron.

The alloy was not particularly satisfactory, mechanically, being brittle, although fairly strong. It could be forged, after which it was considerably stronger than pure iron. Annealed Fe_2Co had about the same ultimate tensile strength as pure iron.

While these researches were in progress, and particularly while difficulties were being encountered in preparing suitably sound castings, a paper appeared by Dr. P. Weiss, Zurich, 1912, in which the saturation value of magnetization of Fe_2Co was described as 10% higher than that of pure iron. Dr. Weiss set forth certain industrial advantages of this alloy over any of the standard materials in use, concerning which he purposed to publish further. Partly on this account, and partly because of the difficulties in the preparation of the alloy, our researches on this particular alloy were more or less displaced by researches on electro-plating with cobalt, and by other researches for the purpose of increasing the industrial importance of the metal cobalt, as set forth in the other papers of this series. Our observations, however, were sufficiently definite to make it certain—

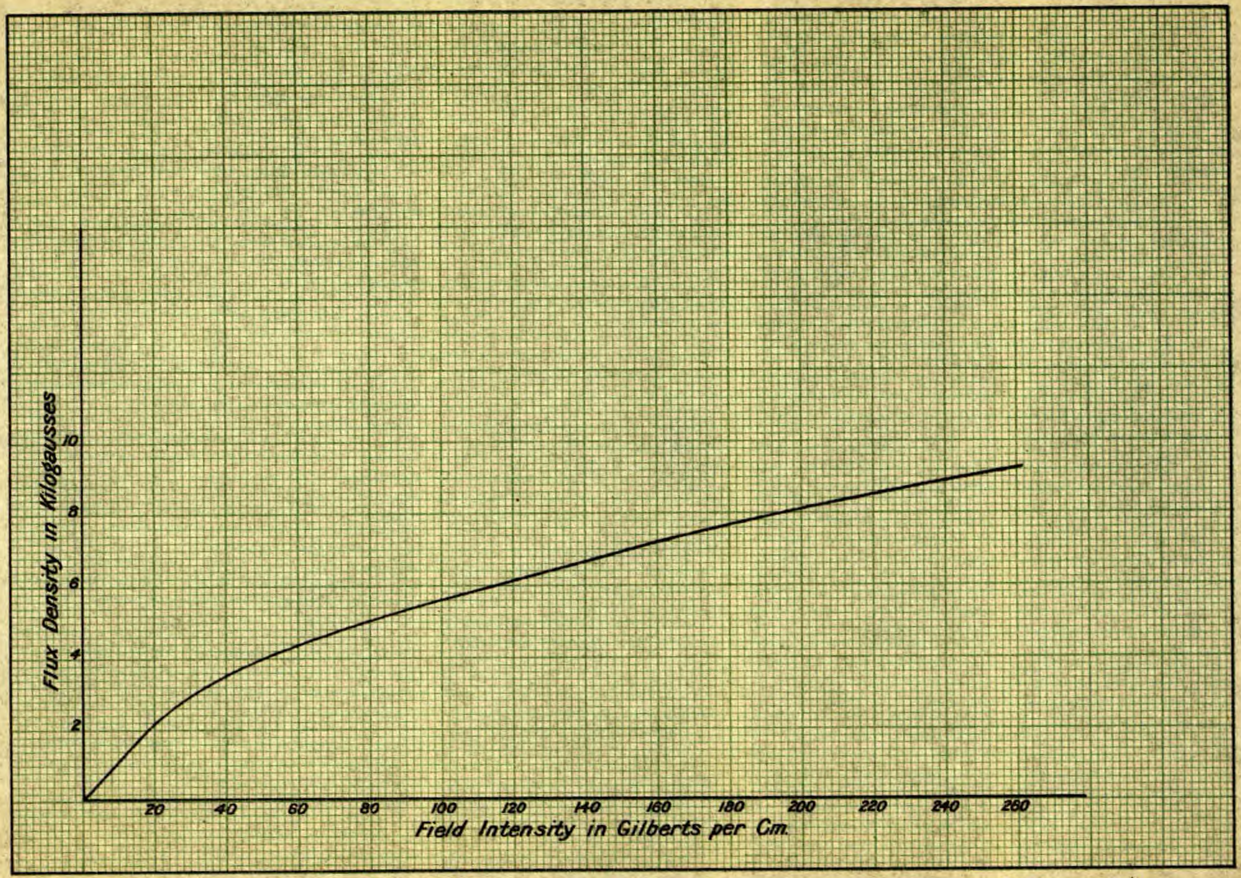


Fig. 10. B-H Curve for Pure Cobalt - Sample H 217

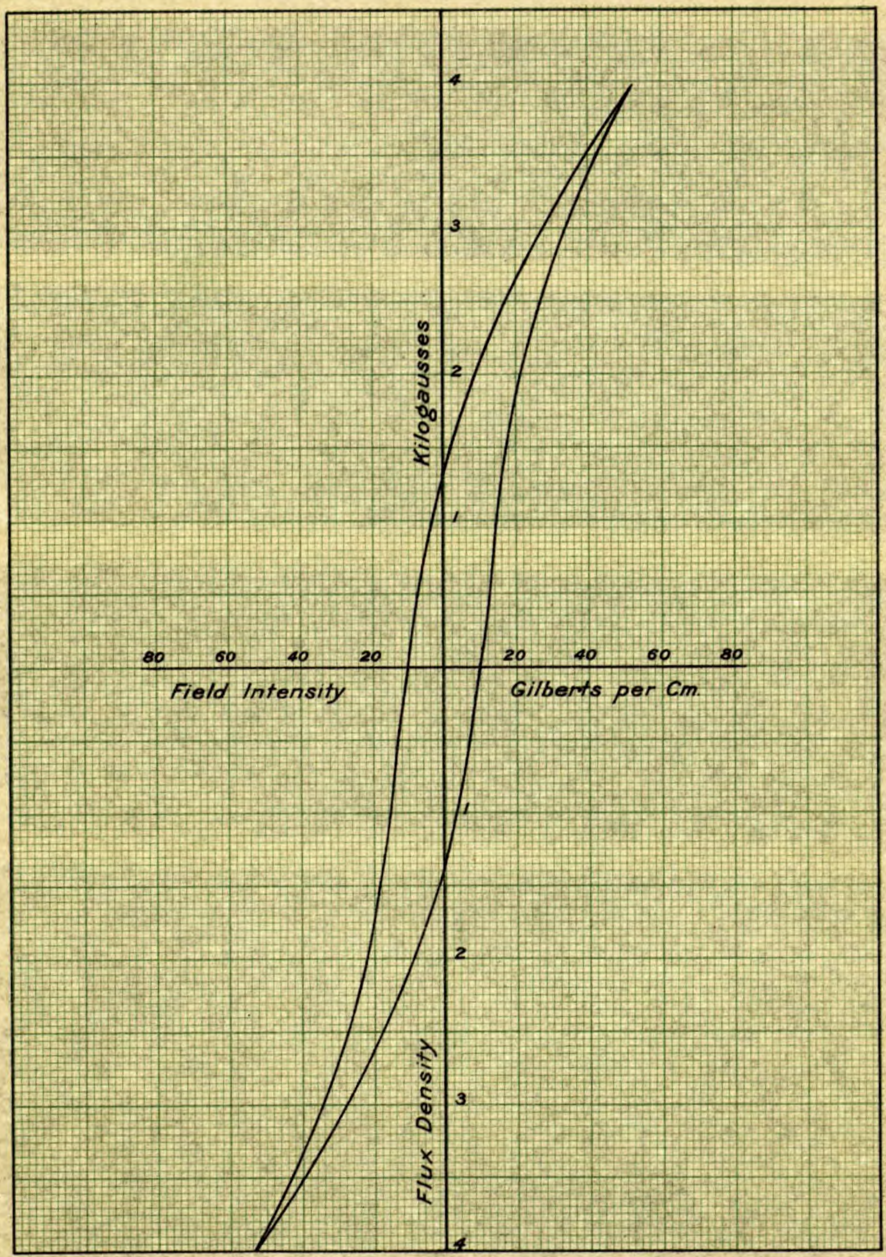
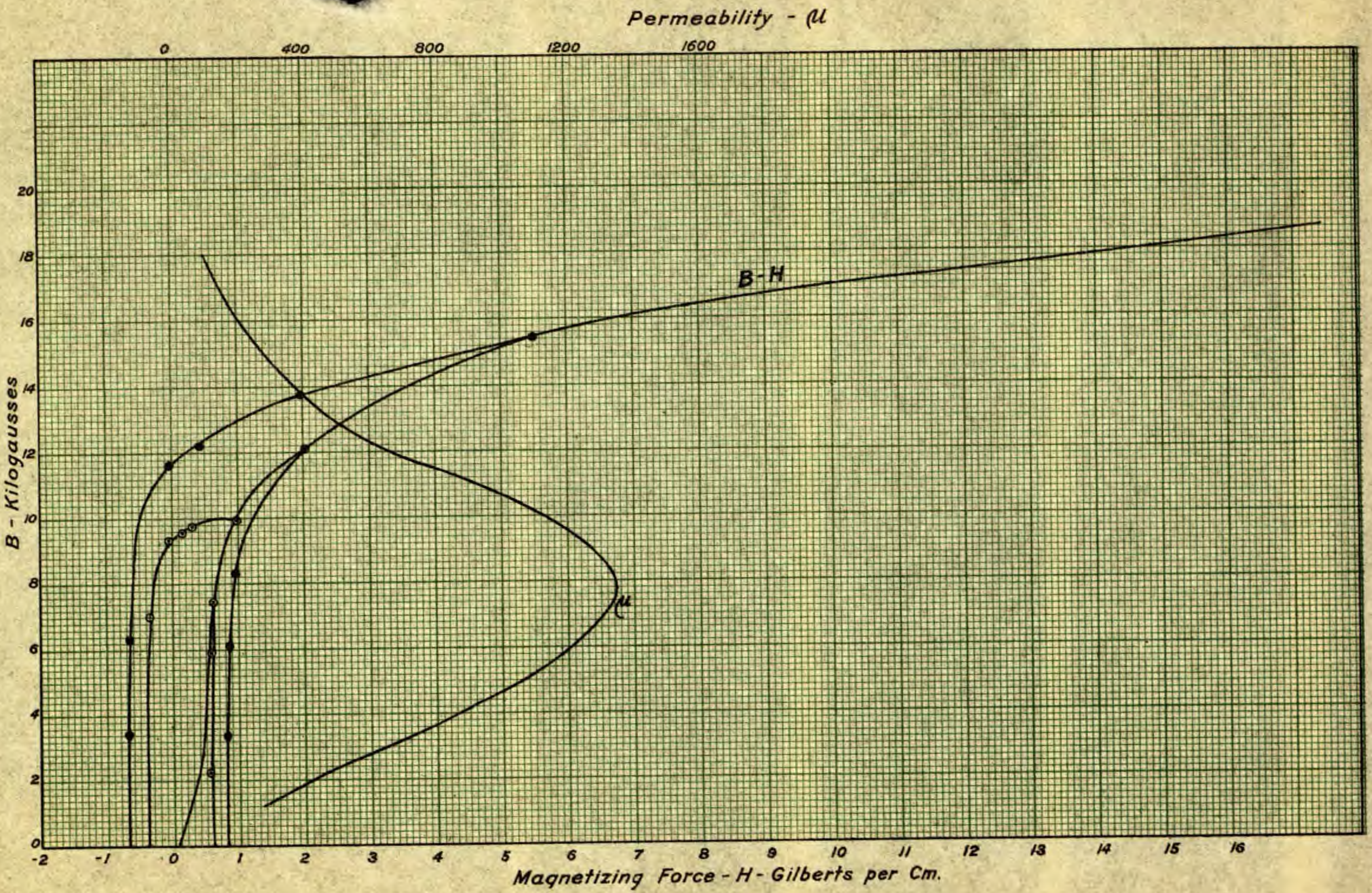


Fig. 11. Hysteresis Loop for Pure Cobalt - Sample H 217



Permeability - μ
0
400
800
1200
1600
B-H
μ
B - Kilogausses
20
18
16
14
12
10
8
6
4
2
0
-2
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
Magnetizing Force - H - Gilberts per Cm.

Fig. 13

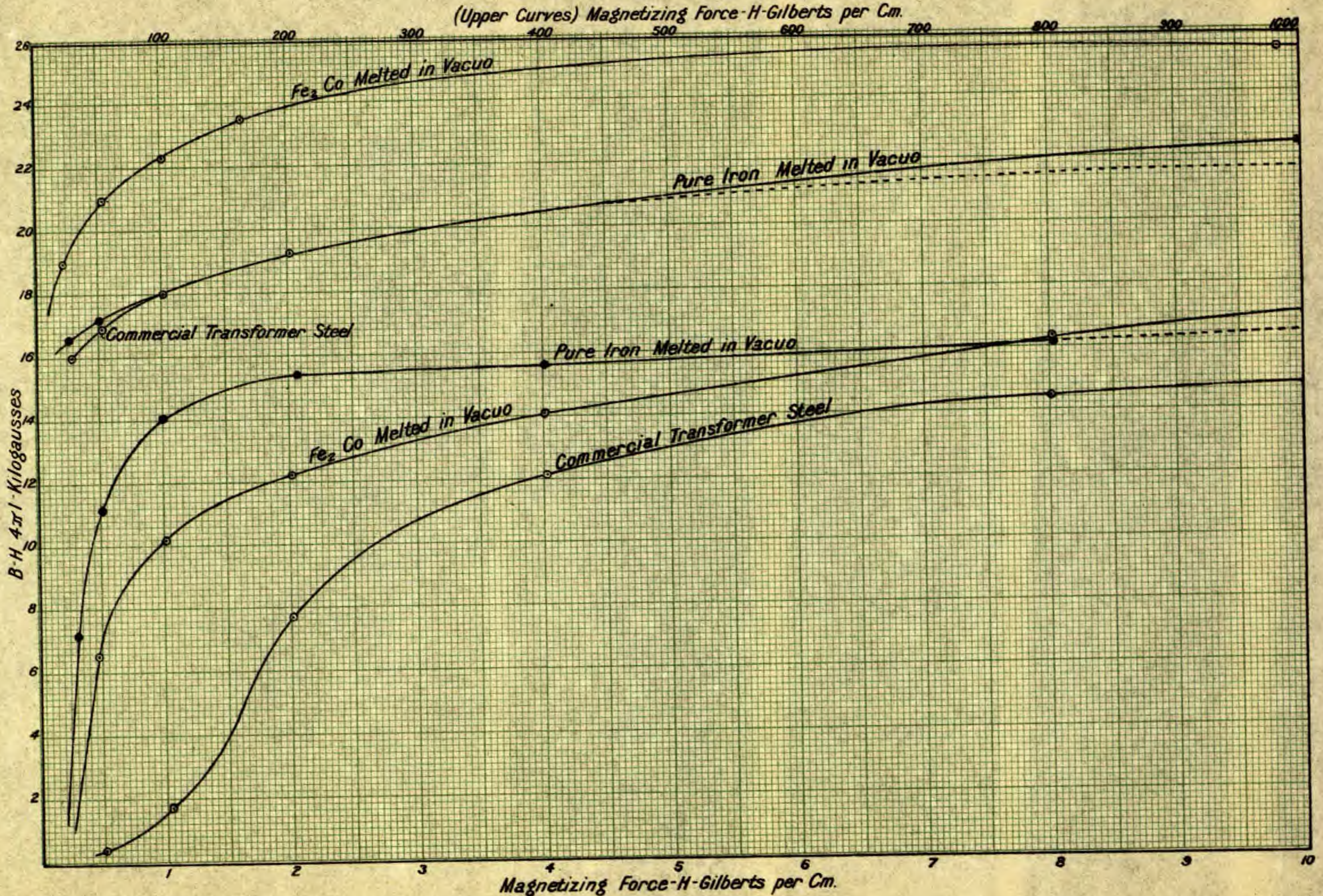

(Upper Curves) Magnetizing Force-H-Gilberts per Cm.
100
200
300
400
500
600
700
800
900
1000
Fe2 Co Melted in Vacuo
Pure Iron Melted in Vacuo
Commercial Transformer Steel
Pure Iron Melted in Vacuo
Fe2 Co Melted in Vacuo
Commercial Transformer Steel
B-H 4π I-Kilogausses
28
24
22
20
18
16
14
12
10
8
6
4
2
1
2
3
4
5
6
7
8
9
10
Magnetizing Force-H-Gilberts per Cm.

Fig. 12

when a sound casting was obtained—that the saturation value of magnetization was in the neighbourhood of 10% greater for Fe_2Co than for pure iron; and that, in medium fields the maximum permeability was very high as compared with pure iron.

More recently an article by Trygve D. Yensen appeared, describing experiments at the Engineering Experiment Station, University of Illinois, entitled "The Iron Cobalt Alloy, Fe_2Co, and Its Magnetic Properties."[1] Inasmuch as the observations recorded in Mr. Yensen's article are more complete than our own, and particularly in view of the fact that our own are in substantial accord with them in all respects, we shall, in the following, review the data of this article, and at the same time state our own results; proper acknowledgment being made to Mr. Yensen.

The magnetic testing was done by means of the Burrows[2] method described earlier in this paper for the measurements of pure cobalt. The data are set forth in the following magnetization curves (Fig. 12) which are given for standard transformer steel, and pure iron for comparison, as well as for the alloy Fe_2Co; also a curve taken from Mr. Yensen's paper (Fig. 13) showing the hysteresis loop for the alloy Fe_2Co is reproduced. It is of particular importance to notice that the magnetization curve for Fe_2Co crosses that of pure iron at a magnetizing force of approximately 8 gilberts per cm. and that, for fields from 50 gilberts per cm. to 200 gilberts per cm., its magnetization is approximately 25% higher than that for pure iron; whereas its saturation value of magnetization is from 10% to 13% higher than that of pure iron.

The hysteresis loss is as low, or lower, than that of commercial grades of iron.

A number of commercial advantages of such material, provided it can be suitably cast and worked, are more or less obvious. Mr. Yensen sets forth one interesting application as follows:—

> Its chief importance, however, lies in its magnetic permeability at high densities. An increase here of 25%, when coupled with a low hysteresis loss, is a highly desirable characteristic, for instance, for the teeth of the armatures of dynamo machinery, where the density is always very high. Without going into detail, a few considerations will make this apparent. By increasing the density in the teeth 25 per cent—which is allowable by using the Fe_2Co alloy—the armature may be shortened a corresponding amount. As the increased density in the teeth necessarily means an increase in the density of the air gap, the latter may be shortened so as to keep the field ampere turns for the air gap and the teeth the same as before. Furthermore, the inside diameter of the armature core may be increased so as to give a smaller core cross-section. The shortening of the armature also shortens the pole pieces and if a high permeability alloy is used in the field magnetic circuit as well as in the armature, the cross-section of the field core and yoke may also be reduced. From the above reasoning it follows that the armature, besides requiring less iron, will also require less copper; and the field spools, while containing the same number of ampere turns as before, will also require less copper. The total reduction of iron and copper may thus amount to as much as 25 per cent each. Passing from the amount of material needed to the energy losses in the machine, it is readily seen that the I^2R loss is reduced in direct proportion to the reduction in copper used. Furthermore, as the hysteresis loss is lower per pound for the Fe_2Co alloy than for ordinary iron, and as the eddy current loss is about the same, the total core loss should be considerably less than with ordinary iron, in spite of the increased density. Thus, it would appear possible with this iron-cobalt alloy to construct dynamo machinery considerably lighter than at present, and with a higher efficiency.

SUMMARY AND CONCLUSIONS.

The general results from these investigations on Fe_2Co may be summarized as follows:—

1. We have been able to cast Fe_2Co in sound ingots only with difficulty,

---

[1] General Electric Review, Sept., 1915.
[2] See p. 9.

microphotographs showing that most of the castings prepared by us lack cohesion, and are crossed with extremely fine cracks.

2. Mechanically, the alloy is brittle, but fairly strong; annealed samples show approximately the same ultimate tensile strength as pure iron.

3. The alloy Fe_2Co may be forged with considerable readiness, after which it has more than twice the strength of pure iron.

4. The iron-cobalt alloy, Fe_2Co, has a saturation value of magnetization from 10% to 13% higher than that of pure iron. No doubt the higher value is the more nearly correct one, as it is obtained from samples prepared in the vacuum furnace, which are substantially free from indications of lack of cohesion.

5. The best castings show a maximum permeability of approximately 13,000 at a density of 8,000 gauss. This is considerably lower than the corresponding value for pure iron, but much greater than that of standard transformer steel or other commercial materials.

6. The most important magnetic property of the alloy Fe_2Co is its permeability in medium fields, that is, for magnetizing force of from 50 to 200 gilberts per cm. Through this range the permeability of Fe_2Co is approximately 25% greater than that of pure iron, or of commercial grades of transformer steel or iron.

7. The hysteresis loss of the alloy Fe_2Co is considerably less than for the best grades of commercial transformer steel at densities of 10,000 gauss, and about the same as for commercial iron at corresponding densities, at densities of about 15,000 gauss.

8. Mr. Yensen reports the specific electrical resistance of Fe_2Co to be about 10 microhms; that is, about the same as for pure iron. (No measurements of electrical resistance of this alloy were made at this laboratory.)

9. These magnetic properties of the alloy Fe_2Co should render it of great value in parts of electro-magnetic machinery, where extreme magnetic densities are required.

CATALOGUE

OF

MINES BRANCH PUBLICATIONS.

CANADA

DEPARTMENT OF MINES

HON. P. E. BLONDIN, MINISTER; R. G. McCONNELL, DEPUTY MINISTER

MINES BRANCH

EUGENE HAANEL, PH.D., DIRECTOR

REPORTS AND MAPS

PUBLISHED BY THE

MINES BRANCH

REPORTS

†1. Mining conditions in the Klondike, Yukon. Report on—by Eugene Haanel, Ph.D., 1902.

†2. Great landslide at Frank, Alta. Report on—by R. G. McConnell, B.A., and R. W. Brock, M.A., 1903.

†3. Investigation of the different electro-thermic processes for the smelting of iron ores and the making of steel, in operation in Europe. Report of Special Commission—by Eugene Haanel, Ph.D., 1904.

5. On the location and examination of magnetic ore deposits by magnetometric measurements—by Eugene Haanel, Ph.D., 1904.

†7. Limestones, and the lime industry of Manitoba. Preliminary report on—by J. W. Wells, M.A., 1905.

†8. Clays and shales of Manitoba: their industrial value. Preliminary report on—by J. W. Wells, M.A., 1905.

†9. Hydraulic cements (raw materials) in Manitoba; manufacture and uses of. Preliminary report on—by J. W. Wells, M.A., 1905.

†10. Mica: its occurrence, exploitation, and uses—by Fritz Cirkel, M.E., 1905. (See No. 118.)

†11 Asbestos: its occurrence, exploitation, and uses—by Fritz Cirkel, M.E., 1905. (See No. 69.)

†12. Zinc resources of British Columbia and the conditions affecting their exploitation. Report of the Commission appointed to investigate—by W. R. Ingalls, M.E., 1905.

†16. Experiments made at Sault Ste. Marie, under Government auspices in the smelting of Canadian iron ores by the electro-thermic process. Final report on—by Eugene Haanel, Ph.D., 1907.

† Publications marked thus † are out of print.

†17. Mines of the silver-cobalt ores of the Cobalt district: their present and prospective output. Report on—by Eugene Haanel, Ph.D., 1907.

†18. Graphite: its properties, occurrences, refining, and uses—by Fritz Cirkel, M.E., 1907.

†19. Peat and lignite: their manufacture and uses in Europe—by Erik Nystrom, M.E., 1908.

†20. Iron ore deposits of Nova Scotia. Report on (Part I)—by J. E. Woodman, D.Sc.

†21. Summary report of Mines Branch, 1907–8.

†22. Iron ore deposits of Thunder Bay and Rainy River districts. Report on—by F. Hille, M.E.

†23. Iron ore deposits along the Ottawa (Quebec side) and Gatineau rivers. Report on—by Fritz Cirkel, M.E.

24. General report on the mining and metallurgical industries of Canada, 1907–8.

†25. The tungsten ores of Canada. Report on—by T. L. Walker, Ph.D.

26. The mineral production of Canada, 1906. Annual report on—by John McLeish, B.A.

†27. The mineral production of Canada, 1907. Preliminary report on—by John McLeish, B.A.

†27a. The mineral production of Canada, 1908. Preliminary report on—by John McLeish, B.A.

†28. Summary report of Mines Branch, 1908.

29. Chrome iron ore deposits of the Eastern Townships. Monograph on—by Fritz Cirkel. (Supplementary section: Experiments with chromite at McGill University—by J. B. Porter, E.M., D.Sc.)

30. Investigation of the peat bogs and peat fuel industry of Canada, 1908, Bulletin No. 1—by Erik Nystrom, M.E., and A. Anrep. Peat Expert.

32. Investigation of electric shaft furnace, Sweden. Report on—by Eugene Haanel, Ph.D.

47. Iron ore deposits of Vancouver and Texada islands. Report on—by Einar Lindeman, M.E.

†55. The bituminous, or oil-shales of New Brunswick and Nova Scotia; also on the oil-shale industry of Scotland. Report on—by R. W. Ells, LL.D.

† Publications marked thus † are out of print.

58. The mineral production of Canada, 1907 and 1908. Annual report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1907–08.*

†31. Production of cement in Canada, 1908.

†42. Production of iron and steel in Canada during the calendar years 1907 and 1908.

43. Production of chromite in Canada during the calendar years 1907 and 1908.

44. Production of asbestos in Canada during the calendar years 1907 and 1908.

†45. Production of coal, coke, and peat in Canada during the calendar years 1907 and 1908.

46. Production of natural gas and petroleum in Canada during the calendar years 1907 and 1908.

59. Chemical analyses of special economic importance made in the laboratories at the Department of Mines, 1906–07–08. Report on—by F. G. Wait, M.A., F.C.S. (With Appendix on the commercial methods and apparatus for the analyses of oil-shales—by H. A. Leverin, Ch.E.)

Schedule of charges for chemical analyses and assays.

†62. Mineral production of Canada, 1909. Preliminary report on—by John McLeish, B.A.

63. Summary report of Mines Branch, 1909.

67. Iron deposits of the Bristol mine, Pontiac county, Quebec. Bulletin No. 2—by Einar Lindeman, M.E., and Geo. C. Mackenzie, B.Sc.

†68. Recent advances in the construction of electric furnaces for the production of pig iron, steel, and zinc. Bulletin No. 3—by Eugene Haanel, Ph.D.

69. Chrysotile-asbestos: its occurrence, exploitation, milling, and uses. Report on—by Fritz Cirkel, M.E. (Second edition, enlarged.)

†71. Investigation of the peat bogs and peat industry of Canada, 1909–10; to which is appended Mr. Alf. Larson's paper on Dr. M. Ekenberg's wet-carbonizing process: from Teknisk Tidskrift, No. 12, December 26, 1908—translation by Mr. A. Anrep, Jr.; also a translation of Lieut. Ekelund's pamphlet entitled "A solution of the peat problem," 1909, describing the Ekelund process for the manufacture of peat powder, by Harold A. Leverin, Ch.E. Bulletin No. 4—by A. Anrep. (Second edition, enlarged.)

† Publications marked thus † are out of print.

82. Magnetic concentration experiments. Bulletin No. 5—by Geo. C. Mackenzie, B.Sc.

83. An investigation of the coals of Canada with reference to their economic qualities: as conducted at McGill University under the authority of the Dominion Government. Report on—by J. B. Porter, E.M., D.Sc., R. J. Durley, Ma.E., and others.
Vol. I—Coal washing and coking tests.
Vol. II—Boiler and gas producer tests.
†Vol. III—
Appendix I
Coal washing tests and diagrams.
†Vol. IV—
Appendix II
Boiler tests and diagrams.
†Vol. V—
Appendix III
Producer tests and diagrams.
†Vol. VI—
Appendix IV
Coking tests.
Appendix V
Chemical tests.

†84. Gypsum deposits of the Maritime provinces of Canada—including the Magdalen islands. Report on—by W. F. Jennison, M.E. (See No. 245.)

88. The mineral production of Canada, 1909. Annual report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1909.*

†79. Production of iron and steel in Canada during the calendar year 1909.
†80. Production of coal and coke in Canada during the calendar year 1909.
85. Production of cement, lime, clay products, stone, and other structural materials during the calendar year 1909.

89. Proceedings of conference on explosives. (Fourth edition).

90. Reprint of presidential address delivered before the American Peat Society at Ottawa, July 25, 1910. By Eugene Haanel, Ph.D.

92. Investigation of the explosives industry in the Dominion of Canada, 1910. Report on—by Capt. Arthur Desborough. (Fourth edition).

†93. Molybdenum ores of Canada. Report on—by Professor T. L. Walker, Ph.D.

100. The building and ornamental stones of Canada: Building and ornamental stones of Ontario. Report on—by Professor W. A. Parks, Ph.D.

† Publications marked thus † are out of print.

† Publications marked thus † are out of print.

184. Magnetite occurrences along the Central Ontario railway. Report on—by E. Lindeman, M.E.

201. The mineral production of Canada during the calendar year 1911. Annual report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1911.*

181. Production of cement, lime, clay products, stone, and other structural materials in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

†182. Production of iron and steel in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

183. General summary of the mineral production in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

†199. Production of copper, gold, lead, nickel, silver, zinc, and other metals of Canada, during the calendar year 1911. Bulletin on—by C. T. Cartwright, B.Sc.

†200. The production of coal and coke in Canada during the calendar year 1911. Bulletin on—by John McLeish, B.A.

203. Building stones of Canada—Vol. II: Building and ornamental stones of the Maritime Provinces. Report on—by W. A. Parks, Ph.D.

209. The copper smelting industry of Canada. Report on—by A. W. G. Wilson, Ph.D.

216. Mineral production of Canada, 1912. Preliminary report on—by John McLeish, B.A.

222. Lode mining in Yukon: an investigation of the quartz deposits of the Klondike division. Report on—by T. A. MacLean, B.Sc.

224. Summary report of the Mines Branch, 1912.

227. Sections of the Sydney coal fields—by J. G. S. Hudson, M.E.

†229. Summary report of the petroleum and natural gas resources of Canada, 1912—by F. G. Clapp, A.M. (See No. 224).

230. Economic minerals and mining industries of Canada.

245. Gypsum in Canada: its occurrence, exploitation, and technology. Report on—by L. H. Cole, B.Sc.

254. Calabogie iron-bearing district. Report on—by E. Lindeman, M.E.

259. Preparation of metallic cobalt by reduction of the oxide. Report on—by H. T. Kalmus, B.Sc., Ph.D.

† Publications marked thus † are out of print.

262. The mineral production of Canada during the calendar year 1912. Annual report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1912.*

238. General summary of the mineral production of Canada during the calendar year 1912. Bulletin on—by John McLeish, B.A.

†247. Production of iron and steel in Canada during the calendar year 1912. Bulletin on—by John McLeish, B.A.

†256. Production of copper, gold, lead, nickel, silver, zinc, and other metals of Canada, during the calendar year 1912—by C. T. Cartwright, B.Sc.

257. Production of cement, lime, clay products, stone, and other structural materials during the calendar year 1912. Report on—by John McLeish, B.A.

†258. Production of coal and coke in Canada, during the calendar year 1912. Bulletin on—by John McLeish, B.A.

266. Investigation of the peat bogs and peat industry of Canada, 1911 and 1912. Bulletin No. 9—by A. Anrep.

279. Building and ornamental stones of Canada—Vol. III: Building and ornamental stones of Quebec. Report on—by W. A. Parks, Ph.D.

281. The bituminous sands of Northern Alberta. Report on—by S. C. Ells, M.E.

283. Mineral production of Canada, 1913. Preliminary report on—by John McLeish, B.A.

285. Summary report of the Mines Branch, 1913.

291. The petroleum and natural gas resources of Canada. Report on—by F. G. Clapp, A.M., and others:—
Vol. I—Technology and exploitation.
Vol. II—Occurrence of petroleum and natural gas in Canada.
Also separates of Vol. II, as follows:—
Part 1, Eastern Canada.
Part 2, Western Canada.

299. Peat, lignite, and coal: their value as fuels for the production of gas and power in the by-product recovery producer. Report on—by B. F. Haanel, B.Sc.

303. Moose Mountain iron-bearing district. Report on—by E. Lindeman, M.E.

305. The non-metallic minerals used in the Canadian manufacturing industries. Report on—by Howells Fréchette, M.Sc.

309. The physical properties of cobalt, Part II. Report on—by H. T. Kalmus, B.Sc., Ph.D.

† Publications marked thus † are out of print.

320. The mineral production of Canada during the calendar year 1913. Annual report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1913.*

315. The production of iron and steel during the calendar year 1913. Bulletin on—by John McLeish, B.A.
†316. The production of coal and coke during the calendar year 1913. Bulletin on—by John McLeish, B.A.
317. The production of copper, gold, lead, nickel, silver, zinc, and other metals, during the calendar year 1913. Bulletin on—by C. T. Cartwright, B.Sc.
318. The production of cement, lime, clay products, and other structural materials, during the calendar year 1913. Bulletin on—by John McLeish, B.A.
319. General summary of the mineral production of Canada during the calendar year 1913. Bulletin on—by John McLeish, B.A.

322. Economic minerals and mining industries of Canada. (Revised Edition).

323. The products and by-products of coal. Report on—by Edgar Stansfield, M.Sc., and F. E. Carter, B.Sc., Dr. Ing.

325. The salt industry of Canada. Report on—by L. H. Cole, B.Sc.

331. The investigation of six samples of Alberta lignites. Report on—by B. F. Haanel, B.Sc., and John Blizard, B.Sc.

333. The mineral production of Canada, 1914. Preliminary report on—by John McLeish, B.A.

334. Electro-plating with cobalt and its alloys. Report on—by H. T. Kalmus, B.Sc., Ph.D.

336. Notes on clay deposits near McMurray, Alberta. Bulletin No. 10—by S. C. Ells, B.A., B.Sc.

338. Coals of Canada: Vol. VII. Weathering of coal. Report on—by J. B. Porter, E.M., Ph.D., D.Sc.

344. Electro-thermic smelting of iron ores in Sweden. Report on—by Alfred Stansfield, D. Sc., A.R.S.M., F.R.S.C.

346. Summary report of the Mines Branch for 1914.

351. Investigation of the peat bogs and the peat industry of Canada, 1913–1914. Bulletin No. 11—by A. Anrep.

384. The Mineral production of Canada during the calendar year 1914. Annual Report on—by John McLeish, B.A.

NOTE.—*The following parts were separately printed and issued in advance of the Annual Report for 1914.*

348. Production of coal and coke in Canada during the calendar year, 1914. Bulletin on—by J. McLeish, B.A.

349. Production of iron and steel in Canada during the calendar year, 1914. Bulletin on—by J. McLeish, B.A.

350. Production of copper, gold, lead, nickel, silver, zinc, and other metals, during the calendar year, 1914. Bulletin on—by J. McLeish, B.A.

383. The production of cement, lime, clay products, stone and other structural materials, during the calendar year 1914. Bulletin on—by John McLeish, B.A.

385. Investigation of a reported discovery of phosphate at Banff, Alberta. Bulletin No. 12—by H. S. de Schmid, M.E., 1915.

406. Description of the laboratories of the Mines Branch of the Department of Mines, 1916. Bulletin No. 13.

408. Mineral production of Canada, 1915. Preliminary report on—by John McLeish, B.A.

411. Cobalt alloys with non-corrosive properties. Report on—by H. T. Kalmus, B.Sc., Ph.D.

413. Magnetic properties of cobalt and of Fe_2Co. Report on—by H. T. Kalmus, B.Sc., Ph.D.

The Division of Mineral Resources and Statistics has prepared the following lists of mine, smelter, and quarry operators: Metal mines and smelters, General list of mines (except coal and metal mines), Coal mines, Stone quarry operators, Manufacturers of clay products and of cement, Manufacturers of lime, and Operators of sand and gravel deposits. Copies of the lists may be obtained on application.

IN THE PRESS

388. The building and ornamental stones of Canada—Vol. IV: building and ornamental stones of the western provinces. Report on—by W. A. Parks, Ph.D.

401. Feldspar in Canada. Report on—by H. S. de Schmid, M.E.

419. Production of iron and steel in Canada during the calendar year 1915. Bulletin on—by J. McLeish, B.A.

FRENCH TRANSLATIONS

971. (26a) Rapport annuel sur les industries minérales du Canada, pour l'année 1905.

†4. Rapport de la Commission nominée pour étudier les divers procédés électro-thermiques pour la réduction des minerais de fer et la fabrication de l'acier employés en Europe—by Eugene Haanel, Ph.D. (French Edition), 1905.

26a. The mineral production of Canada, 1906. Annual report on—by John McLeish, B.A.

†28a. Summary report of Mines Branch, 1908.

56. Bituminous or oil-shales of New Brunswick and Nova Scotia; also on the oil-shale industry of Scotland. Report on—by R. W. Ells, LL.D.

81. Chrysotile-asbestos, its occurrence, exploitation, milling, and uses Report on—by Fritz Cirkel, M.E.

100a. The building and ornamental stones of Canada: Building and ornamental stones of Ontario. Report on—by W. A. Parks, Ph.D.

149. Magnetic iron sands of Natashkwan, Saguenay county, Que. Report on—by Geo. C. Mackenzie, B.Sc.

155. The utilization of peat fuel for the production of power, being a record of experiments conducted at the Fuel Testing Station, Ottawa, 1910–11. Report on—by B. F. Haanel, B.Sc.

†156. The tungsten ores of Canada. Report on—by T. L. Walker, Ph.D.

169. Pyrites in Canada: its occurrences, exploitation, dressing, and uses.. Report on—by A. W. G. Wilson, Ph.D.

179. The nickel industry: with special reference to the Sudbury region, Ont. Report on—by Professor A. P. Coleman, Ph.D.

180. Investigation of the peat bogs, and peat industry of Canada, 1910–11. Bulletin No. 8—by A. Anrep.

195. Magnetite occurrences along the Central Ontario railway. Report on —by E. Lindeman, M.E.

†196. Investigation of the peat bogs and peat industry of Canada, 1909–10, to which is appended Mr. Alf. Larson's paper on Dr. M. Ekenburg's wet-carbonizing process: from Teknisk Tidskrift, No. 12, December 26, 1908—translation by Mr. A. Anrep; also a translation of Lieut. Ekelund's pamphlet entitled "A solution of the peat problem," 1909, describing the Ekelund process for the manufacture of peat powder, by Harold A. Leverin, Ch.E. Bulletin No. 4—by A. Anrep. (Second Edition, enlarged.)

197. Molybdenum ores of Canada. Report on—by T. L. Walker, Ph.D.

† Publications marked thus † are out of print.

†198. Peat and lignite: their manufacture and uses in Europe. Report on—by Erik Nystrom, M.E., 1908.

202. Graphite: its properties, occurrences, refining, and uses. Report on—by Fritz Cirkel, M.E., 1907.

204. Building stones of Canada—Vol. II: Building and ornamental stones of the Maritime Provinces. Report on—by W. A. Parks, Ph.D.

219. Austin Brook iron-bearing district. Report on—by E. Lindeman, M.E.

223. Lode Mining in the Yukon: an investigation of quartz deposits in the Klondike division. Report on—by T. A. MacLean, B.Sc.

224a. Mines Branch Summary report for 1912.

†226. Chrome iron ore deposits of the Eastern Townships. Monograph on—by Fritz Cirkel, M.E. (Supplementary section: Experiments with chromite at McGill University—by J. B. Porter, E.M., D.Sc.).

231. Economic minerals and mining industries of Canada.

233. Gypsum deposits of the Maritime Provinces of Canada—including the Magdalen islands. Report on—by W. F. Jennison, M.E.

246. Gypsum in Canada: its occurrence, exploitation, and technology. Report on—by L. H. Cole, B.Sc.

260. The preparation of metallic cobalt by reduction of the oxide. Report on—by H. T. Kalmus, B.Sc., Ph.D.

263. Recent advances in the construction of electric furnaces for the production of pig iron, steel, and zinc. Bulletin No. 3—by Eugene Haanel, Ph.D.

†264. Mica: its occurrence, exploitation, and uses. Report on—by Hugh S. de Schmid, M.E.

265. Annual mineral production of Canada, 1911. Report on—by John McLeish, B.A.

286. Summary Report of Mines Branch, 1913.

287. Production of iron and steel in Canada during the calendar year 1912. Bulletin on—by John McLeish, B.A.

288. Production of coal and coke in Canada, during the calendar year 1912. Bulletin on—by John McLeish, B.A.

289. Production of cement, lime, clay products, stone, and other structural materials during the calendar year 1912. Bulletin on—by John McLeish, B.A.

† Publications marked thus † are out of print.

290. Production of copper, gold, lead, nickel, silver, zinc, and other metals of Canada during the calendar year 1912. Bulletin on—by C. T. Cartwright, B.Sc.

307. Cataologue of French publications of the Mines Branch and of the Geological Survey, up to July, 1914.

308. An investigation of the coals of Canada with reference to their economic qualities: as conducted at McGill University under the authority of the Dominion Government. Report on—by J. B. Porter, E.M., D.Sc., R. J. Durley, Ma.E., and others.
   Vol. I—Coal washing and coking tests.
   Vol. II—Boiler and gas producer tests.
   Vol. III—
     Appendix I
       Coal washing tests and diagrams.
   Vol. IV—
     Appendix II
       Boiler tests and diagrams.

314. Iron ore deposits, Bristol mine, Pontiac county, Quebec, Report on—by E. Lindeman, M.E.

321. Annual mineral production of Canada, during the calendar year 1913. Report on—by J. McLeish, B.A.

IN THE PRESS

280. The building and ornamental stones of Canada, Vol. III; Province of Quebec. Report on—by Professor W. A. Parks, Ph.D.

292. The petroleum and natural gas resources of Canada. Report on—by F. G. Clapp, A.M., and others.
   Vol. I.—Technology and exploitation.

306. The non-metallic minerals used in the Canadian manufacturing industries Report on—by Howells Fréchette, M.Sc.

310. The physical properties of the metal cobalt, Part II. Report on—by H. T. Kalmus, B.Sc., Ph.D.

MAPS

†6. Magnetometric survey, vertical intensity: Calabogie mine, Bagot township, Renfrew county, Ontario—by E. Nystrom, 1904. Scale 60 feet to 1 inch. Summary report 1905. (See Map No. 249.)

†13. Magnetometric survey of the Belmont iron mines, Belmont township, Peterborough county, Ontario—by B. F. Haanel,. 1905. Scale 60 feet to 1 inch. Summary report, 1906. (See Map No. 186).

†14. Magnetometric survey of the Wilbur mine, Lavant township, Lanark county, Ontario—by B. F. Haanel, 1905. Scale 60 feet to 1 inch. Summary report, 1906.

†33. Magnetometric survey, vertical intensity: lot 1, concession VI, Mayo township, Hastings county, Ontario—by Howells Fréchette, 1909. Scale 60 feet to 1 inch. (See Maps Nos. 191 and 191A.)

†34. Magnetometric survey, vertical intensity: lots 2 and 3, concession VI, Mayo township, Hastings county, Ontario—by Howells Fréchette, 1909. Scale 60 feet to 1 inch. (See Maps Nos. 191 and 191A.)

†35. Magnetometric survey, vertical intensity: lots 10, 11, and 12 concession IX, and lots 11 and 12, concession VIII, Mayo township, Hastings county. Ontario—by Howells Fréchette, 1909. Scale 60 feet to 1 inch. (See Maps Nos. 191 and 191A.)

*36. Survey of Mer Bleue peat bog, Gloucester township, Carleton county, and Cumberland township, Russel county, Ontario—by Erik Nystrom, and A. Anrep. (Accompanying report No. 30.)

*37. Survey of Alfred peat bog. Alfred and Caledonia townships, Prescott county, Ontario—by Erik Nystrom and A. Anrep. (Accompanying report No. 30.)

*38. Survey of Welland peat bog, Wainfleet and Humberstone townships, Welland county, Ontario—by Erik Nystrom and A. Anrep. (Accompanying report No. 30.)

*39. Survey of Newington peat bog, Osnabruck, Roxborough, and Cornwall townships, Stormont county, Ontario—by Erik Nystrom and A. Anrep. (Accompanying report No. 30.)

*40. Survey of Perth peat bog, Drummond township, Lanark county, Ontario—by Erik Nystrom and A. Anrep. (Accompanying report No. 30.)

†41. Survey of Victoria Road peat bog, Bexley and Carden townships, Victoria county, Ontario—Erik Nystrom and A. Anrep. (Accompanying report No. 30).

*48. Magnetometric survey of Iron Crown claim at Nimpkish (Klaanch) river, Vancouver island, B.C.—by E. Lindeman. Scale 60 feet to 1 inch. (Accompanying report No. 47).

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus† have been printed independently of reports, hence can be procured separately by applicants.

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†98. General map of coal fields in British Columbia. (Accompanying report No. 83—by Dr. J. B. Porter.)

†99. General map of coal field in Yukon Territory. (Accompanying report No. 85—by Dr. J. B. Porter.)

†106. Geological map of Austin Brook iron-bearing district, Bathurst township, Gloucester county, N.B.—by E. Lindeman. Scale 400 feet to 1 inch. (Accompanying report No. 105.)

†107. Magnetometric survey, vertical intensity: Austin Brook iron-bearing district—by E. Lindeman. Scale 400 feet to 1 inch. (Accompanying report No. 105.)

†108. Index map showing iron-bearing area at Austin Brook—by E. Lindeman. (Accompanying report No. 105.)

*112. Sketch plan showing geology of Point Mamainse, Ont.—by Professor A. C. Lane. Scale 4,000 feet to 1 inch. (Accompanying report No. 111.)

†113. Holland peat bog Ontario—by A. Anrep. (Accompanying report No. 151.)

*119–137. Mica: township maps, Ontario and Quebec—by Hugh S. de Schmid. (Accompanying report No. 118.)

†138. Mica: showing location of principal mines and occurrences in the Quebec mica area—by Hugh S. de Schmid. Scale 3·95 miles to 1 inch. (Accompanying report No. 118.)

†139. Mica: showing location of principal mines and occurrences in the Ontario mica area—by Hugh S. de Schmid. Scale 3·95 miles to 1 inch. (Accompanying report No. 118.)

†140. Mica: showing distribution of the principal mica occurrences in the Dominion of Canada—by Hugh S. de Schmid. Scale 3·95 miles to 1 inch. (Accompanying report No. 118.)

†141. Torbrook iron-bearing district Annapolis county, N.S.—by Howells Fréchette. Scale 400 feet to 1 inch. (Accompanying report No. 110.)

146. Distribution of iron ore sands of the iron ore deposits on the north shore of the River and Gulf of St. Lawrence, Canada—by Geo. C. Mackenzie. Scale 100 miles to 1 inch. (Accompanying report No. 145.)

†147. Magnetic iron sand deposits in relation to Natashkwan harbour and Great Natashkwan river, Que. (Index Map)—by Geo. C. Mackenzie. Scale 40 chains to 1 inch. (Accompanying report No. 145.)

†148. Natashkwan magnetic iron sand deposits, Saguenay county, Que.—by Geo. C. Mackenzie. Scale 1,000 feet to 1 inch. (Accompanying report No. 145.)

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†152. Map showing the location of peat bogs investigated in Ontario—by A. Anrep. (See Map No. 354.)

†153. Map showing the location of peat bogs, as investigated in Manitoba—by A. Anrep.

†157. Lac du Bonnet peat bog, Manitoba—by A. Anrep.

†158. Transmission peat bog, Manitoba— " "

†159. Corduroy peat bog, Manitoba— " "

†160. Boggy Creek peat bog, Manitoba— " "

†161. Rice Lake peat bog, Manitoba— " "

†162. Mud Lake peat bog, Manitoba— " "

†163. Litter peat bog, Manitoba— " "

†164. Julius peat litter bog, Manitoba— " "

†165. Fort Frances peat bog, Ontario— " "

(Accompanying report No. 151.) [for Nos. 152–165]

*166. Magnetometric map of No. 3 mine, lot 7, concessions V and VI, McKim township, Sudbury district, Ont.—by E. Lindeman. (Accompanying Summary report, 1911.)

†168. Map showing pyrites mines and prospects in Eastern Canada, and their relation to the United States market—by A. W. G. Wilson. Scale 125 miles to 1 inch. (Accompanying report No. 167.)

†171. Geological map of Sudbury nickel region, Ont.—by Prof. A. P. Coleman. Scale 1 mile to 1 inch. (Accompanying report No. 170.)

†172. Geological map of Victoria mine—by Prof. A. P. Coleman.

†173. " Crean Hill mine—by Prof. A. P. Coleman

†174. " Creighton mine—by Prof. A. P. Coleman.

(Accompanying report No. 170.) [for Nos. 172–174]

†175. " showing contact of norite and Laurentian in vicinity of Creighton mine—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†176. " Copper Cliff offset—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†177. " No. 3 mine—by Prof. A. P. Coleman. (Accompanying report No. 170.)

†178. " showing vicinity of Stobie and No. 3 mines—by Prof. A. P. Coleman. (Accompanying report No. 170.)

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†185. Magnetometric survey, vertical intensity: Blairton iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†185a. Geological map, Blairton iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†186. Magnetometric survey, Belmont iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†186a. Geological map, Belmont iron mine, Belmont township, Peterborough county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†187. Magnetometric survey, vertical intensity: St. Charles mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†187a. Geological map, St. Charles mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†188. Magnetometric survey, vertical intensity: Baker mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†188a. Geological map, Baker mine, Tudor township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†189. Magnetometric survey, vertical intensity: Ridge iron ore deposits, Wollaston township, Hastings county, Ontario—by E. Lindeman. 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†190. Magnetometric survey, vertical intensity: Coehill and Jenkins mines, Wollaston township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†190a. Geological map, Coehill and Jenkins mines, Wollaston township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†191. Magnetometric survey, vertical intensity: Bessemer iron ore deposits, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†191a. Geological map, Bessemer iron ore deposits, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†192. Magnetometric survey, vertical intensity: Rankin, Childs, and Stevens mines, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†192a. Geological map, Rankin, Childs, and Stevens mines, Mayo township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†193. Magnetometric survey, vertical intensity: Kennedy property, Carlow township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†193a. Geological map, Kennedy property, Carlow township, Hastings county Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†194. Magnetometric survey, vertical intensity: Bow Lake iron ore occurrences, Faraday township, Hastings county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 184.)

†204. Index map, magnetite occurrences along the Central Ontario railway—by E. Lindeman, 1911. (Accompanying report No. 184.)

†205. Magnetometric map, Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposits Nos. 1, 2, 3, 4, 5, 6, and 7—by E. Lindeman, 1911. (Accompanying report No. 303.)

†205a. Geological map, Moose Mountain iron-bearing district, Sudbury district, Ontario, Deposits Nos. 1, 2, 3, 4, 5, 6, and 7—by E. Lindeman. (Accompanying report No. 303.)

†206. Magnetometric survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: northern part of deposit No. 2—by E Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†207. Magnetometric survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposits Nos. 8, 9, and 9A—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208. Magnetometric survey of Moose Mountain iron-bearing district, Sudbury district, Ontario: Deposit No. 10—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208a. Magnetometric survey, Moose Mountain iron-bearing district, Sudbury district, Ontario: eastern portion of Deposit No. 11—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208b. Magnetometric survey, Moose Mountain iron-bearing district, Sudbury district, Ontario: western portion of deposit No. 11—by E. Lindeman, 1912. Scale 200 feet to 1 inch. (Accompanying report No. 303.)

†208c. General geological map, Moose Mountain iron-bearing district, Sudbury district, Ontario—by E. Lindeman, 1912. Scale 800 feet to 1 inch. (Accompanying report No. 303.)

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†210. Location of copper smelters in Canada—by A. W. G. Wilson. Scale 197·3 miles to 1 inch. (Accompanying report No. 209.)

†215. Province of Alberta: showing properties from which samples of coal were taken for gas producer tests, Fuel Testing Division, Ottawa. (Accompanying Summary report, 1912.)

†220. Mining districts, Yukon. Scale 35 miles to 1 inch—by T. A. MacLean. (Accompanying report No. 222.)

†221. Dawson mining district, Yukon. Scale 2 miles to 1 inch—by T. A. MacLean. (Accompanying report No. 222.)

*228. Index map of the Sydney coal fields, Cape Breton, N.S. (Accompanying report No. 227.)

†232. Mineral map of Canada. Scale 100 miles to 1 inch. (Accompanying report No. 230.)

†239. Index map of Canada showing gypsum occurrences. (Accompanying report No. 245.)

†240. Map showing Lower Carboniferous formation in which gypsum occurs in the Maritime provinces. Scale 100 miles to 1 inch. (Accompanying report No. 345.)

†241. Map showing relation of gypsum deposits in Northern Ontario to railway lines. Scale 100 miles to 1 inch. (Accompanying report No. 245.)

†242. Map, Grand River gypsum deposits, Ontario. Scale 4 miles to 1 inch. (Accompanying report No. 245.)

†243. Plan of Manitoba Gypsum Co.'s properties. (Accompanying report No. 245.)

†244. Map showing relation of gypsum deposits in British Columbia to railway lines and market. Scale 35 miles to 1 inch. (Accompanying report No. 245.)

†249. Magnetometric survey, Caldwell and Campbell mines, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†250. Magnetometric survey, Black Bay or Williams mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†251. Magnetometric survey, Bluff Point iron mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†252. Magnetometric survey, Culhane mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†253. Magnetometric survey, Martel or Wilson iron mine, Calabogie district, Renfrew county, Ontario—by E. Lindeman, 1911. Scale 200 feet to 1 inch. (Accompanying report No. 254.)

†261. Magnetometric survey, Northeast Arm iron range, lot 339 E.T.W. Lake Timagami, Nipissing district, Ontario—by E. Nystrom. 1903. Scale 200 feet to 1 inch.

†268. Map of peat bogs investigated in Quebec—by A. Anrep, 1912.

†269. Large Tea Field peat bog, Quebec " "

†270. Small Tea Field peat bog, Quebec " "

†271. Lanoraie peat bog, Quebec " "

†272. St. Hyacinthe peat bog, Quebec " "

†273. Rivière du Loup peat bog " "

†274. Cacouna peat bog " "

†275. Le Parc peat bog, Quebec " "

†276. St. Denis peat bog, Quebec " "

†277. Rivière Ouelle peat bog, Quebec " "

†278. Moose Mountain peat bog, Quebec " "

†284. Map of northern portion of Alberta, showing position of outcrops of bituminous sand. Scale $12\frac{1}{2}$ miles to 1 inch. (Accompanying report No. 281.)

†293. Map of Dominion of Canada, showing the occurrences of oil, gas, and tar sands. Scale 197 miles to 1 inch. (Accompanying report No. 291.)

†294. Reconnaissance map of part of Albert and Westmorland counties. New Brunswick. Scale 1 mile to 1 inch. (Accompanying report No. 291.)

†295. Sketch plan of Gaspé oil fields, Quebec, showing location of wells. Scale 2 miles to 1 inch. (Accompanying report No. 291.)

†296. Map showing gas and oil fields and pipe-lines in southwestern Ontario. Scale 4 miles to 1 inch. (Accompanying report No. 291.)

†297. Geological map of Alberta, Saskatchewan, and Manitoba. Scale 35 miles to 1 inch. (Accompanying report No. 291.)

†298. Map, geology of the forty-ninth parallel, 0·9864 miles to 1 inch. (Accompanying report No. 291).

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†302. Map showing location of main gas line, Bow Island, Calgary. Scale 12½ miles to 1 inch. (Accompanying report No. 291.)

†311. Magnetometric map, McPherson mine, Barachois, Cape Breton county, Nova Scotia—by A. H. A. Robinson, 1913. Scale 200 feet to 1 inch.

†312. Magnetometric map, iron ore deposits at Upper Glencoe, Inverness county, Nova Scotia—by E. Lindeman, 1913. Scale 200 feet to 1 inch.

†313. Magnetometric map, iron ore deposits at Grand Mira, Cape Breton county, Nova Scotia—by A. H. A. Robinson, 1913. Scale 200 feet to 1 inch.

†327. Map showing location of Saline Springs and Salt Areas in the Dominion of Canada. (Accompanying Report No. 325.)

†328. Map showing location of Saline Springs in the Maritime Provinces. Scale 100 miles to 1 inch. (Accompanying Report No. 325.)

†329. Map of Ontario-Michigan Salt Basin, showing probable limit of productive area. Scale 25 miles to 1 inch. (Accompanying Report No. 325.)

†330. Map showing location of Saline Springs in Northern Manitoba. Scale 12½ miles to 1 inch. (Accompanying Report No. 325.)

†340. Magnetometric map of Atikokan iron-bearing district, Atikokan Mine and Vicinity. Claims Nos. 10E, 11E, 12E, 24E, 25E, and 26E, Rainy River district, Ontario. By A. H. A. Robinson, 1914. Scale 400 feet to 1 inch.

†340a. Geological map of Atikokan iron-bearing district, Atikokan Mine and Vicinity. Claims Nos. 10E, 11E, 12E, 24E, 25E, and 26E, Rainy River district, Ontario. By A. H. A. Robsinson, 1914. Scale 400 feet to 1 inch.

†341. Magnetometric map of Atikokan iron-bearing district, Sheet No. 1, Claims Nos. 400R, 401R, 402R, 112X, and 403R. Rainy River district, Ontario. By E. Lindeman, 1914. Scale 400 feet to 1 inch.

†341a. Geological map of Atikokan iron-bearing district. Sheet No. 1. Claims Nos. 400R, 401R, 402R, 112X, and 403R, Rainy River district, Ontario. By E. Lindeman, 1914. Scale 400 feet to 1 inch.

†342. Magnetometric map of Atikokan iron-bearing district. Sheet No. 2. Claims Nos. 403R, 404R, 138X, 139X, and 140X, Rainy River district, Ontario. By E. Lindeman, 1914. Scale 400 feet to 1 inch.

†342a. Geological map of Atikokan iron-bearing district. Sheet No. 2. Claims Nos. 403R, 404R, 138X, 139X, and 140X, Rainy River district, Ontario. By E. Lindeman, 1914. Scale 400 feet to 1 inch.

† Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†343. Magnetometric map of Atikokan iron-bearing district. Mile Post No. 140, Canadian Northern railway, Rainy River district, Ontario. By E. Lindeman, 1914. Scale 400 feet to 1 inch.

†343a. Geological map, Atikokan iron-bearing district. Mile Post No. 140, Canadian Northern railway, Rainy River district, Ontario. By E. Lindeman, 1914. Scale 400 feet to 1 inch.

†354. Index Map, showing location of peat bogs investigated in Ontario— by A. Anrep, 1913–14.

†355. Richmond peat bog, Carleton county, Ontario— " "

†356. Luther peat bog, Wellington and Dufferin counties, Ontario— " "

†357. Amaranth peat bog, Dufferin county, Ontario— " "

†358. Cargill peat bog, Bruce county, Ontario— " "

†359. Westover peat bog, Wentworth county, Ontario— " "

†360. Marsh Hill peat bog, Ontario county, Ontario— " "

†361. Sunderland peat bog, Ontario county, Ontario— " "

†362. Manilla peat bog, Victoria county, Ontario— " "

†363. Stoco peat bog, Hastings county, Ontario— " "

†364. Clareview peat bog, Lennox and Addington counties, Ontario— " "

†365. Index Map, showing location of peat bogs investigated in Quebec— " "

†366. L'Assomption peat bog, L'Assomption county, Quebec— " "

†367. St. Isidore peat bog, La Prairie county, Quebec— " "

†368. Holton peat bog, Chateauguay county, Quebec— " "

†369. Index Map, showing location of peat bogs investigated in Nova Scotia and Prince Edward Island— " "

†370. Black Marsh peat bog, Prince county, Prince Edward Island— " "

†371. Portage peat bog, Prince county, Prince Edward Island— " "

†372. Miscouche peat bog, Prince county, Prince Edward Island— " "

†373. Muddy Creek peat bog, Prince county, Prince Edward Island— " "

†374. The Black Banks peat bog, Prince county, Prince Edward Island— " "

† Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.

†375. Mermaid peat bog, Queens county, Prince Edward Island..........................by A. Anrep, 1913–14.

†376. Caribou peat bog, Kings county, Prince Edward Island— " "

†377. Cherryfield peat bog, Lunenburg County, Nova Scotia— " "

†378. Tusket peat bog, Yarmouth county, Nova Scotia— " "

†379. Makoke peat bog, Yarmouth county, Nova Scotia— " "

†380. Heath peat bog, Yarmouth county, Nova Scotia— " "

†381. Port Clyde peat bog, Shelburne county, Nova Scotia— " "

†382. Latour peat bog, Shelburne county, Nova Scotia— " "

†383. Clyde peat bog, Shelburne county, Nova Scotia— " "

†387. Geological map Banff district, Alberta, showing location of phosphate beds—by Hugh S. de Schmid, 1915. (Accompanying report No. 385.)

†390. Christina river map showing outcrops of bituminous sand along Christina valley; contour intervals of 20 feet—by S. C. Ells, 1915. Scale 1,000 feet to 1 inch.

†391. Clearwater river map, showing outcrops of bituminous sand along Clearwater valley; contour intervals of 20 feet—by S. C. Ells, 1915. Scale 1,000 feet to 1 inch.

†392. Hangingstone-Horse rivers, showing outcrops of bituminous sand along Hangingstone and Horse River valleys: contour intervals of 20 feet—by S. C. Ells, 1915. Scale 1,000 feet to 1 inch.

†393. Steepbank river, showing outcrops of bituminous sand along Steepbank valley; contour intervals of 20 feet—by S. C. Ells, 1915. Scale 1,000 feet to 1 inch.

†394. McKay river, 3 sheets, showing outcrops of bituminous sand along McKay valley; contour intervals of 20 feet—by S. C. Ells, 1915. Scale 1,000 feet to 1 inch.

†395. Moose river, showing outcrops of bituminous sand along Moose valley; contour intervals of 20 feet—by S. C. Ells, 1915. Scale 1,000 feet to 1 inch.

Address all communications to—

DIRECTOR MINES BRANCH,
DEPARTMENT OF MINES,
SUSSEX STREET, OTTAWA.

Note.—1. Maps marked thus * are to be found only in reports.
2. Maps marked thus † have been printed independently of reports, hence can be procured separately by applicants.